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Diachronic Evidence in Nonmetric Morphological Characters of Teeth in Armenian Highland and Georgia Populations

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Keywords: Dental variation, biological distance

ABSTRACT The aim of the study is the assessment of biological distance between populations from Armenian highland and Georgia based on the frequency of nonmetric odontological traits. These traits are characterized by high inter-population differentiation, low sexual dimorphism, and relatively small intra and inter observer recordation error. This paper presents the results of the odontological differentiation of human populations from Armenian highland and Georgia. The comparative analysis was carried out on 12 populations. Trait frequencies for all populations were analysed using principal component analysis. Results support the following conclusions: The populations of Armenian highland and Georgia can be differentiated as far as the frequency of odontological traits are concerned. Biocultural diversity of ancient Transcaucasian populations has not been studied extensively, therefore delineating some of the patterns of phenotypic variation may be useful for understanding their ongoing evolution.

Dental anthropology, the study of modern and archaeologically-derived human dentitions, is a well-established sub-discipline of Physical Anthropology. It is defined by Hillson (1996:1) as "a study of people (and their close relatives) from the evidence provided by teeth." Such research yields information on a variety of topics, including growth and development, health, diet, occupational activity, and biological affinities. This information can be used in studies of individuals as well as populations. The analysis of nonmetric dental traits, when compared with similar studies, can be used to infer biological relationships between populations and track evolutionary variation related to changing settlement patterns. Dental morphology can provide insights into phenotypic group differences, and these may be suggestive of differences in genotypic affiliation (Varela and Cocilovo, 2000). Nonmetric dental traits are controlled in large part by genetics and are relatively free of sex and age bias (Scott and Turner, 1997). The analysis of biological relatedness using dental nonmetric traits has been helpful even in commingled samples when standardized procedures are followed (Ullinger et al., 2005). For these reasons, the reconstruction of biological relationships among ancient human groups using teeth is an important research strategy for Transcaucasian bioarcheologists. The aim of the present study is to provide new non-metric dental data for ancient Transcaucasian groups.

Several investigations provide information about nonmetric variation from a local scale in human groups from Asia and the Pacific (Hanihara, 1965, 1966; Hanihara and Minamidate, 1965; Sasaki and Kanasawa, 1998; Kitagawa, 2000), Africa (Grine, 1984, 1986, 1990; Lease, 2003), India (Lukacs, Walimbe, 1984; Lukacs, Hemphill, 1991), Central Asia (Rikushina et al., 2003; Bagdasarova, 2000), Europe (Jørgensen, 1956; Aksjanova, 1978; Segeda, 1993; Cucina et al., 1999; Gravere, 1999; Lease, 2003; Coppa et al., 2007; Vargiu et al., 2009; Zubova, 2010), the Near East (Smith, 1978; Smith et al., 1987; Moskona et al., 1998), Siberia (Khaldeeva, 1979; Tur, 2009; Zubova, 2008), Australia (Townsend and Brown, 1981; Townsend et al., 1986, 1990) and North America (Sciulli, 1998, Tocheri, 2002; Ullinger, 2003; Lease, 2003; Lease and Sciulli, 2005; Edgar and Lease, 2007). Surprisingly, past and present Transcaucasian populations have received little attention (Kashibadze, 1990, 2006; Palikyan, Nalban-dyan, 2006; Khudaverdyan, 2009, 2011a, b, 2013, 2014). The study of phenotypic diversity can help us understand the evolution and biocultural variation of the ancient and contemporary communities that today inhabit Transcaucasian. This will provide a more complete landscape of the dynamics that configure their gene pool.

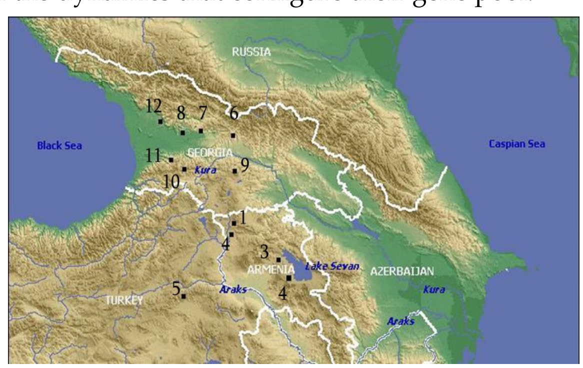

Fig. 1 Locations of Transcaucasian groups

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	Country	Sample Name	Date	Researchers
1	Armenian highland	Total group: Landjik, Black Fortress	c. 4000- 2000BC	Khudaverdyan, 2009, 2011a
2	Armenian highland	Total group: Lchashen, Shirakavan, Keti, Karchakhpyur	c. 2000BC c. 1 BC – AD 3	Kashibadze, 1990
3	Armenian highland	Lchashen	c. 3000 - 2000 BC	Kashibadze, 2006
4	Armenian highland	Total group: Beniamin, Vardbakh, Black Fortress I, Karmrakar	c. 1 BC – AD 3	Khudaverdyan, 2009
5	Armenian highland	Bingel Dag	20th century	Kashibadze, 2006
6	Georgia	Total group: Digomi, Mckheti	c. 3000- 2000BC	Kashibadze, 2006
7	Georgia	Total group: Chiaturia, Mckheti I, Mckheti	c. 1 BC – AD 3	Kashibadze, 2006
8	Georgia	Total group: Dzinvali, Samtavro, Mckheti I, Mckheti	c. VI - X AD	Kashibadze, 2006
9	Georgia	Total group: Dzinvali, Adjaria, Shatili, Adigeya, Mckheti	c. X - XII AD	Kashibadze, 2006
10	Georgia	Total group: Dzinvali, Rustavi, Sioni, Shatili	c. XIII – XIX AD	Kashibadze, 2006
11	Georgia	Total Group	Total Group	Kashibadze, 2006
12	Georgia	Dzinvali	20th century	Kashibadze, 2006

MATERIALS AND METHODS

In total, the intergroup analysis included 12 series (Table 1) from the territory of Transcaucasian (Kashibadze, 1990, 2006; Khudaverdyan, 2009, 2013, 2014) (Fig. 1). We assess dental reduction trends in two regions during three (Armenia) and four (Georgia) prehistoric transitions, Bronze Age to modern period.

I have examined 6 samples (more than 181 individuals) of Bronze and Classical periods from the territory of the Armenia. The series were grouped according to periods and local groups. The Early Bronze period (4000-3000 BC) farmer and cattle-breeder Landjik represent the Kuro-Arexes population of the Armenian Highland. The Late Bronze period sample is represented by remains from one Armenian Highland site (Black Fortress). The combination of remains from these two sites is justified for three reasons. First, the small sample sizes for sites (Landjik, Black Fortress) were inadequate (from 10-13 individuals) for subsequent biodistance analysis. Second, the Landjik, Black Fortress sites they represent a cemetery from Shirak Plain (Table 2). Indeed, the geographic distance among sites a small. Finally, analysis of all nonmetric traits revealed no significant differences exist among remains from the two sites, so data from these sites were combined for subsequent statistical analyses (Khudaverdyan, 2009).

Remains from the Lchashen site were treated as an independent sample because a sufficient number of crania from burials in Sevan pool were available for study (Kashibadze, 2006). The Bronze Age sample is represented by remains from four Armenian sites (Lchashen, Shirakavan, Keti, Karchakhpyur). Two of the four Armenian sites, i.e., Shirakavan and Karchakhpyur represent a samples with an date of 1st century BC - 3rd century AD (i.e. ancient time) (Kashibadze, 1990, p. 287).

The Classical period (1st century BC - 3rd century AD) samples examined include remains from Beniamin, Vardbakh, Black Fortress I, and Karmracar (Table 2). The small sample sizes for sites of Vardbakh, Black Fortress I, and Karmracar were inadequate (from 12-23 individuals) for subsequent biodistance analysis. The Beniamin, Vardbakh, Black Fortress I, and Karmracar sites represent a cemetery from the Shirak Plain and the geographic distances among sites are relatively close. After the Armenian genocide, V.V. Bunak collected a large number of human skulls in 1915 that were victims of the genocide (now housed at Museum of Anthropology, Moscow). The modern population includes remains from these individuals (Bingel Dag: Armenians from Musha) (Kashibadze, 2006).

Two Bronze period samples from Georgia (Digomi, Mckheti) were analyzed in this investigation. Combining the remains from these two sites is justified because of the small number of groups (Table 2). The Classical period/ Late An-tiquity period (1st century BC – 3rd cen-tury AD)

Trait	1	2	3	4	5
Midline Diastema [1]	23.7 /17/	2.4	3.6	10.5 /86/	9.2
Dental crowding	62.5 /16/	1.2	1.8	78.5 /79/	3.0
Reduced, peg-formed tooth I^2 (2+3)	0.0	0.0	0.0	10.9 /83/	1.0
Reduced, peg-formed tooth I^2 (1)	67.5 /15/	12.9	0.0	65.1 /83/	19.4
Shovelling I^1	35.8 /15	0.0	0.0	45.1 /62/	-
Hypocone M^2∑3,3+	37.5 /14	34.2	32.7	30.5 /69/	40.6
Cara M^1 (2-5)	31.3 /16/	43.4	38.7	46.7 /75/	58.8
$M_1$4	14.3 /15/	16.7	23.3	17.8 /79/	-
$M_1$6	0.0	2.8	3.3	5.8 /52/	-
$M_2$4	64.7 /17/	78.9	72.4	71.3 /66/	-
1eo (3) M^1	21.5 /16/	43.4	38.4	41.94 /31/	41.7
DTC	42.5 /18/	7.1 64	10	50.9 /57/	-
DW	42.5 /18/	16.7	16.7	38.1 /42/	-
2 med II M_1	29.2 /17/	41.7	40.0	53.4 /45/	-

Trait	6	7	8	9	10	12*
Midline Diastema [1]	4.9	11.4	3.2	3.2	5.2	-
Dental crowding	1.7	0.0	4.6	1.2	1.7	-
Reduced, peg-formed tooth I^2 (2+3)	3.6	0.0	0.0	0.32	0.0	-
Reduced, peg-formed tooth I^2 (1)	8.2	0.0	0.0	0.0	0.0	-
Shovelling I^1	15.5	7.1	7.7	4.0	33.4	-
Hypocone M^2∑3,3+	10.3	23.8	25.7	20.6	32.9	33.3
Cara M^1 (2-5)	47.1	43.8	28.6	36.7	60.1	100.0
$M_1$4	9.7	10.8	11.8	8.92	5.1	66.7
$M_1$6	4.9	5.4	0.0	6.5	2.3	0.0
$M_2$4	87.6	93.0	83.6	93.3	95.0	100.0
1eo (3) M^1	78.6 2	33.3	25.0	38.8	40.5	-
DTC	8.9	0.0	0.0	6.6	2.1	-
DW	18.5	28.5	8.3	7.5	0.0	-
2 med II M_1	14.8	33.3	12.5	17.5	12.5	-

samples from Georgia exam-ined by this study include remains from Chiaturia, Mckheti I, Mckheti I (total group). Inadequate number of remains were available from this site and, there-fore, they were analyzed as a single sam-ple. Four Early Feudal period samples from Georgia (Dzinvali, Samtavro, Mckheti I, Mckheti / total group/) were analyzed. Average Feudal period (c. X - XII AD) samples examined include remains from Dzinvali, Adjaria, Shatili, Adigeya and Mckheti. Late Feudal period (c. XIII - XIX AD) samples examined include remains from Dzinvali, Rustavi, Sioni and Shatili. The modern population includes remains from Dzinvali (Kashibadze, 2006).

Human dentitions exhibit highly heritable non-metric morphological crown and roots traits that vary within and between populations. The term non-metric implies structural variations of individual crown and root forms that are visually scored in two ways: "presence-absence" characters such as furrow patterns, accessory ridges, supernumerary cusps and roots, or, as differences in form such as curvature and angles (Hillson, 1996; Scott and Turner, 1997; Zubov, 1973, 1979). Numerous studies have demonstrated that morphological dental forms respond to microevolutionary forces of admixture (e.g. Turner, 1969; Pinto-Cisternas et. al., 1995; Khudaverdyan, 2011), mutation (e.g. Morris et al., 1978), genetic drift (e.g. Turner 1969; Scott and Dahlberg, 1982; Segeda, 1993; Khudaverdyan, 2009, 2013, 2014; Vargiu et al., 2009; Zubova, 2008, 2010), and selection (e.g. Dahlberg, 1963; Scott and Turner, 1988), thus evincing their high degree of genetic control.

The method A.A. Zubova (1973, 1974), the most widely employed system in Russian school of anthropology, was used to score non-metric dental traits. These traits are characterized by high inter-population differentiation and the analysis of their occurrence enables researchers to obtain data concerning the genetic relationships between populations identified as falling in different ethnic complexes. Odontological traits are used successfully in the description and explanation of both evolutionary and microevolutionary processes. Such studies are commonly used to assess specific research questions such as the synchronic biological relatedness of segments of a particular society (e.g. Johnson and Lovell, 1994), or diachronic changes in trait expressions in a particular region (e.g. Lukacs and Hemphill, 1991; Cucina et al., 1999; Gravere, 1999; Coppa et al., 2007). Since teeth complete their growth during the early stages of an individual's development, they are strongly determined be genes and their morphological structures are only slightly sensitive to environmental influences. Teeth are usually well preserved in archaeological materials and are often the only source of observation of human remains.

The following odontological traits were used in this comparative analysis: (1) diastema of I1-I1, (2)crowding of I1; (3)shovelling of I1; (4) reduction of I2 (grades 2+3); (5) reduction of I2 (grade 1); (6) reduction hypocone (forms 3+ and 3) of the upper second molar; (7) Carabelli's cusp on M1; (8) form 1 pa (eo) on M1; (9) four-cusped forms on M1; (10) fix-cusped forms on M1; (11) four-cusped forms on M2; (12) deflecting wrinkle of the metaconid of M1; (13) the variant 2med II position of the second furrow of the metaconid on M1; and (14) distal crest of trigonid on M1 (Table 3).

The above-mentioned traits were selected because they meet the following criteria:

1) the traits should not reveal inter-correlations for the frequency of occurrence;

2) they should reveal high inter-group variability;

3) the degree of variant formation cannot change with an individual's age,

4) it should be easy to find comparative data for different populations.

Data are subjected to the component (factor) and cluster analysis. A.G. Kozintseva and B.A. Kozintseva's statistical package was used (Museum of Anthropology and Ethnography of name of the Peter the Great, St. Petersburg).

RESULTS AND DISCUSSION

Secular dental changes in the populations of the Transcaucasian

Diachronic tendencies in cranial and dental morphology have occurred ever since anatomically modern humans began to populate the planet. One of the major tendencies was the increase of body length. Cranially, one of the most important trends was brachycephalization (Alexeev, 1974). Apart from those tendencies, irregular fructuations in body size occurred, whereas the overall proportions displayed greater stability (Godina et al., 2000). A secular increase in body length observed over most of the 20th century was not exceptional. Dental changes are related to somatic ones. Certain aspects of dentition are rather labile, as evidenced by various patterns of the gracilization process, which is probably continuing. While brachycephalization (or debrachycephalization), gracilization, dental reduction, and the increase of body length may occur in parallel, the causes of those processes probably vary. Microevolutionary tendencies may be triggered by ontogenetic changes, specifically acceleration or deceleration of growth caused by endocrine, neurohumoral, trophic, and other factors. With our taking into account the secular changes in the dentition, an adequate reconstruction of population history is hardly possible, especially when issues of continuity versus replacement are discussed. Secular

Trait	Tooth	Trait definition used in this study (Zubov 1968)	Matching ASU Dental Anthropology System and Zubov system ASU=Zubov
Midline Diastema	UI1	space between the upper central incisors equal or larger than 2 mm; 0 – no diastema, space	0=0; 1=1
Dental crowding	UI2	crowding of the upper lateral incisors; 0 – crowding is not observed; 1 – crowding is observed	0=0; 1=1
Shovelling	UI1	shoveling of the upper central incisors; observed when the marginal ridges of the incisors are prominent and enclose a deep fossa in the lingual surface of the tooth: 0 – none; 1 – poorly delineated rollers along edges; 2 – well differentiated ridges on both sides, somewhat projecting above the surface; 3 – clearly expressed high ridges on the lingual surface giving the characteristic shovel- shaped form	0=0; 1=1; 2=2; 3–6=3
Reduced, peg-formed tooth	UI2	Distal lobe of second incisors reduced enough to produce a peg-shaped form; 0 – no reduction, lateral incisor width approximately 70 to 80% that of central incisor; 1 – lateral incisor mesial-distal width approximately 50% that of central; 2 – conical incisor with a pointed apex; 3 – peg-form tooth, crown height considerably less than adjacent tooth	2=2+3
Reduced, peg-formed tooth	UI2	Please follow above sample	0=0; 1=1
Hypocone	UM2	degree of reduction of the hypoconus on the second upper molars; 4 Hypocone well developed, forming a distinct disto-lingual corner of the crown, 4– Hypocone diminished, not forming a corner, 3+ Hypocone very reduced, 3 Absence of hypocone	3.5,3=4–
Carabelli's cusp	UM1	the small additional cusp on the mesiolingual corner of the upper first molar presents in a variety of different forms; 0 Absence, 1 Slightly uneven surface due to one or two barely visible grooves, 2 Slight swelling limited from the mesial and occulusal sides by a curved weakly expressed groove, 3 Groove has character of a cusp, 4 Cusp clearly expressed, 5 Large free-standing cusp	0=0; 1=1; 2=2; 3–5=3
1 pa (eo) 3	UM1	type of structure of the first furrow of the paracone on the first upper molar	Trait not used in the ASU System
Four-cusped	LM1	Cusp number mandibular molars 4 4 is highest number of cusps	4=4
Four-cusped	LM2	4 4 is highest number of cusps	4=4
Six-cusped	LM1	6 6 is highest number of cusps	6=6
Deflecting wrinkle	LM1	The deflecting wrinkle is one of the particular formations of the median ridge of the metaconid. The ridge, when the deflecting wrinkle appears, shows a stronger development in either its length or breadth and curves distalward at the central part of the occlusal surface.	0–1=0
2med II	LM1	the variant 2med II position of the second furrow of the metaconid	Trait not used in the ASU System
Distal Trigonid Crest	LM1	This trait is characterized by a crest or ridge that courses buccolingually along the distal aspect of the primitive trigonid, represented by the protoconid and metaconid. It often appears as an extension of the distal accessory ridge of the protoconid although the distal accessory ridge of the metaconid may also be involved in forming the crest.	0–1=0

Table 3. Non-metric dental traits definitions and code matching for the ranked traits used in this study (Zubov scheme) and in the Arizona State University Dental System (ASU scheme) cited according to Haeussler and Turner (1992): 277–278

changes in dentition over the last few centuries and millennia have been studied in various countries. A diachronic dental crown size reduction has been observed among Middle, Late and Post-Pleistocene hominid palaeo-populations and modern human populations (Brace, 1976, 1979, 1980; Brace and Mahler, 1971; Brace et al., 1987; Brose and Wolpoff, 1971; Wolpoff, 1971; Smith, 1977; Frayer, 1977, 1978, 1984; y'Edynak, 1989; Chamla, 1980; Calcagno, 1986; Calcagno and Gibson, 1988; Keiser, 1990; Pinhasi, 1998). Various researchers report that this trend varies by tooth type and tooth dimension (Brace et al., 1987; Wolpoff, 1971; Frayer, 1978, 1984).

It has long been suggested that these changes might be caused by the transition to soft food (Dutta, 1983) and the ensuing reduction of functional load. Comparative studies of twins (Potter et al., 1976), of parent and offspring (Goose, 1971) and full versus half siblings (Townsend and Brown, 1978) substantiate the claim that more than half the variability in tooth crown size could be attributed to genetic factors (Brabant and Twiesselmann, 1964; Townsend and Brown, 1978; Scott and Turner, 1997). Other experts point to the importance of environmental or biochemical processes, etc. (Dahlberg, 1963; Shapiro, 1963). Dahlberg (1963) observed considerable population-specific variability in tooth size and form, so he hypothesized that changes in the human dentition are the result of a relaxation of certain environmental pressures. He therefore proposed that European populations have a smaller tooth mass than do populations in "less favoured environments." Small teeth may be the outcome of “selection by crowding,” whereby reduced load on the masticatory apparatus causes the eduction of alveolar processes, resulting in too little space for teeth (Zubov and Khaldeeva, 1989). Brace (1963) presented the Probable Mutation Effect theory (PME) that suggests that in the absence of natural selection, mutations will be the main force acting toward a reduction of structural size and complexity of teeth and other organs. Thus, developmental processes, controlled by complex genetic mechanisms, will be disrupted resulting in an incomplete or a simplified dental structure (such as the change in cusp pattern). The PME is based on the concept of drift and stochastic microevolutionary mechanisms that act in the absence of selection (Sciulli and Mahaney, 1991). Another possible factor in dental gracilization may be the high occurrence of caries, which mostly affects large teeth with complex occlusal surfaces (Khudaverdyan, 2005). These processes demonstrate the importance of cultural factors in dental evolution. Transition to agriculture may lead to a reduction of dental size, as demonstrated by P. Sciulli (1979), who compared the dentition of hunters and gatherers with that of agriculturalists. It has been demonstrated that the Neolithic Revolution may have caused an abrupt decrease in tooth size. According to D. Frayer (1977), the dimensions of the facial skeleton during the Upper Paleolithic and Mesolithic in Europe decreased more rapidly than did the size of teeth.

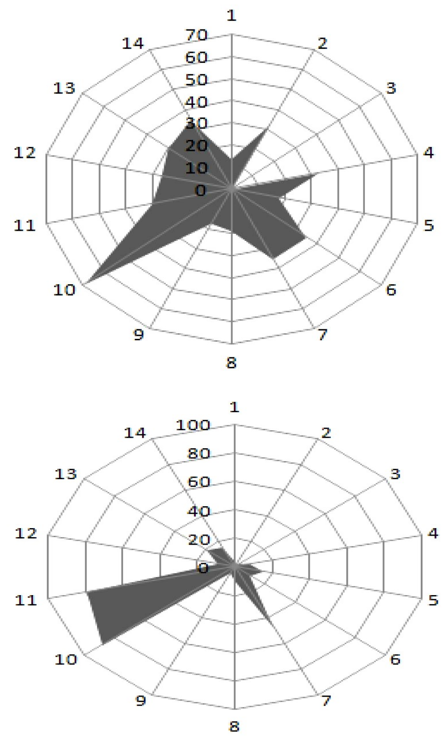

Fig. 3. Ranges of dental non-metric traits in samples from Armenian Highland (1) and Georgia (2) in Bronze Age: 1 – I^1-I^1 diastema, 2 - I^2 crowding, 3 - I^2 reduction (grades 2+3), 4 - I^2 reduction (grade 1), 5 - double shoveling, 6 - hypocone reduction on M^2, 7 - Carabelli cusp on M^1, 8 - four-cusped M_1, 9 - six-cusped M_1, 10 - four-cusped M_2, 11 – 1eo (3) M^1, 12 – distal ridge of trigonid, 13 – deflecting wrinkle of metaconid, 14 - 2 med II

Dental reduction in the Near East over the last six thousand years was quite pronounced (Smith, 1976). As P. Smith has shown, the direction of the microevolutionary process was the same, and differences between the Near Eastern groups were mainly due to various rates of this process and to isolation. Dental reduction, therefore, can lead not only to the decrease of between-group variation, but also to an increase. The objective of this study is to compare prehistoric and recent populations of the Transcaucasian to trace secular changes in dental morphology. Information about the southern gracile dental types can be found in Zubov (1979). The southern gracile type has low percentages of Carabelli’s trait, somewhat increased frequencies for the distal trigonid crest, M14, M24 and low variant 2 med (Khaldeeva, 1992). The southern gracile type is characteristic for peoples of the Transcaucasian (Kochiev, 1979; Kashibadze, 1990, 2006; Khudaverdyan, 2009, 2011, 2013, 2014), Daghestan (Gadjiev, 1979) and Bulgaria (Minkov, 1979). The 14 traits, their frequencies, and the number of individuals observed for each trait for the Armenian Highland and Georgia samples are provided in Table 2. The differentiation which can be traced in Transcaucasian populations is demonstrated Figures 2 and 3. In the following, patterns of dental reduction in populations of the Transcaucasian are described.

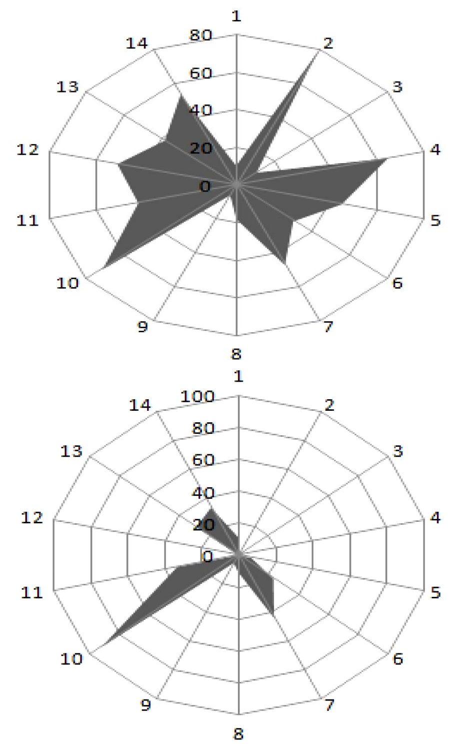

Fig. 4. Ranges of dental non-metric traits in samples from Armenian Highland (1) and Georgia (2) in Ancient Age: 1 – I1-I1 diastema, 2 - I2 crowding, 3 - I2 reduction (grades 2+3), 4 - I2 reduction (grade 1), 5 - double shoveling, 6 - hypocone reduction on M2, 7 - Carabelli cusp on M1, 8 - four-cusped M1, 9 - six-cusped M1, 10 - four-cusped M2, 11 – 1eo (3) M¹, 12 – distal ridge of trigonid,

Diastema

A “diastema” is a dental term referring to a space or gap between two teeth, and its size depends on that of the alveolar process (Zubov, 1973). It is most commonly applied to the space between the two maxillary central incisor teeth (upper front teeth: I1-I1). The secular decrease in the frequency of this trait reflects one of the aspects of dental reduction. The frequency of diastema in the Bronze Age populations of the Armenian Highland ranges from 2.4% to 23.7 %. It is rather low in the Bronze Age population of Georgia (Fig. 4-1). In the Classical period, it drops to (10.5%), and in moderm Armenians the occurrence remains low (9.2%). The tendency, therefore, is quite pronounced. The frequency of diastema in the Classical period and Feudal Age populations of the Georgia ranges from 3.2% to 11.4 %.

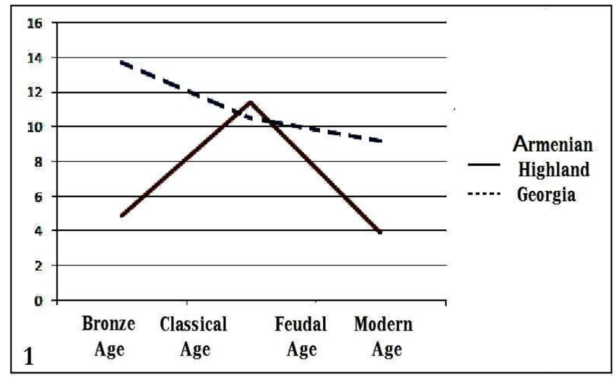

Fig. 4-1. Diastema (I1-I1) in samples from Armenian Highland and Georgia

I2 crowding

Crowding (mainly that of incisors) is an anomaly in the position of teeth, being a phenotypic dental response to jaw size reduction. Crowding occurs when there is disharmony in the tooth-to-jaw size relationship or when the teeth are larger than the available space. Although crowding is morphologically opposed to the diastema, the secular tendencies in these traits are not necessarily opposed; in fact, they sometimes occur in parallel. The frequency of lateral maxillary incisor crowding in populations of the Armenian Highland ranges from 1.2% to 78.5%. It was high in Classical period people of Beniamin, Black Fortress I, Vardbakh, and Karmrakar. The drop of frequency to 3% in 20th century Armenians is rather unusual. Crowding of the teeth in Early Feudal Age Georgia is higher than in the Bronze Age. It is rare in Georgian populations (Fig. 4-2).

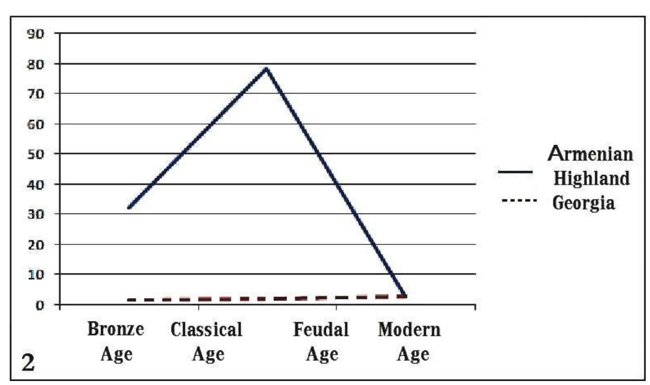

Fig. 4-2. Crowding (I2) in samples from Armenian Highland and Georgia

I2 reduction

Lateral incisors are frequently smaller than medial ones. Maximal reduction of the lateral maxillary incisors, ultimately resulting in peg-shaped incisors, was rare of the Transcaucasian. A small increase of frequency of grades 2+3 is observed in the Classical period from Armenian Highland (10.9%) and in the Bronze Age from Georgia (3.6%).

Grade 1 reduction (Fig. 4-3) was frequent during the Bronze Age (Landjik, Black Fortress) and the Classical period (Beniamin, Vardbakh, Black Fortress I, Karmracar) in populations of the Armenian Highland. Its low frequency (19.4%) is observed in modern (20th century) Armenians. Whereas the frequency of reduction (grade 1) in the Bronze Age people of Georgia is 8.2%, not a single case has been registered from burials of the Classical period and Feudal Age.

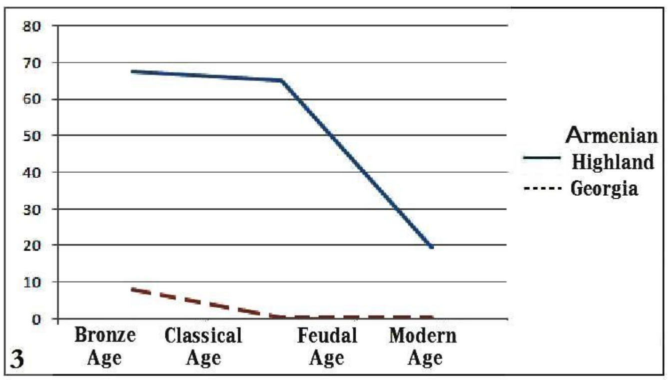

Fig. 4-3. I2 reduction in samples from Armenian Highland and Georgia

Double shoveling

Shoveling is a combination of a concave lingual surface and elevated marginal ridges enclosing a central fossa in the upper central incisor teeth. The mesial and distal lingual ridges of the incisors may be elevated producing a 'shovel-shaped' incisor. This trait is quite variable on the world scale and displays clear-cut geographical regularities. According to A. Zubov (1973), evolutionary tendencies are quite different: in Eastern groups, the trait remained stable or tended to become more common, while the frequencies of the shoveling gene in the West decreased markedly and in a regular fashion. At present, the frequency of the shoveling gene in the West appears to continue dropping, making the East-West differences even more pronounced (Zubov, 1973). This process is counterbalanced by admixture. In the Bronze Age from Armenian Highland, the mean total shoveling frequency is 35.8, and it increases in Classical period (45.1%). People of the Classical period exhibit the highest frequency possibly evidencing admixture. It was high and in Late Feudal Age people of Georgia (33.4%).

In Classical times (1st century BC – 3rd century AD) in the Caucasus, there was interaction between different ethno-cultural units – Iranian-speaking nomads (Scythians, Sarmatians, Sauromatians, Saka) (Herodotus IV; Strabo XI; Piotrovskii, 1959) and local populations. The advancement of the Scythians, Sarmatians and Saka in the territory of Transcaucasia was accompanied by not only an interaction of various cultural elements, but also admixture. The invasions of various tribes led, in stages, to a mixture of outsiders among the native Armenians and a dilution of their ranks on the plateau. The artificial modification of skulls (such as bregmatic, ring deformations of a head was known in the ancient population of the Beniamin, Shirakavan and Karmrakar, Vardbakh) and teeth in Ancient peoples of the Armenian Highland may be related to emerging social complexity and the need to differentiate among people, creating a niche for highly visual bodily markers (Khudaverdyan, 2011c).

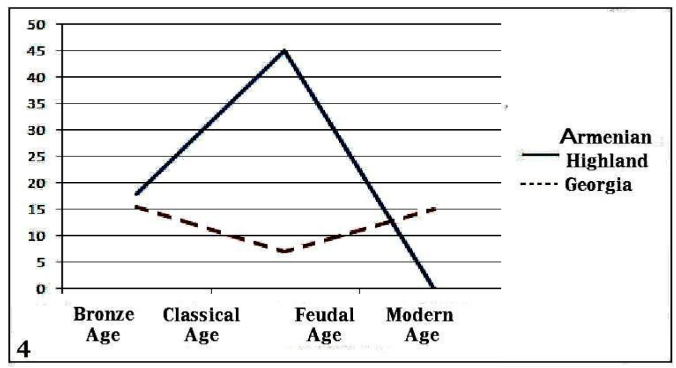

Fig. 4-4. Double shoveling in samples from Armenian Highland and Georgia

Molar shape (M2∑3,3+)

Hypocone (distolingual cusp) reduction of maxillary second permanent molar. Dahlberg's diagrams of degrees of cusp reduction were used for recording hypocone expression (Zubov, 1973). The total occurrence of reduced forms 3+ and 3 of the upper second molars gradually increases from the Bronze Age to the 20th century. In the Armenian Highland, a distinctive feature of the Bronze Age populations is a relatively high frequency of hypocone reduction on the upper second molar; later, the trait becomes less frequent in groups of the Classical period. The population of Shirakavan and Karchakhpyur (Armenia, Classical period) is also characterized by a very high of reduction of the hypocone on M2 (45,8%) (Palikyan, Nalbandyan, 2006). Its highest frequency is observed in modern (20th century) Armenians (Fig. 4-5).

In people of the Georgia the range of variation is considerable: Bronze Age (10.3%), Classical period (23.8 %), Early Feudal Age (c. VI - X AD) (25.7%), Middle Feudal Age (c. X - XII AD) (20.6%); Late Feudal Age (c. XIII – XIX AD) (32.9%), and modern Georgians (20 century) (33.3%). The trait, therefore, is temporally unstable, and its variation is rather erratic.

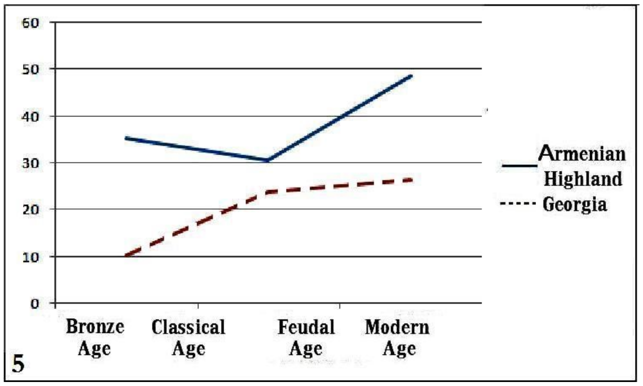

Fig. 4-5. Molar shape in samples from Armenian Highland and Georgia

Carabelli cusp on the upper first molar

Carabelli's trait is a morphological feature that is expressed on the protocone of human maxillary molars. It is a quasicontinuous variable, i.e. it can be either present or absent, but when present, it exhibits continuous variation in expression (Sofaer, 1970). The expression of the trait varies from a slight or distinct single furrow, pit, double furrow, y-shaped furrow, or slight protuberance lacking a free apex, to a small, moderate, or large cusp, which occasionally equals in size the main occlusal cusp. A pit and a furrow (single, double, y-shaped) are negative expressions of the trait, whereas a protuberance and a cusp are positive expressions (Alvesalo et al., 1975). Certain researchers have noted the frequency of this trait has increased over the last centuries (Brabant and Twiesselmann, 1964; Donina, 1969).

A similar tendency is observed in Armenian Highland groups (Bronze Age: 31.3 – 43.4%; Classical period: 46.7%, moderm Armenians: 58.8 %). In people of the Georgia the variation range is considerable: Bronze Age 47.1%, Classical period 43.8 %, Early Feudal Age (c. VI - X AD) 28.6%, Middle Feudal Age (c. X - XII AD) 36.7%; Late Feudal Age 60.1%, modern Georgians 100%.

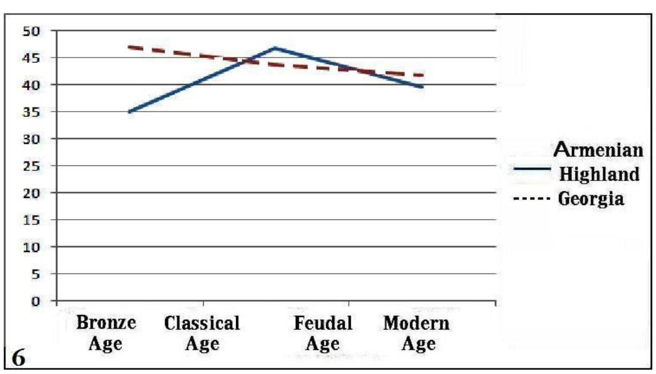

Fig. 4-6. Carabelli cusp in samples from Armenian Highland and Georgia

Number of cusps on the lower molars

The occurrence of four-cusped lower first molars in the Bronze Age population of the Armenian Highland ranges from14.3 - 23.3% (Fig. 4-7). People of the burial from Lchashen exhibit the highest frequency. In people of the Classical period of the Armenian Highland the mean total four-cusp score is 17.8%. The frequencies of four-cusp LM1 in populations of Georgia range from 5.1% to 66.7 %. Its highest frequency is observed in modern Georgians (Dzinvali).

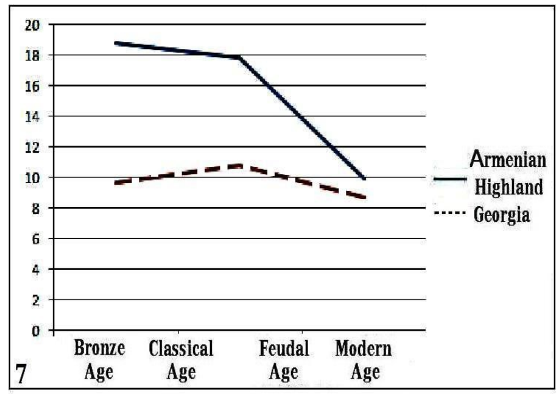

Fig. 4-7. Four-cusp lower first molars in samples from Armenian Highland and Georgia

In populations of the Armenian Highland, the frequency of the four-cusped lower second molars tends to increase over time. People of the Georgia display a high degree of lower second molar cusp reduction (Fig. 4-8).

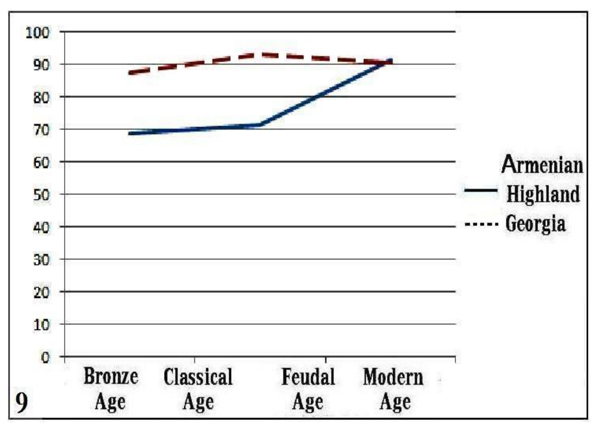

Fig. 4-8. Four-cusp lower second molars in samples from Armenian Highland and Georgia

The frequency of the sixth-cusp on the lower first molar is low in nearly all populations of the Transcaucasian. The trait is virtually absent in the Bronze Age population (Landjik, Black Fortress) of the Armenian Highland and Early Feudal Age of the Georgia (Fig. 4-9). People of the Classical period of the Armenian Highland (5.8%)

and Middle Feudal Age of the Georgia (6.5%) exhibit the highest frequencies of the sixth cusp.

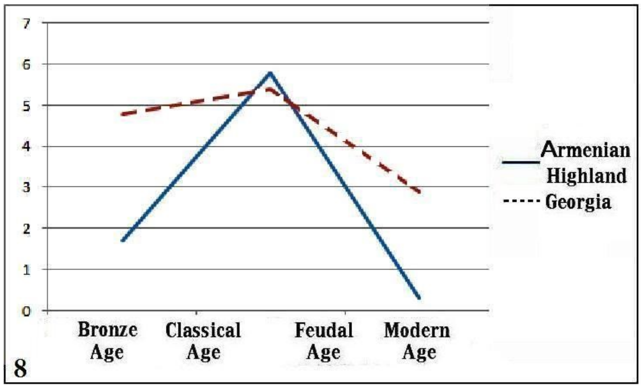

Fig. 4-9. Sixth-cusp lower first molars in samples from Armenian Highland and Georgia

Type 3 of the first eocone groove on the upper first molar (1 eo (3) on M1)

The frequency of type 3 of the first eocone groove on the upper first molar in populations of the Bronze Age Armenian Highland ranges from 21.5% to 43.4%. The population of the Classical period (41.94%) and the early 20th century Armenian series described in Bingel Dag (41.7%) reveals rather similar frequencies (Fig. 4-10). Populations of the Bronze Age display a high degree of type 3 of the first eocone groove on the upper first molar. The trait becomes less frequent in groups of the Classical period (33.3%) and even rarer in Early Feudal Age samples (25.0%).

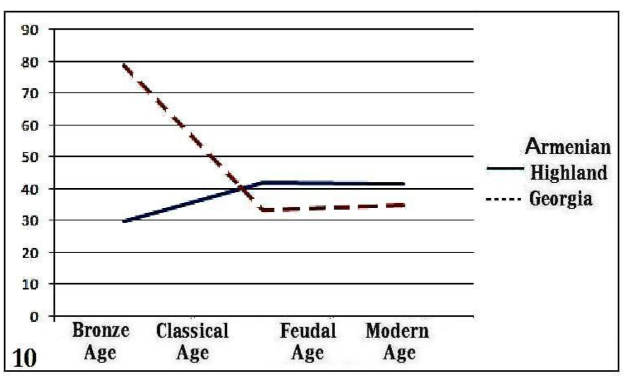

Fig. 4-10. Type 3 of the first eocone groove on the upper first molar in samples from Armenian Highland and Georgia

Distal trigonid crest (DTC)

This trait is ancient and stable. Some specialists believe it is highly diagnostic (Zubov, 1973, 1979; Khaldeyeva, 1992). Discrete dental traits are under genetic control (Nichol, 1990; Scott, 1973; Scott and Turner, 1997) and can be used to estimate genetic relationships among populations (Coppa et al., 2007; Haydenblit, 1996; Howell and Kintigh, 1996; Irish, 2005, 2006; Scott and Turner, 1988, 2006; Sofaer et al., 1986). The frequency of distal trigonid crest in populations of the Bronze Age Armenian Highland ranges from 7.1% to 42.5%. In the Classical period from the Armenian Highland, the frequency of the distal trigonid crest is 50.9; it decreases in 20th century Armenians (Fig. 4-11). People of Georgia display a low incidence of the distal trigonid crest (Bronze Age 8.9; Middle Feudal Age (c. X - XII AD) 6.6 %; Late Feudal Age 2.1%).

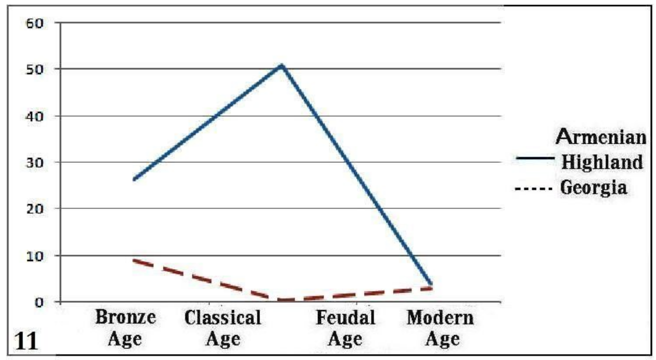

Fig. 4-11. Distal trigonid crest in samples from Armenian Highland and Georgia

Deflecting wrinkle of metaconid (DW)

The deflecting wrinkle is a particular formation of the median ridge of the metaconid. When the deflecting wrinkle is present, the median ridge shows a stronger development in either its length or breadth and curves distalward at the central part of the occlusal surface. This character was first described by F. Weidenreich (1937) in his papers on Sinanthropus and Gigantopithecus, and subsequently, von G.H.R. Koenigswald (1952) drew attention to the deflecting wrinkle in the deciduous mandibular molars in modern Javanese.

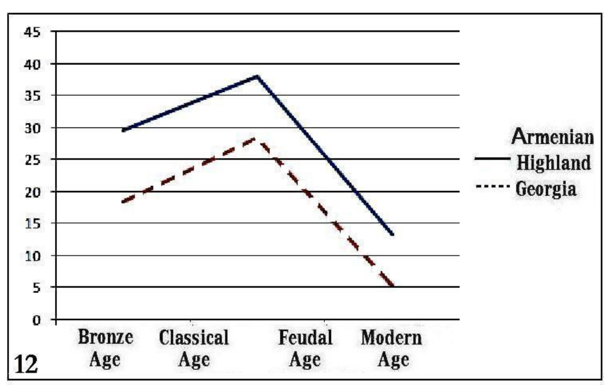

Fig. 4-12. Deflecting wrinkle of metaconid in samples from Armenian Highland and Georgia

In addition, the frequency distribution of this character in Japanese permanent molars was reported by M. Suzuki and T. Sakai (1956) and in Japanese permanent and deciduous molars by K. Hanihara et al, (1964) and K. Hanihara (1970).

In Bronze Age Armenians (Landjik, Black Fortress, 42.5%), the frequency of the deflecting wrinkle of metaconid is higher than Classical period (38.1%). It was low in Bronze Age people of Georgia (18.5%), being maximal in the Classical period (28.5%) (Fig. 4-12). Interestingly, the frequency of the deflecting wrinkle in Early Feudal Age (8.3%) and Middle Feudal Age samples (7.5%) is low.

2(II) med

2(II) med is the notation for an odontoglyphic trait on the metaconid (med) of lower molars. 2 (II) indicates that furrow 2 (a second order furrow that occurs closer to the fovea centrale than furrow 1) goes into furrow II (a first order furrow that separates the protoconid from the metaconid) (Zubov, 1973).

The frequency of 2(II) med in populations of the Bronze Age Armenian Highland ranges from 29.2% to 41.7%. In a Classical period sample from the Armenian Highland, the 2(II) med frequency is 53.4. The trait is low in a Bronze Age population in Georgia (14.8%). In Classical period Georgia, the frequency of the 2(II) med is 33.3, and it decreases in Feudal Age (Early Feudal Age 12.5 %, Middle Feudal Age 17.5 %; Late Feudal Age 12.5 %).

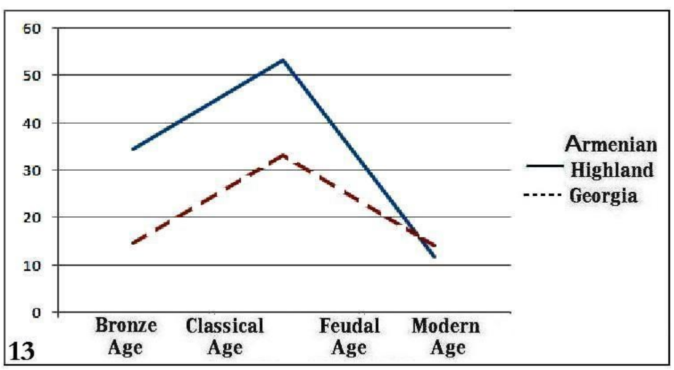

Fig. 4-13. 2(II) med in samples from Armenian Highland and Georgia

Figures 2 and 3 presents the differentiation of the comparative populations from Armenian Highland and Georgia (Bronze Age and Classical period). Teeth of the population from Armenian Highland (Bronze Age) are characterized by a low frequency of Carabelli's cusp on M1, a low frequency of six-cusped forms on M1. and the 1eo (3) on M^1. The occurrence of pronounced reduction of upper second incisors was not recorded (variants 2 and 3). The frequency of crowding, diastema, reduction of incisors (grade 1), hypocone reduction of maxillary second permanent molar (M2∑3,3+), four-cusp lower first molars, distal ridge of trigonid and deflecting wrinkle of metaconid was very high (Fig. 2). Teeth of the population from Georgia (Bronze Age) are characterized by a high frequency of Carabelli's cusp on M1, six-cusped lower first molars, four-cusped lower second molars, and type 3 of the first eocone groove on the upper first molar. The frequency of the distal trigonid crest on M1, double shoveling, reduction of incisors (grade 1), hypocone reduction of maxillary second permanent molar, four-cusped lower first molars and the deflecting wrinkle is moderately higher in the population from the Armenian Highland (Classical period) that the average value for Georgian populations (Fig. 3).

Comparative analysis

Table 4 presents data concerning the frequency of the occurrence of 10 odontological traits in 11 populations of the Armenian Highland and Georgia. The frequency of traits in percents was converted into frequencies expressed as radians. A modified set of initial data was used to assess the degree of differentiation by means of principal component analysis. This method converts original traits (in radians) into new traits (meta-traits) that are called principal components. The principal component analysis reduces the multidimensional set of variety to two or three-dimensional level, losing only a small percent of information.

Taking into account the character of the connection between attributes in this component, it is possible to tell that the large values up to the first dimension axes

Trait	I	II	III
I^1-I^1 diastema	**0.597**	-0.324	**0.745**
I^2 crowding	**0.541**	0.116	0.117
Hypocone reduction on M^2	0.494	**-0.746**	0.351
Carabelli cusp on M^1	-0.421	**0.672**	**0.632**
Four-cusped M_1	**0.979**	**0.501**	-0.492
Four-cusped M_2	**-0.814**	-0.134	**0.541**
Distal trigonid crest	-0.158	**0.689**	0.221
Deflecting wrinkle of me-ta-conid	**0.771**	0.352	0.426
1eo (3) M^1	**0.686**	**0.511**	-0.269
2 med II M_1	**0.501**	0.203	-0.462
Values	54.561	28.671	20.352

Table 4. Elements of three initial components for 11 groups

(correspond to groups with four-cusped lower first molars (0.979), the deflecting wrinkle (0.771), the 1eo (3) M¹ (0.686), diastema (I1-I1) (0.597), I2crowding (0.541), and 2 med II M1 (0.501). A negative weight is associated with four-cusped lower second molars (-0.814).

Maximal values for the second component (28.6% of the total variability) are for distal ridge of the trigonid (0.689), the Carabelli cusp on the upper first molar (0.672), type 3 of the first eocone groove on the upper first molar (0.511), and four-cusped lower first molars (0.501). The negative weight is associated with hypocone reduction of the maxillary second permanent molar (-0.746). The third component accounts for 11.4% of intergroup variation. The strongest weights are with the diastema (I1-I1) (0.745), Carabelli cusp on the upper first molar (0.632), and four-cusped lower second molars (0.541).

For positive coordinates of the first axis, the most discriminating dental traits are the four-cusped lower first molars, the deflecting wrinkle, and type 3 of the first eocone groove of the upper first molar. The first two traits show higher frequencies in the Lchashen (3), Landjik, Black Fortress (1) and Beniamin, Vardbakh, Black Fortress I, and Karmracar (4) samples, and slightly lower frequencies in the groups from Georgia. For negative coordinates, the most significant trait is four-cusped lower second molars, which show higher frequencies in the groups from Georgia.

Next, we applied the cluster analysis (Fig. 5). Two main clusters are illustrated in the dendrogram, obtained by using hierarchic method from the first 3 axes. The first cluster is represented by Bronze Age samples from the Armenian Highland, differentiated from the second cluster composed of all the other groups. Within the latter, two sub-groups can be shown. The first is formed by the Bingel Dag (20th century Armenian) and the Feudal and Classical periods samples of Georgia. The Classical period sample can be chronologically placed between the Early Feudal Age and Middle Feudal Age periods. They may have maintained archaic traits because of their geographical isolation. The 2 supgroup consists of the Digomi, Mckheti (Bronze Age) and the Late Feudal Age samples.

From the analysis of non-metric dental traits, a common biological background can be hypothesized among the populations that inhabited Transcaucasian. The Armenian Highland groups perfectly fit this pattern, showing a high degree of biological continuity between the two periods (Bronze Age - Classical period). The 20th century Armenians (Bingel Dag) are strictly linked between the groups from Georgia (Feudal and Classical periods). Clear affinities are visible between the samples from Georgia.

Comparative analysis reveals that the populations of the Armenian Highland and Georgia differentiated as far as the frequency of odontological traits is concerned. Armenian Highland samples are characterised by a different frequency in trait reduction compared to the series from Georgia. Morphological traits of teeth (odontological traits) differentiated markedly between the comparative populations. Therefore, they provide a good tool for studying the biological differentiation of skeletal populations. Diachronic changes in nonmetric morphological characters of teeth in the Armenian highland and Georgia populations occurred at different rates for different traits.

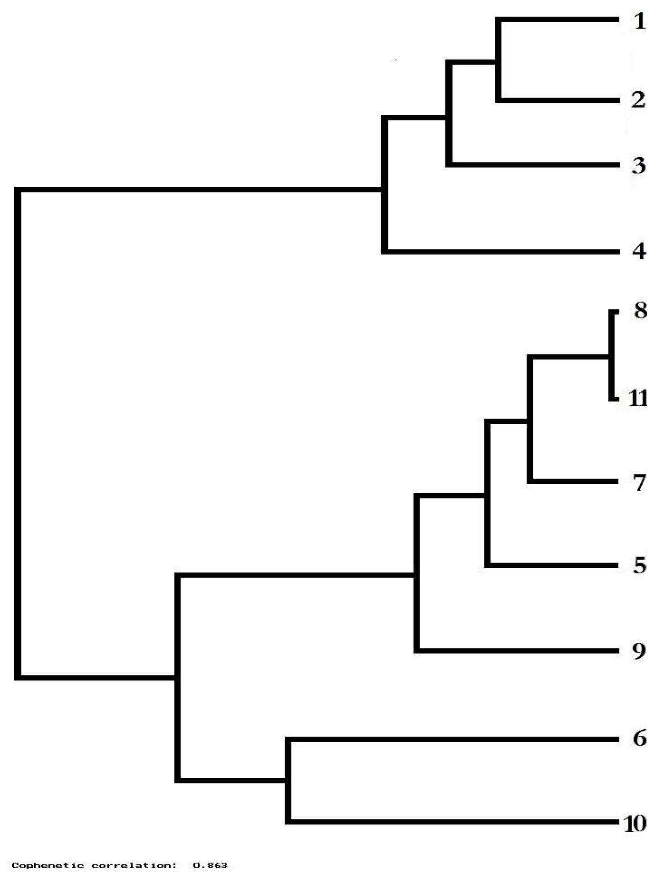

Fig. 5.
Cluster tree:
1 - Armenian Highland (Bronze Age),
2 - (Bronze Age and Classical period),
3 - Armenian Highland (Bronze Age),
4 - Armenian highland (Classical period),
5 - Armenian Highland (Modern population),
6 - Georgia (Bronze Age),
7 - Georgia (Classical period),
8 - Georgia (Early Feudal period),
9 - Georgia (Average Feudal period),
10 - Georgia (Late Feudal period),
11 - Georgia (Feudal period)

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Contextualizing Buccal Dental Microwear Variations During the Byzantine Period in Jordan

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Keywords: Diet, Dental Wear, Hunter-Gatherers, Food Processing, Natufian

ABSTRACT This study scanned 14 buccal surfaces of teeth casts microscopically from the Byzantine sites of Yajuz and Sa'ad in Jordan, and 7 samples from the Natufian site of El Wad in Palestine for the purpose of studying buccal microwear. The results show no differences in the pattern of dental microwear between the two byzantine sites, while a difference was existed when these sites compared to El Wad. The results indicate that subsistence economy did not trigger buccal microwear but cultural development. Although the economies during the Byzantine period were diversified, technological adaptation diffused into region, which eased food accession and procession.

INTRODUCTION

The Byzantine period (324–638 CE) in the Levant and particularly in Jordan has received influential thoughts by historians on both sociopolitical and economic levels (Jones, 1964). The archaeological studies refuted the historians' thoughts (Kingsley, 2001) but unfortunately few dealt with the subject in a broader economic view (Rose et al., 2007). However, local economic variations must have been existed, triggered by the varied subsistence economies. One of the best models in this regard is the Byzantine site of Natfieh, where agriculture and animal husbandry were the sources of food (Al-Bashaireh et al., 2010). Social stratification in terms of populace and elites was common during this period, which exerted a wider gap in wealth accumulation between urban and rural settlements, or even on a settlement level (Grossman, 1974; Garnsey and Saller, 1987). Therefore, self-sufficient economies that relied on land as the main source of food production and improvisation were presumably site-specific and might not be applied at other contemporaneous Byzantine settlements in Jordan. The function of a settlement might have possessed another check on economic success, such as, the late Roman/Early Byzantine military garrison discovered near Queen Alia International Airport (Ibrahim and Gordon, 1987), these sites did not excersiced a complex subsistence economy but mostly relied on aid from the central goverment.

Another unique Byzantine settlement, in this sense, is Khirbit Yajuz in the middle of Jordan. The site was proved to be a substantial producer of textile in the region (Khalil, 1998; Al-Shorman, 2003; Al-Shorman and Khalil, 2006) but it is not known yet if other subsistence economies were additionally practiced. During the same period, the people of the Byzantine site of Sa'ad -- at the edge of the arid zone -- in northern Jordan subsisted on agriculture, produced huge amounts of wine for export purposes, and believed to be self-sufficient (Rose et al., 1997). The two different economic models in Khirbit Yajuz and Sa'ad (fig. 1) would have created two different dietary forms for local consumption that could be reconstructed. Accordingly, this study investigates the type of diet among the people of these sites using buccal dental microwear depicted by scanning electron microscopy of teeth.

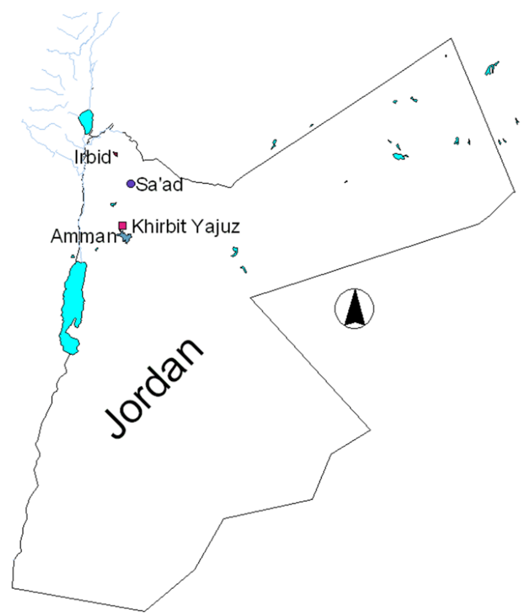

Fig. 1. The archaeological sites of Khirbit Yajuz and Sa'ad, Jordan.

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The buccal dental microwear analysis is one of the direct methods in reconstructing diet through examining the microscopic surfaces of teeth (Grine et al., 2002). Contrary to occlusal microwear, buccal microwear provides insights on diet over a longer time and is not affected by tooth-to-tooth contact (Pérez-Pérez et al. 1994; Pérez-Pérez, 2004; Romero et al., 2012). For this reason, buccal dental microwear has become very common and widely accepted as a tool for reconstructing primates' diet and ecology (Galbany et al., 2003; 2004; 2005; 2009), and dietary adaptation and behavior of extinct human populations (Romero et al., 2004; Martinez et al., 2004; Romero, 2005; Polo-Carda et al., 2007; Romero and De Juan, 2007; Alrousan and Pérez-Pérez, 2008; 2012 Estaberanz et al., 2008; 2009; Alrousan et al., 2009). The recent studies have focused on the experimental research to improve the quantification of buccal microwear analysis using precise digital techniques (Martinez and Pérez-Pérez, 2004; Galbany et al., 2005).

The abrasive particles in the diet induce microwear on the buccal surfaces of teeth. These particles are either intrinsic to diet, such as, phytoliths of plant tissues, which have hardness that exceeds dental enamel (Piperno, 1988; Lauleza and Pérez-Pérez, 1994) or extrinsic when dust, ash, or sand contaminates food during processing (Mahoney, 2006; Alrousan and Pérez-Pérez, 2008; 2012; Alrousan, 2011). Despite the source of these particles, they eventually cause both pits and striations on occlusal surfaces of teeth (Teaford and Oyen, 1989; Schmidt, 2001; Mahoney, 2006; Ungar et al., 2008; Alrousan, 2011) but only striations on the vestibular or buccal surfaces (Puech and Albertini, Pérez-Pérez 1983; Pérez-Pérez; 1994; 1999; 2003; Alrousan and Pérez-Pérez, 2008; 2012). Meat, for example, is correlated with a large number and longer vertical striations on the buccal surfaces of the teeth, whereas plant items tend to cause higher densities of longer horizontal striations (Puech, 1976; 1979; Puech and Albertini, 1981; 1984; Puech and Pant, 1980; Puech et al., 1980; 1983; 1986; Pérez-Pérez et la., 1994; Lalueza et al., 1996; Alrousan and Pérez-Pérez, 2012). Accordingly, the buccal microwear pattern is a reliable, nondestructive, and accurate method for dietary reconstruction because it can reflect dietary changes over the long term rather than providing evidence on the "last supper" (Pérez-Pérez et al., 1994; Alrousan, 2009; Romero et al., 2012).

The presence of microwear features on the occlusal surface depends on many factors; the mechanics of chewing, mastication forces, the position of analyzed wear facet, and the section of analyzed wear facet (Kay and Hiiemae, 1974; Gordon and Walker, 1983; Pérez-Pérez, 2004; Mahoney, 2006). On the other hand, buccal surfaces are not affected by tooth-to-tooth contact during chewing cycle, with minimal effect by the forces of mastication (Puech and Pant, 1980; Lalueza and Pérez-Pérez, 1993; Pérez-Pérez et al., 1994; Pérez-Pérez, 2004). The presence of extensive tooth wear or the use of teeth as a tool makes the analysis of occlusal microwear impossible. For these reasons, bioarchaeoligiests tend to extract dietary information from the enamel surface using buccal dental microwear technique.

MATERIALS AND METHODS

For the purpose of this study, buccal dental microwear patterns were collected from 14 individuals; 7 from the Byzantine site of Khirbit Yajuz in the middle of Jordan and 7 from the Byzantine site of Sa'ad in northeastern Jordan. A Single post-canine tooth was chosen to represent each individual, all individuals are right fully developed third molars (Alrousan and Pérez-Pérez, 2008; Pérez-Pérez et al., 2003). The samples have well-preserved enamel surfaces without dental pathologies. According to microwear standards, post-mortem changes, taphonomic changes, and unpreserved enamel surfaces were determined after Teaford (1988), Martinez and Pérez-Pérez (2004) and Pérez-Pérez et al. (2003). The surfaces of dental enamel were gently cleaned with pure acetone and then rinsed with 70% ethanol using cotton swabs. Molds of the original teeth were obtained using Polyvinyl-siloxane President Microsystems™ (Coltene Regular Body) (Galbany et al. 2006; Ungar et al. 2006). Positive casts of tooth molds were obtained using epoxy resin (Epo-Tek 301, By QdA) with a two-stage centrifugation procedure to prevent the formation of air bubbles.

Before examining the casts under SEM (Scanning Electron Microscope), the samples were mounted on aluminum stubs with carbon gum. The casts were then coated with a 400 Å gold layer. The SEM observation settings were 15 KV with 0º tilt angle of the secondary electrons. The micrographs were obtained at 100X magnification on the medial aspect of the buccal surface of the cast at a distance from the occlusal rim of the cusps and the cement-enamel junction. The images were then cropped to cover an area of 0.56 mm2, where the measure of the side border of each square micrograph was 748.33 μm (Fig. 2) (Pérez-Pérez et al. 2003; Alrousan and Pérez-Pérez 2008; 2012).

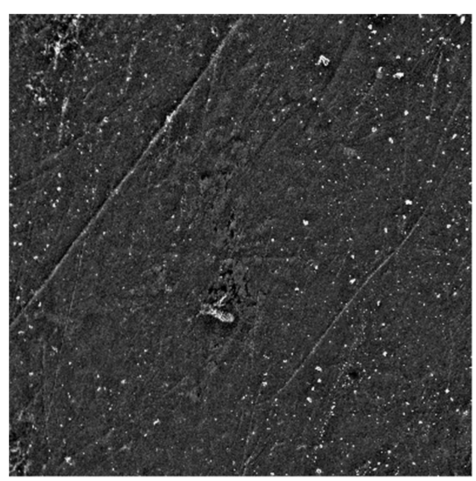

Fig. 2. Micrograph of buccal microwear

Each micrograph was processed using Adobe Photoshop by applying a "high pass" (50 pixels) filter and "automatic" level enhancement. In order to quantify buccal dental microwear pattern (striation length and density), Sigma Scan Pro 5 (SPSS) package was used. The slope and the length of striations in each micrograph were digitally measured. The orientations of the striations were measured according to Lalueza et al. (1996) and Pérez-Pérez et al. (1994; 2003). The orientation was measured from 0º to180º and classified as follows (Fig. 3):

1. Vertical (V): angle ≥ 67.5º and ≤ 112.5º.
2. Mesio-occlusal to Disto-cervical (MD): from 112.5º to 157.5º for the upper left and the lower right teeth.
3. Disto-occlusal to Mesio-cervical (DM): from 22.5º to 67.5º for the upper right tooth and lower left.
4. Horizontal (H): angle ≥ 0º and ≤ 22.2º, and angle ≥ 157.5º and ≤ 180º.

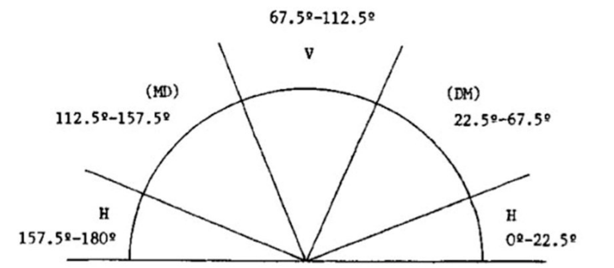

Fig. 3. Orientations of striation (Pérez-Pérez *et al.*, 1994)

For all orientation categories (H, V, MD, DM),the total number of striations (T), the density (N), average length (X) and standard deviation of the length (S) of the striations were computed and, thus, a total of 15 microwear variables were derived for each sample (Pérez-Pérez et al. 1994). A second stage comparison was performed: the first stage is between the two sites; the normality of the frequency distributions of the 15 variables was tested with the Kolmogorov-Smirnov test for goodness of fit. Then, a one-factor ANOVA test was used to compare the 15 variables in the two sites. The second stage of comparison compared the microwear pattern of the Byzantine teeth with the Natufian teeth from El Wad after Alrousan and Pérez-Pérez (2012). EL wad is a hunter-gatherer site located in Palestine, and dated to 12,950 - 10,680 years bp based on relative and 14C dating (Garrod, 1931; Weinstein-Evron 1991). This comparison is aimed to understand the cultural development regarding food acquisition and processing from hunting and gathering to farming.

RESULTS

The means and standard deviations of the above variables are presented in table 1. The results of statistical analysis are presented in table 2. First stage of comparison results; Kolmogorov-Smirnov normality tests shows that none of the 15 variables differed significantly from normality for the two sites considered. Therefore, parametric statistical tests could be applied to the raw data. No significant differences were discovered between the two sites, Sa'ad and Yajuz, considering the 15 variables of buccal dental microwear (fig. 4).

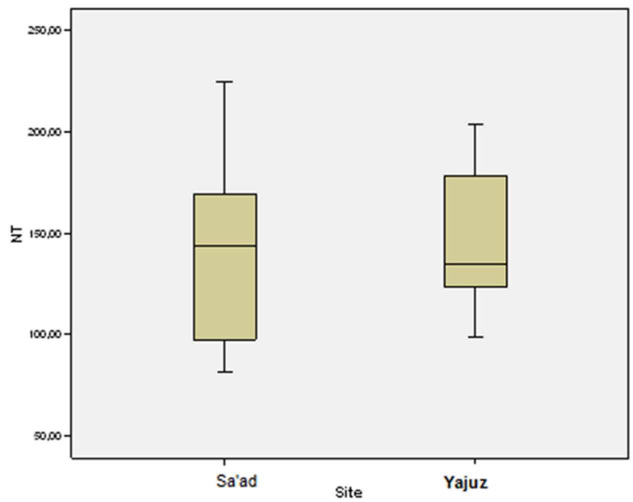

Fig. 4. Total number of striation of the Byzantain Sites Sa'ad and Yajuz.

The second stage of comparison indicates that there are significant differences between the Natufian people and the Byzantain people at least in ten variables; the length and the standard deviation of horizontal striations, vertical striations, Mesodistal striations, Distomesial striations, and total striations. The characteristic feature of the buccal dental microwear of the Natufian samples is the longer striations in a comparing with that of the Byzantine samples (Fig. 5).

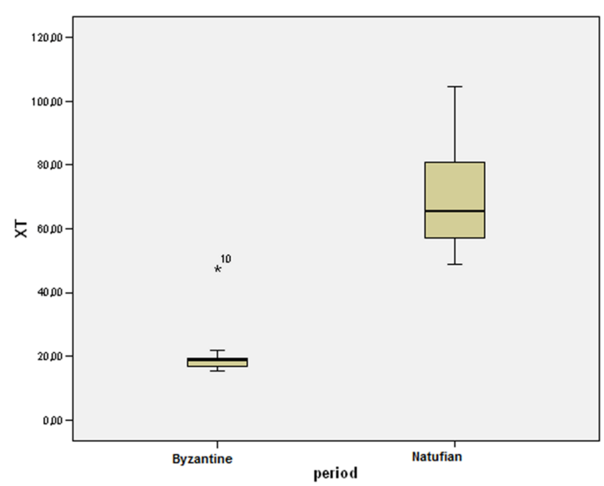

Figure 5: Length of all striations of the two periods

Site	Sa'ad No.=8		Yajuz (No.=7)		El Wad (No.=7)		Byz (No.=15)	
	Mean	Sd.	Mean	Sd.	Mean	Sd.	Mean	Sd.
NH	26.875	10.629	31.571	14.604	35.286	14.930	29.067	12.400
XH	19.779	3.090	20.447	11,009	83.043	40.215	20.091	7.539
SH	10636	2.990	10.394	7.374	59.094	46.071	10.523	5.271
NV	21125	14.759	26.000	8.869	30.143	19.651	23.400	12.205
XV	19.356	4.142	27.006	16.135	79.091	22.976	22.927	11.651
SV	11.657	4.033	18.069	10.914	66.237	23.140	14.649	8.375
NMD	48.125	18.849	55.286	24.088	66.571	39.136	51.467	20.976
XMD	17.394	2.433	22.342	13.331	60.633	13.067	19.703	9.255
SMD	11.309	5.913	14.170	10.674	35.056	10.597	12.644	8.276
NDM	44.750	22.487	35.857	10,946	44.000	14.674	40.600	18.035
XDM	17.065	1.896	18.832	7.539	61.189	17.519	17.890	5.195
SDM	9.113	3.888	8.660	4.714	41.134	15.621	8.902	4.140
NT	140.875	48287	148.714	38.156	176.000	63.765	144.533	42.499
XT	18.315	1.685	22.267	11.256	70.652	21.255	20.159	7.739
ST	11.515	2.841	14.156	8.489	55.063	24.310	12.747	6.065

Table 1: Descriptive statistics. El wad results after Alrousan and Pérez-Pérez (2012).

	Sum of squares	Degree of Freedoom	Mean of Squares	F	Probability
XH	18914.104	1	18914.104	36.029	.000
SH	11259.504	1	11259.504	17.158	.001
XV	15055.583	1	15055.583	59.417	.000
SV	12701.519	1	12701.519	60.560	.000
XMD	7995.701	1	7995.701	71.912	.000
SMD	2397.317	1	2397.317	29.366	.000
XDM	8948.033	1	8948.033	80.640	.000
SDM	4958.516	1	4958.516	58.196	.000
XT	12168.150	1	12168.150	68.573	.000
ST	8546.363	1	8546.363	42.093	.000

Table 2: ANOVA results

DISCUSSION

Diet is one of the most important aspects used to understand the paleobiology, evolution, and culture of extinct human populations. In order to reconstruct diet, Bioarchaeologists use teeth because of they are the most preserved human skeletal remains, where they are commonly found in ancient burials. The results of buccal dental microwear of this study are highly correlated with the archaeological data and records. The main sources of inter population variation in buccal dental microwear are the number and the length of striations that eventually depended on ecological factors including food availability and resources. For example, buccal microwear patterns from Pliocene Hominids, in comparison with modern Hunter-gatherers with relatively known diet, have showed higher density of striations in corresponding to higher abrasiveness of the diet (Pérez-Pérez et al., 1994; 2003). The patterns of buccal microwear from Neolithic and Natufian teeth in the ancient Near East showed that the longer striations in the Neolithic teeth is due to food processing technique and introduction of more cereals and plants in diet (Alrousan, 2009). The index of NH/NV is highly an indicator of the type of consumed diet; hunter -gatherers (meat dependant) and pastoralists tend to have a lower value of this index (Lauleza et al., 1996; Alrousan and Pérez-Pérez, 2012). Since there are no significant variations between Sa'ad and Yajuz, this study suggests that the diet in both sites is similar in relation to resource or even processing although the two sites practiced different subsistence economies. Sa'ad people depended on agriculture and animal husbandry, while Yajuz people practiced textual manufacturing. The previous study of occlusal dental microwear of the same samples of Yajuz (Al-Shorman and Khalil, 2006) did not extract any information regarding diet and/or dietary adaptation, where occlusal dental microwear pattern was masked by using teeth as tools. The length of striations here is positively correlated with the abrasiveness of diet, more abrasive diet tend to leave longer striations on the buccal surface due to the exerted heavy masticatory forces (Puech, 1978; 1982; Pérez-Pérez et al., 1994; Alrousan and Pérez-Pérez, 2008). Therefore, the people of El Wad probably consumed a harder diet compared to the Byzantine population.

The difference between the Natufian and the Byzantine periods is probably due to the differences in food intake and food processing (cultural development) rather than environmental conditions. The Natufian people of El Wad were hunter-gatherers; depending more on gathering than hunting (Alrousan and Perez- Pérez-Pérez, 2012). The gross wear that they had resembled that of Pre Pottery Neolithic people (Smith, 1970) as triggered by the presence of grinding tools (Henry, 1989; Bar Yosef, 1998). The large component of plant food created more abrasive materials that needed more masticatory forces and thus caused longer striations. Food processing is another factor that affects microwear pattern (Teaford and Lytle, 1996; Ungar and Spencer, 1999; Alrousan and Pérez-Pérez, 2008), where after the introduction of pottery in the Neolithic period, cooking was facilitated and the texture became softer, which required less maticatory forces.

CONCLUSION

Despite the variation in subsistence economy in rural Byzantine settlements, the inhabitants consumed diet that was probably similar in texture, which stresses on the diffusion of cultural development throughout the region. Throughout the history of the region, it seems that the technological innovation in cooking utensils reduced the abrasiveness on the enamel surfaces of teeth. The variation in the local economies in rural areas during the Byzantine period have imposed little if any restrictions on technological adaptation but does not negate the access to better quality and quantity of food items by the elites.

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BOOK REVIEW

Legacy of a Longitudinal Growth Study in Central Australia. By Tasman Brown, Grant C Townsend, Sandra K Pinkerton, James R Rogers. Published in Adelaide by University of Adelaide Press, 2011. pp. 327. ISBN: 978-0-9807230-9-0, price A$35.00, paperback. 978-0-9870730-0-6, Free, e-book PDF.

Aboriginal Australians have been in their island setting for at least 40,000 years (Crane 2013), but most change has occurred via immigration of Europeans over the past two centuries (Singh 2013). (Australia was "discovered" in 1606 by the Dutch vessel Duyfken, captained by Willem Janszoon—though some claim an earlier European discovery). The social history of native Australians unfortunately mirrors the deceit and abuse of American Indians as the United States was peopled westward by Europeans (Prucha 1997).

It is inspiring, then, that this nicely-written book, "The Yuendumu: Legacy of a longitudinal growth study in Central Australia" describes positive experiences for both Aboriginals and academicians. This readable book is structured as a narrative history with chapters devoted to themes as diverse as tooth crown sizes (the well-known works of Maury Barrett 1963a,b on tooth crown sizes) to anthropometric dimensions of a cohort of Aboriginal measured annually during the 1960s. It was written as a group effort but principally by Tasman Brown and Grant Townsend, both long-time participants with the Yuendumu. The book is an homage to Professor Brown who devoted much of his professional career to the physical anthropological study of the Yuendumu. A singular feature of this wonderfully-illustrated book is its ready availability. It can be purchased in the conventional paper format, but it can also be downloaded gratis as a PDF. The hard copy functions for high-lighting and notation, but the electronic version is available everywhere, has the same colored plates, and can be annotated with any PDF reader.

The book is presented from a historical vantage point, high-lighting the seminal dental and anthropological investigated spearheaded by Dr. Murray James Barrett (1916-1975) of the University of Adelaide, a student of Thomas Draper Campbell (e.g., Campbell 1925).

Yuendumu is a settlement northeast of Alice Springs in Central Australia. Its attraction was a steady source of water that evolved into a sheep ranch and Baptist mission with outreach to the Aboriginals. Today, the settlement consists of wooden houses, cars, and a native contingent of about 300. The book emphasizes that,

From its inception, Yuendumu was a government settlement and not a mission, with the responsibility for policy and daily affairs being that of the government. Thus the missionaries were required to operate within the bounds of such policies as assimilation. However the Baptists were involved in much more than meeting spiritual needs. They helped supply clothing and medical supplies, taught sewing, commenced and ran the first store, helped build and often staffed the hospital, commenced a kindergarten, and commenced the first school.

Early work at Yuendumu involved Barrett (and students and collaborators) making dental casts of the children and adults, though attrition and antemortem loss commonly affected the adults. This work was remarkable for the Adelaide team's repeated visits. The resulting mixed longitudinal nature of the study design is quite uncommon in the anthropological literature. The feat is the more remarkable because of the paucity (and, often, absence of) institutional funding for the teams. The semi-serial design was possible largely because of the Aboriginals' sedentism plus the trust and alliances between the researchers and the host population. Group leaders even were given Warlpiri names. Murray Barrett became a member of the Jungarrayi group and Tasman Brown became a Jakamarra. This rapport between the cultures—attributed mostly to Barrett's exuberant personality—formed the backbone for the years of study of this one Aboriginal lineage.

Another fascinating feature of the "Yuendumu Study" was its multifaceted outlook. Dental casts formed the base of the study, but many other data were collected, including kinship patterns, anthropometrics, lateral and posteroanterior head x-rays, genealogies, and more. While Barrett's classical studies of tooth size (1963a,b) are familiar to most dental anthropologists, other information is not—and it is all detailed in this book (including numerous useful references).

The book offers much more, but it serves as a useful primer dealing with the logistics and organization of the ever-varying team from Adelaide to Yuendumu—originally a several-day safari some 285 km northwest from Alice Springs. Over the course of the study, many renowned clinicians and scientists from abroad, including Arne Bjőrk, William Proffit, and Tsunehiko Hanihara, accompanied the group, always extending the scope of studies with their particular interests. This history—well-documented in the text—also promotes the value of a multidisciplinary approach and how the components build synergistically on one another. Bjőrk suggested the addition of cephalometric radiographs; Proffit took telemetry recordings of the people's masticatory patterns. The resulting breadth of the data collection forms a uniquely broad-ranging picture of an otherwise little-known non-European group.

One of the other joys of the book is the careful and thorough list of references stemming from the decades of study. Comprehensive lists are provided at the end of the chapters as well as an appendix. These collections of citations alone make the book invaluable.

One message of the book is the irreplaceable value of a visionary and dedicated leader (Murray Barrett; Tasman Brown) coupled with a multidisciplinary approach—which are at the heart of anthropological studies—in combination with the merit of involving researchers with diverse but well-organized projects. Funding for the Yuendumu project was always meager, but the diversity of the studies permitted the broadest sources of funding, both in Australia and internationally.

This book is written by people deeply committed to the Yuendumu project who described its history in detail. The Yuendumu have continued to change, of course, including falling under the blight of unemployment. This book commemorates some of the positive histories of this group—a wonderful coming together of the Aboriginals and researchers, and now documented for all time by a select group of dedicated researchers.

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