ORIGINAL ARTICLE

Eur J Anat, 15 (3): 162-175 (2011)

Unusual occipital condyles and craniovertebral anomalies of skulls buried in the Late Antiquity period (1st century BC – 3rd century AD) in Armenia

Anahit Y. Khudaverdyan

Institute of Archaeology and Ethnography, National Academy of Science, Yerevan 0025, Republic of Armenia

SUMMARY

The aim of the present study is to analyze the unusual occipital condyles and craniovertebral anomalies of skulls from the Late Antiquity period (1st century BC – 3rd century AD) in Armenia to acquire such morphometric data regarding the occipital condyle and classify it according to its shape and size. The results of this study reveal the variability of occipital condyle parameters, including shape, length and width. The shape of the occipital condyles was classified in eight types. The occipital condyles and the foramen magnum were affected by marginal osteophytosis. Most foramina magna were oval- and diamond-shaped. The lateral cervical spine in two individuals from the Black Fortress shows an ovoid terminale ossiculum. The skeleton of a young adult woman, whose skull exhibited a remarkable degree of assimilation of the atlas, was found during an archaeological exploration in Beniamin. It is likely that both genetic and environmental factors would have contributed to the etiology of the skeletal defects. Environmental factors, in particular nutritional deficiency and disease, may trigger or enhance the genetic predisposition for developmental defects. The findings of this research reveal a documented list of pathologies that ailed the people in the Late Antiquity period in their daily lives.

Key words: Foramen magnum – Occipital condyle – Anatomical variations – Terminale ossiculum – Assimilation of the atlas

INTRODUCTION

The cranial base is a complex structure with several different significant bony landmarks that anthropologists use on a regular basis. The entire cranial base underwent changes from our early hominid ancestors to modern *Homo sapiens sapiens*. Some of the osteological features that have undergone evolutionary changes include: the petrous portion, the postglenoid process, the tympanic bone, the squamosal portion of the temporal bone, and the foramen magnum (Scott, 1958; Nevell and Wood, 2008). The occipital condyles are small, bilateral inferior extensions of the occipital bones and form a portion of the lateral aspect of the foramen magnum. Several types of anomalies and traumas are associated with the occipital condyles. The condyles articulate with the lateral masses of the C-1 vertebral body. This unique anatomical feature results in a unique biomechanical characteristic. Its integrity is of vital impor-

Submitted: July 26, 2011
Accepted: September 28, 2011

Correspondence to:
Dr. Anahit Khudaverdyan. Institute of Archaeology and Ethnography, National Academy of Science, Charents st.15, Yerevan 0025, Republic of Armenia.
Phone: +(374) 099 577-991; +(374) 565-884.
E-mail: ankhudaverdyan@gmail.com; akhudaverdyan@mail.ru

tance for the stability of the craniovertebral junction. They are intimately related to the other osseous structures at the foramen magnum and skull base by a number of ligamentous attachments. A variety of disease processes may affect the craniovertebral junction. In the population, abnormalities may be either congenital (Arnold-Chiari malformations) or acquired (posttraumatic, inflammatory, neoplastic) (Stroobants et al., 1994; Binatli et al., 1995). In individuals, acquired lesions involving the craniovertebral junction and foramen magnum may be the result of trauma (occipital condyle fractures related to axial loading injuries in association with ipsilateral flexion, avulsion fractures from a combination of head rotation and contralateral head flexion) (Anderson and Montesano, 1988; Deeb et al., 1988). Inflammatory disorders such as rheumatoid arthritis and metabolic disorders such as Paget's disease, and hyperparathyroidism may result in basilar invagination (Johnson and Smoker, 1994).

The cranial base and endocranial base are directly affected by the cervical vertebrae, which play a substantial role in the development and modification of the foramen magnum. Congenital and developmental osseous abnormalities and anomalies affecting the craniovertebral junction complex can result in neural compression. Assimilation of the atlas or atlantooccipital fusion, a common skeletal abnormality of the upper cervical spine, was found during an archaeological exploration in Beniamin (1st century BC – 3rd century AD) (Khudaverdyan, 2000). Three forms were observed in the Black Fortress I and Vardbakh skeletal series: the terminale ossiculum, which manifests as a cone-like protuberance on the lateral side (s) of an occipital bone; the precondylar tubercle is a small spicule of bone that projects from the anterior rim of the foramen magnum, and several manifestations that are expressed as bony protuberances around the foramen magnum. These axial anomalies are believed to be triggered by combined delays in vertebral development and intervertebral disc formation of the affected border region (Barnes, 1994; Khudaverdyan, 2005). A congenital anomaly of the craniovertebral junction, assimilation of the atlas with the occipital bone, is generally associated with bony torticollis (Bharucha and Dastur, 1964; Tachdjian, 1990). Although vertebral border shifting is believed to have a strong genetic component, some researchers have argued that the etiology of these anomalies is not only complex, but also poorly understood (Merbs, 1974). As suggested by Barnes (1994), these vertebral borders are unstable, and hence more sensitive, regions of the skeleton. It seems logical that they may also be those most susceptible to extrinsic stressors, such as malnutrition and disease, which can interfere with proper ontogeny.

The primary goal of this research project is to document and analyze the foramen magnum shape (with consideration of the occipital condyles) and craniovertebral anomalies to determine whether there is a correlation between the shape, the anomalies and stress indicators. The skeletal collections used in the present study represent individuals whose remains were found in the Shirak plateau (Armenia). This illustrated paper presents the findings of the study of the craniovertebral anomalies in the population in Late Antiquity.

The Armenian Highland (also known as the Armenian Upland, Armenian plateau, or simply Armenia (Hewsen, 1997) is the central-most and highest of three land-locked plateaus that together form the northern sector of the Middle East (Hewsen, 1997). The present Armenian Republic (Fig. 1), which consists of perhaps a tenth of historic Armenia, is located in the South Caucasus on the eastern end of the historic Armenian plateau. In early history, the Armenian highlands were a crossroads linking the worlds of the East and West (Martirosyan, 1964). Morphological analysis of the material has revealed the heterogeneity of the population of the Shirak plateau of Armenia (Khudaverdyan, 2000, 2009). The intragroup analysis revealed two groups of the population. The horizontal profile of the face (group II) in them is slightly weakened. It should be noted that carriers of this complex are reminiscent of representatives from the territory of Moldova (Nikolaevka) and Turkmenistan (Meshreti-Takhta) (Khudaverdyan, 2000).

Materials and Methods

The human remains analyzed here were excavated by a Gyumri team under the direction of Step n Ter-Markaryan (Vardbakh and the Black Fortress I, both sites located on the Shiraksky plateau, Fig. 1). In most cases, the remains were found to be remarkably well preserved Sex determination and estimation of the age at death were performed on each skeleton. The rites of single inhumations in the late Ancient period were located in hillforts or well-defined burial areas.

Individuals were placed in extended positions, accompanied by burial goods of metalwork, pottery etc. The site of Black Fortress is remarkable due to the archaeological presence of two time periods of ancient Armenian history (Late Bronze Age and Ancient period – 1st century BC – 3rd century AD). Many sites with very large cemeteries are found here.

Fig. 1.- Main sites discussed in the text.

The Black Fortress I (1st century BC - 3rd century AD) site is a regular cemetery and has been excavated since 1993; the excavations are on going (Ter-Markaryan and Avagyan, 2000; Avagyan, 2003). A fortress made of black stone was called the "Black Fortress." Black stone of high quality was available regionally, and was presumably highly valued. The cemetery is located near the Aleksandrapol tower in the city of Gyumri. All the burials appear to have been typical of the Late Antiquity Armenian period, and are oriented in an east-west direction. A total of 28 individual skeletons were exhumed from the burial site; these included 10 males, 13 females (Table 1). Four children (2-10 years) and 1 juvenile between 12 and 19 years were the only non-adults present in the sample. Small animals were common, the majority animal bone fragments recovered at the Black Fortress were from horned livestock and reptiles (especially turtles) (Avagyan, 2003).

A total of 14 skeletons were found during excavation works at the Vardbakh cemetery (Ter-Markaryan, 1991; Eganyan, 2010). In most cases, the upper extremities were placed along the bodies, while in only a few cases one or both hands rested on the pelvis. However, many sites had been re-buried or the human remains were lost or could not be located. Therefore, only burials with an archive, curated human remains, and already published or in the process thereof were chosen (Khudaverdyan, 2005). Most of these bones were in a good state of preservation, allowing determination of the sex, age and pathologies of the individuals. Half of the skeletons analyzed, i.e. eight, were females and the others males. There were two children's skeletons. The graves were oriented with their heads toward the east-west. Within the graves, a variety of burial accompaniments were recovered, including jewelry (e.g., rings, pendants), tools (e.g., knives), household goods (e.g., dishes, needles), and other goods (e.g., coins). At the Vardbakh necropolis,among the usual graves with human skeletons there was a burial of a horse (Ter-Markaryan, 1991).

Table 1. Number of individuals from Black Fortress I and Vardbakh.

Age categories	Black Fortress I			Vardbakh		
	male	female	indeterm.	male	female	indeterm.
0-6	-	-	2	-	-	2
7-12	-	-	2	-	-	-
13-20	-	-	1	-	-	-
21-40	6	9	-	3	6	-
41-50	3	4	-	1	2	-
60+	1	-	-	-	-	-
Total	10	13	5	4	8	2

The present author participated in both research projects, and took charge of the paleopathological examination of the skeletal remains from both sites. Age-at-death and sex were assessed through the use of multiple indicators. Morphological features of the pelvis and crania were used for the identification of sex (Phenice, 1969; Brothwell, 1981; Buikstra and Ubelaker, 1994). All systematically scored non-metric traits are listed in Brothwell (1981). A combination of pubic symphysis changes (Gilbert and McKern, 1973; Katz and Suchey, 1986; Meindl et al., 1985), sacroauricular surface indicators (Lovejoy et al., 1985), degree of epiphyseal union (Bass, 1981), and cranial suture closure (Meindl et al., 1985) were used for adult age estimation. In the case of the infants, dental development and eruption, long bone length, and the appearance of ossification centres and epiphyseal fusion were used (Moorrees et al., 1963a, b; Ubelaker, 1989; Bass, 1981).

A study was conducted on 42 human cranial bases. All 42 were assessed visually for classification of the shape of the foramen magnum; 10 were suitable for metric assessment.

The following measurements were taken following Holland (1986a):

1. Foramen magnum length - maximum internal length of the foramen magnum along the midsagittal plane, from the opisthion to the basion (White, 2000) (Fig. 2);
2. Foramen magnum width - maximum internal width of the foramen magnum along the transverse plane (Fig. 2);
3. Right occipital condyle maximum width - maximum width of the right occipital condyle taken along the articular surface perpendicular to the right occipital condyle length (Fig. 2);
4. Right occipital condyle length - maximum length of the right occipital condyle taken along the articular surface perpendicular to the right occipital condyle width (Fig. 2);
5. Left occipital condyle maximum width - maximum width of the left occipital condyle taken along the articular surface perpendicular to the left occipital condyle length;
6. Left occipital condyle length - maximum length of the left occipital condyle taken along the articular surface perpendicular to the left occipital condyle width.

The base of the skull in the region of the occipital condyles was studied in detail and was classified according to its shape and size. A comparison was performed between the right and left sides regarding symmetrical structures. A visual classification and categorization were made for all foramina magna in this study. Each foramen magnum was then classified in one of four categories: Circle, Diamond, Egg, and Oval.

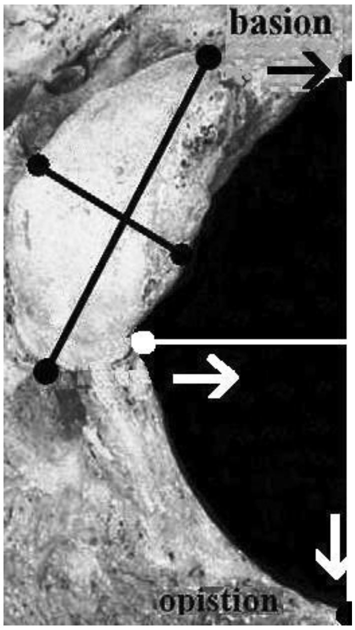
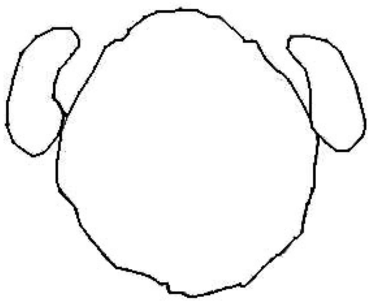
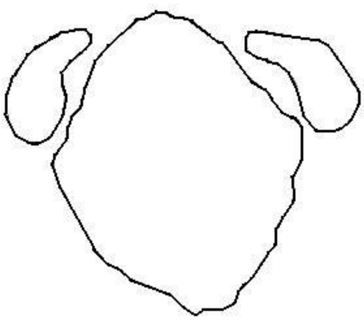
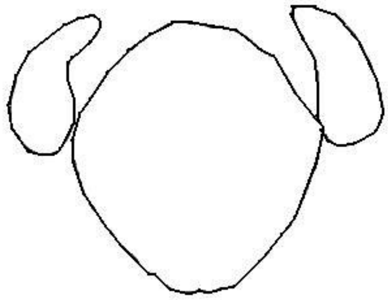
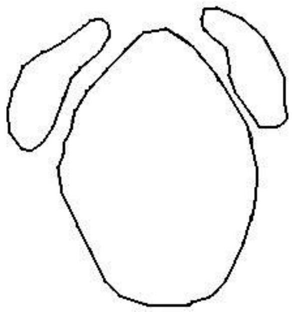


Fig. 2. Depiction of some important parameters measured.

Table 2. Foramen magnum shapes: descriptions and examples.

Category	Criteria for Inclusion	Example (anterior is at the top of the square)
Circle	Round shape with consistently smooth curvature; throughout the curvature of the foramen magnum are no points formed; symmetrical	
Diamond	Classic diamond shape is based on a nearly symmetrical four points equidistance from each other	

Category	Criteria for Inclusion	Example (anterior is at the top of the square)
Egg	Elongated shape with a clear base where the curvature rounds out to form a wider region then the opposing end that is almost pointed, yet still rounded	
Oval	Elongated shape with a smooth curvature, without any pointed regions	

The occipital condyles were classified according to their shape and size: type 1: S-like condyle; type 2: kidney-like condyle; type 3: triangle condyle; type 4: square condyle; type 5: eight-like condyle; type 6: oval-like condyle; type 7: two-portioned condyle and type 8: foot condyle (visual classification).

Results

Surface of the occipital condyles

An incomplete longitudinal groove and a transverse groove were observed on the facets of the occipital condyles on the left and right sides respectively (Figs. 3 and 4) in two individuals from Black Fortress I. Multiple elevations were noted on the facet (Fig. 3). An incomplete longitudinal groove was noticed on the medial aspect of the occipital condyle. The surface of the facet was rough and serrated. Many pits and projections were noted on the facet. There were small pits on the facet and a prominent transverse groove traversed the facet and divided it into two parts (Fig. 3). The surface of the facet also displayed serrations. The occipital condyles and foramina magna were asymmetric. In the present case, the anomalous occipital condyles may have formed as a result of a developmental defect in the anterior segment. The facets on the inferior surface of the occipital condyles of the skull are responsible for articulating with the superior articular facets of the atlas vertebra. In individual 12 the articular surfaces of the facets of the occipital condyles were rough and serrated, and this may have caused a disturbance in the stability and movements of the atlanto-occipital joint (Fig. 3). The presence of bony elevations on the facet may have exerted pressure upon the the alar ligaments, thereby altering the biomechanics of the atlanto-occipital articulation. The presence of bony projections and grooves provide morphological evidence of possible developmental defects.

The skull from Black Fortress I (burial 15: child II: 8-10 years) showed erosion of the occipital condyles. The occipital left condyle and the left border of the foramen magnum appear distorted and scalloped, and are irregularly shaped (Fig. 6). The articular surfaces are pitted and rough, and seem as though the epiphyseal cartilages had been separated by maceration. The erosion of bone also extended into the right occipital condyle. These joint disorders can be broadly classified in pathogenetic categories, non-inflammatory and inflammatory. The non-inflammatory category includes degenerative joint disease, traumatic joint disease, and developmental, dietary, metabolic, and neoplastic arthropathies.

The inflammatory category includes infectious (bacterial, viral, fungal, protozoal) and noninfectious (immunologic, crystal-induced) arthritis. Differentiating between the noninflammatory and inflammatory types of joint disorders can be complex, since non-inflammatory disorders may be accompanied by secondary inflammation, and inflammatory disorders commonly result in secondary, often severe degenerative changes.

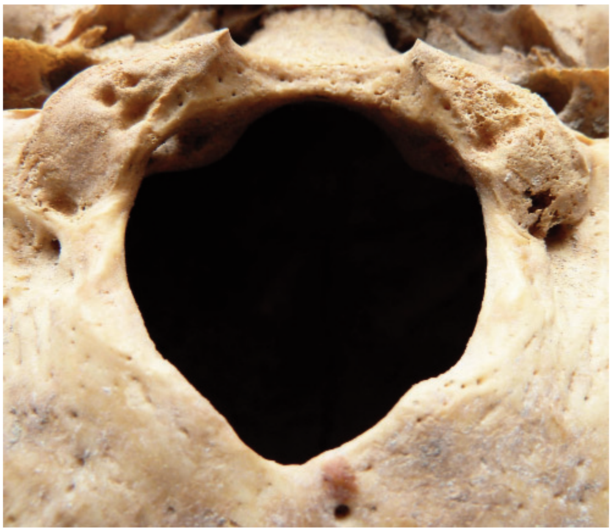


Fig. 3. Longitudinal and transverse groove on the occipital condyle. Materials from excavation of burial ground the Black Fortress I (burial 12: child, 8-10 years).

Fig. 4. Longitudinal and transverse groove on the occipital condyle. Materials from excavation of burial ground the Vardbakh (burial 9: ♀young adult).

Fig. 5. Asymmetrical occipital condyles. Materials from excavation of the burial ground at the Black Fortress I (burial 41: ♂ young adult).

Fig. 6. Erosion of the occipital condyles. Materials from excavation of the burial ground at the Black Fortress I (burial 15: child, 8-10 years).

Asymmetrical articular facets on occipital condyles

The present study describes a case of asymmetrical articular facets on the inferior aspects of the occipital condyles detected in human skulls from Late Antiquity period in Armenia. Asymmetrical facets may be responsible for altered kinematics in the atlanto-occipital joint. The atlanto-occipital joint is an important joint that contributes to the movements of the head. The movements of flexion, extension and lateral bending, which normally occur at this joint, may be disturbed as a result of the asymmetric shape of the articular surfaces (Das and Chaudhuri, 2008). Degenerative changes may alter the shapes of the articular facets and as a result joint biomechanics may be altered. Even hypertrophy of the occipital condyles has been reported to cause cervical myelopathy (Ohaegbulam et al., 2005). Thus, in the presence of anomalies pertaining to the occipital condyles, associated symptoms may also arise.

Thirty-five skulls were used for this study. The asymmetric occipital condyles were found in 7/23 (Table 3) from the Black Fortress I (Figs. 5, 6 and 7) and 3/12 (Table 4) from Vardbakh (Fig. 8). There were significant differences between the results on the right and left sides.

Table 3. Asymmetric occipital condyles from Black Fortress I.

	Length of occipital condyle	Width of occipital condyle	Length of foramen magnum	Width of foramen magnum	Shape of foramen magnum
Burial 12 (child II: 8-10 years)	22.2 (right) 24.3 (left)	11.5 (right) 11.0 (left)	38.2 mm	33mm	Egg
Burial 41 (male, young adult)	29.1 (right) 21.4 (left)	12.5 (right) 11.2 (left)	31.2 mm	28.5 mm	Diamond
Burial 7 (women, young adult)	23.2 (right) 19.5 (left)	12.5 (right) 12.0 (left)	36.1 mm	26.2 mm	Oval
Burial 15 (child II: 8-10 years)	14.5 (right) 26.7 (left)	12.7 (right) 12.5 (left)	36.8 mm	29.5 mm	Diamond
Burial 24/1 (women, young adult)	28.3 (right) 25.1 (left)	11.2 (right) 12.4 (left)	36.0 mm	25 mm	Egg
Burial 9 (women, young adult)	25.0 (right) 24.1 (left)	11.0 (right) 12.2 (left)	34.6 mm	28.6 mm	Circle
Burial 19 (women, young adult)	21.1 (right) 19.6 (left)	10.0 (right) 12.2 (left)	47.2 mm	-	Oval

Table 4. Asymmetric occipital condyles from Vardbakh.

	Length of occipital condyle	Width of occipital condyle	Length of foramen magnum	Width of foramen magnum	Shape of foramen magnum
Burial 3 (women, young adult)	24.0 (right) 24.5 (left)	10.1 (right) 12.0 (left)	30.2 mm	24.5 mm	Egg
Burial 9 (women, young adult)	11.1 (right) 10.0 (left)	9.1 (right) 11.5 (left)	34.0 mm	27 mm	Oval
Burial 5/2 (male, young adult)	24.4 (right) 22.0 (left)	12.0 (right) 14.2 (left)	34.0 mm	28 mm	Oval

Fig. 7 and 7a. Asymmetric occipital condyles. Materials from excavation of the burial ground at the Black Fortress I (burial 24/1: ♀ young adult).

Some authors have addressed the shape of the occipital condyle. Guidotti (1984) classified the occipital condyle as (1) flat, (2) partitioned without interruption of the articular surface and (3) partitioned with a clear angle but without separation of the surfaces or doubling of the condyles. Guidotti reported that flat condyles are seen more commonly in the left side. Oliver (1975) classified the occipital condyle as (1) normal constricted and (2) subdivided. Naderi et al. (2005) classified the occipital condyle as oval-like, kidney-like, S-like, eight-like, triangle-like, ring-like, two-portioned, and deformed. We also classified occipital condyles according to their lengths. The shape of occipital condyles was classified in eight types as follows - type 1: S-like condyle; type 2: kidney-like condyle; type 3: triangle condyle; type 4: square condyle; type 5: eight-like condyle; type 6: oval-like condyle; type 7: two- portioned condyle and type 8: foot condyle (Fig. 9).

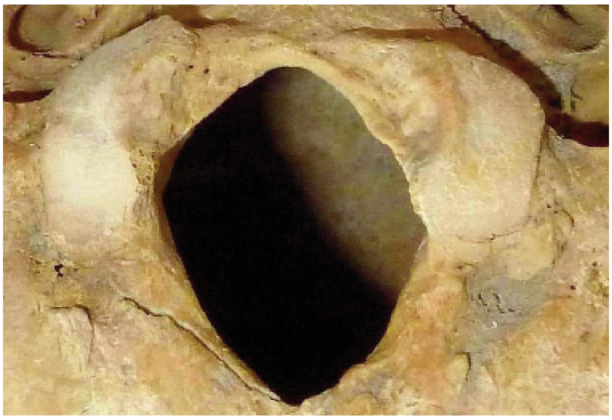


Fig. 8.- Asymmetric occipital condyles (from an individual from Vardbakh displaying a trapezoidal shape of the skull, which is a diagnostic criterion of unilateral lambdoid synostosis) (Khudaverdyan, 2010a). Materials from excavation of burial ground the Vardbakh (burial 5/2, ♂ young adult).

The most common type in group Black Fortress I was type 1 (5 individuals: 1 - ♂: middle adult, 4 - ♀: young adult), whereas the most unusual type was type 6 (1 individual: ♀ middle adult). Other types were seen — type 2: 3 individuals: ♀, young adult, type 3: 2 individuals (♀, young and middle adults), type 4: 2 individuals (♀, young and middle adults), type 5: 4 individuals (2 - ♂, young and middle adults, 2 - adolescent), type 7: 2 individuals (1 - ♀ young adult, 1 ♂ middle adult). When the right and left occipital condyles of the same skull were compared an asymmetric shape was found in 7 skulls.

The most common type in the Vardbakh group was type 6 (3 individuals: (♀, young and middle-aged adults), whereas the most unusual type was type 8 (1 individual: ♀ young adult). Other types were seen — type 2: 2 individuals (♀ young adult), type 3: 2 individuals: ♂ young adult, ♀ middle adult), type 4: 1 individual (♀ middle adult). An asymmetric shape was found in 3 skulls. The shape of the occipital condyle may affect the amount of condylectomy. Among the different types of occipital condyle, the triangular, the oval-like condyle, and the kidney-like occipital condyle may require a more extensive condylectomy to reach to the ventral lesions.

Thus, the prevalence type I was higher in females (4 individuals) than in males (1). Type II affected a total of 5 females. The prevalence of type III was higher in females (3 individuals) than in males (1). Type IV was present in 3 females. Type V affected a total of 4 individuals (2 males and 2 adolescents). Type VI was present in 1 female. Type VII affected a total of 2 individuals (1 male and 1 female).

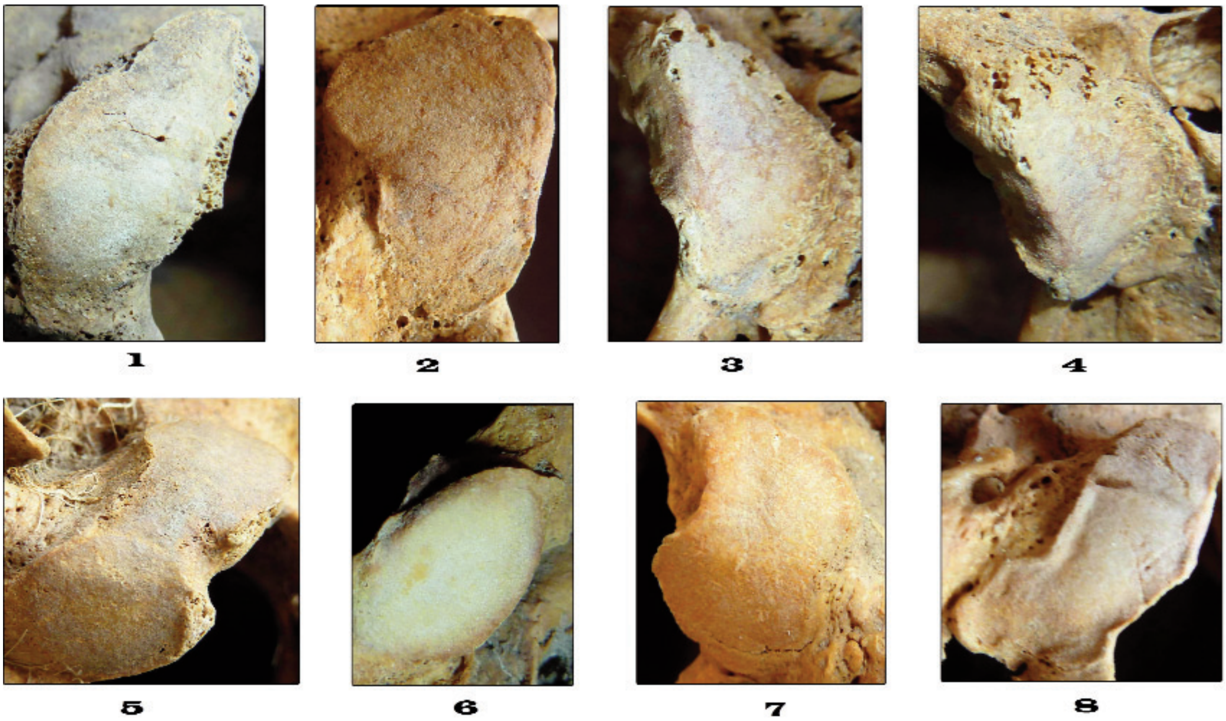


Fig. 9.- Types of occipital condyles: type 1: S-like condyle; type 2: kidney-like condyle; type 3: triangular condyle; typ e 4: square condyle; type 5: eight-like condyle; type 6: oval-like condyle; type 7: two-portioned condyle and type 8: foot condyle.

The shape of the foramen magnum is highly variable. Most foramen magnum shapes were Oval- (7 individuals) and Diamond (8 individuals)-shaped. The Egg shape was seen in 5 individuals, and the Circle shape in 3 (Black Fortress I and Vardbakh groups).

Assimilation of the atlas

There are several types of craniovertebral fusion. We report one of these: the paracondylar process. The paracondylar process has also been called a paramastoid process, a paraoccipital process, a jugular process and a parajugular process (Williams, 1982; Hauser, Stefano, 1989). Here we report a previously undescribed cranium (burial 21, woman 20-30 years) from the Beniamin historic population, which shows a very rare pathology – fusion of the atlas with the occipital bone (Fig. 10). Apart from a slit above the anterior arch of the atlas, the fusion extends solidly. to just beyond the site of both occipital condyles. The circumference of the foramen magnum is minimally diminished by the osseous structures of the atlas fused to the occipital bone. The transverse processes are markedly asymmetric; each is traversed by a foramen for the vertebral artery. In addition, there appears to be torsion between the skull base and the orientation of the fused atlas, which is rotated slightly to the left. Its left posterior arch encroaches into the foramen magnum to a considerable extent. The left arch terminates shortly before the midline and, when the medial sagittal end of this arch was examined, its slightly ‘scooped-out’ nature led us to suspect that it had never fused with its right-side partner, that is, we were looking at a case of posterior spina bifida, or posterior arch rachischisis (Smoker, 1994; Gholve et al., 2007).

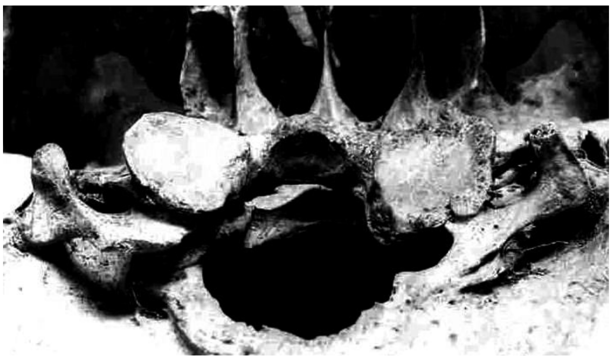


Fig. 10.- Assimilation of the atlas. Materials from excavation of the burial ground at Beniamin (burial 21: ♀ young adult).

Atlanto-occipital fusion will inevitably shorten the neck and shrinking of the intervertebral discs may force the odontoid process upward into the foramen magnum, adding to the compression of the spinal cord which, in the current case, is already compressed posteriorly by the left posterior atlantic arch. Our case’s least problem would have been her head directed to the left, with limited lateral head movement due to angulation of the inferior atlantic condyles, followed by, variously, headache, neck pain, numbness and pain in the limbs, weakness, tinnitus, visual disturbances, and lower cranial nerve palsies leading to dysphagia and dysarthria (Merbs and Euler, 1985; Jayanthi et al., 2003; Nayak et al., 2005). Saunders and Popovich (1978) researched the bridging of the atlas to determine whether it is an inherited trait. Radiographs taken of both parents and their children led the researchers to conclude that atlas bridging is an inherited trait. Assimilation of the atlas is rare, affecting less than one percent of the overall population, but is a debilitating pathology for the cervical vertebrae (Al-Motabagani and Surendra, 2006). Approximately 50% of individuals with atlanto-occipital fusion develop atlanto-axial instability (Warner, 2003) and concurrent subluxation (Turek, 1984).

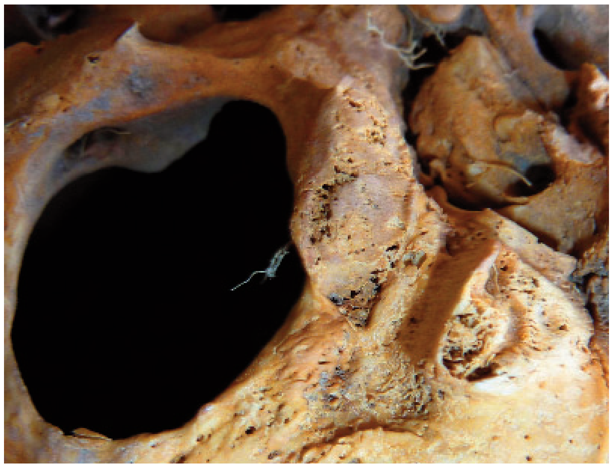


Fig. 11.- Ossiculum terminale. Materials from excavation of the burial ground at the Black Fortress I (burial 7: ♀ young adult).

Ossiculum terminale

The craniovertebral joints are shaped to give a wide range of movement to the head and to transmit the weight of the head to the rest of the vertebral column. The movements include: bilateral bending and rotation, flexion, extension, distraction, and axial loading. However, the proper biomechanics of these joints may be disrupted by pathological ossification, which may develop on an occipital bone, and also between the occipital condyles and the superior articular facets of the atlas. We report ossiculum terminale persistens associated with atlantoaxial instability in two cases (a woman of 20-30 years, burial 7, and a male of 30-40 years, burial 41) buried at the Black Fortress I (Fig. 11). The signs and symptoms associated with atlantoaxial instability due to ossiculum terminale peristens are similar to instability from any other cause - traumatic, neoplastic, degenerative, or inflammatory. These include recurrent torticollis, Lhermitte's sign, and neck pain with limited head movements. The ossicle in ossiculum terminale peristens has intact sclerotic cortical margins circumferentially (Liang et al., 2001) and varies in size from a few millimeters to 12 mm (Bret et al., 1980).

Precondylar tubercles

Precondylar tubercles are ventral rudiments of the occipital vertebra. A single midline or bilateral faceted tuberosity, a unilateral or bilateral nonarticular tubercle along the anterior margin of foramen magnum (Fig. 12), spines or lamina continuous with the occipital condyles are documented as the presentations of these tubercles (Marshall, 1955; Broman, 1957). A foramen magnum tubercle is more frequently found in Southeast Asian populations (Pastor-Vazquez et al., 1996). Paracondylar processes are believed to be under strong genetic influence and can be part of a broader congenital syndrome associated with underlying neurological disorders (Taitz, 2000). Berry and Berry (1967) and Berry (1975) regarded precondylar tubercles as nonmetric epigenetic anthropological markers to measure genetic distinctiveness or divergence between a pair of populations. Opinions concerning the etiology of precondylar tubercles are divided; some investigators have considered them as 'developmental relics' (Kollmann, 1905; Ingelmark, 1947; Keith, 1948; Broman, 1957; Putz, 1975), while others have postulated ossification 'within the atlanto-occipital ligaments or that artificial deformation practices on adults such as 'head binding' may be responsible (Oetteking, 1923; Marshall, 1955). Artificial deformation cannot be excluded in our-study. Artificial deformations, such as bregmatic, ring deformation of a head, were known in the ancient population of the Armenia (Beniamin, Shirakavan, Vardbakh and Karmrakar) (Khudaverdyan, 2011).

Around the margin of the foramen magnum are indications of lateral masses (ridges) (Figs. 5, 7, 13), which may reduce the circumference of the foramen or cause asymmetry (Nicholson and Sherk, 1968). Of the 28.6% (4/14) of skulls from Vardbakh displaying precondylar tubercles unilaterally or bilaterally, 35.8% show ridges. Sexual dimorphism is evident, with female skulls showing a higher incidence (21.4%) in comparison with male skulls (7.2%). The 21.1% (4/19) of skulls from the Black Fortress presented precondylar tubercles and 36.8% - ridges. Evidence of precondylar tubercles in the Beniamin group was seen in 27.3% (Khudaverdyan, 2000). Sexual dimorphism was also evident, with female skulls showing a higher incidence (29.5 %) compared with male skulls (20%).

Fig. 12. Precondylar tubercles. Materials from excavation of the burial ground at the Black Fortress I (burial 26, ♀ young adult).

Fig. 13. Ridges. Materials from excavation of the burial ground at the Black Fortress I (burial 9, ♀ young adult).

Discussion

The results of this study are in keeping with the results of other studies focusing on craniovertebral junction anatomy,and particularly on occipital condyle anatomy (Oliver, 1975; Guidotti, 1984; Lang and Hornung, 1993). These results confirm the variability of the occipital condyle parameters, including length and width. This variability seems to be due to the use of occipital condyles from each age and gender as material. Their length ranges between 14.5 and 29.1mm (right) (mean 23.4 mm), 19.5 and 26.7mm (left) (mean 22.9 mm) in the Black Fortress I group (mean 23.1 mm). This measured length is comparable to the measured occipital condyle length reported by Guidotti (1984) (23.7 mm), Lang and Hornung (1993) (22.9 mm), Oliver (1975) (23.7 mm). The length of occipital condyle ranges between 11.1 and 24.4mm (right) (mean 19.8 mm), 10.0 and 24.5mm (left) (mean 18.9 mm) in the Vardbakh group (mean 19.4mm). This is less than the results reported by Guidotti (1984), Lang and Hornung (1993) and Oliver (1975). Occipital condyle width ranges between 10.0 to 12.7mm (right) (mean 11.6 mm) and 11.0 to 12.5mm (left) (mean 11.9 mm) in the Black Fortress I group (mean 11.8 mm). Occipital condyle width ranges between 9.1 to 12.0mm (right) (mean 10.4mm) and 11.5 to 14.2mm (left) (mean 12.6 mm) in the Vardbakh group (mean 12.3 mm). This broad range reflects the asymmetry in the orientation, length and shape of occipital condyles. No correlation was found between occipital condyle length and basion-opisthion distance.

On the skulls from Armenia we observed more precondylar tubercles and ridges than the results reported by Anderson and other researchers. Anderson (1996) examined 1300 skulls from an excavation at St. Gregory's Priory from Medieval Canterbury. Six skulls had evidence of paracondylar tubercles (0.46%) and one skull had a well defined paracondylar process (0.077%). Williams (1982) reports variations in frequency of between 2% and 30%, which he feels is population-specific. Pastor-Vazquez et al. (1996) studied 382 skulls from the Anatomical Museum of the University of Valladolid; they were from white adults of both sexes from the Castilla area of Spain. Five cases of the tubercle in the anterior margin of the foramen magnum were encountered, representing an incidence of 1.3%. The basiocciput of 265 adult Indian human skulls was examined by Vasudeva and Choudhry (1996). Of the 14% of skulls displaying these tubercles unilaterally or bilaterally, 5.3 % demonstrated ridges; 4.9% showed spines and 3.8 % exhibited processes. The frequency of these tubercules in Indians make up 15% (Lakhtakia et al., 1991). Hence, we cannot connect an epigenetic variation with a racial component.

Clinical and osteological research suggests that malnutrition or non-specific systemic stress are strongly correlated with the incidence of vertebral anomalies (Bergman, 1993; See et al., 2008). See et al. (2008) documented numerous vertebral anomalies in the offspring of vitamin A-deficient rats, including cleft neural arches, occipital vertebrae, vertebral blocks etc. In addition, over 80% of the offspring exhibited basioccipital malformation of some variety (See et al., 2008). In his analysis of non-metric traits in human crania, Bergman (1993) also found a statistically significant association between cribra orbitalia and the precondylar tubercle, which he attributed to a common morbid factor. Although cribra orbitalia is a non-specific skeletal stress marker, it is nonetheless indicative of systemic insult, which is often attributable to malnutrition, disease, or infection (Stuart-Macadam, 1987). The results of the stress indicator analysis may also support this hypothesis since frequencies of cribra orbitalia and enamel hypoplasias were fairly high for both sites (cribra orbitalia: Vardbakh - 84.7% (n=13); Black Fortress I - 37.1% (n=27), enamel hypoplasias: Vardbakh - 63.7% (n=11), Black Fortress I - 17.4% (n=23). Cribra orbitalia was a frequent pathology of the historic population Beniamin (28.1%, 39/139), only in three individuals (3.3% of individuals) was hypoplasia observed (Khudaverdyan, 2010b). When comparisons are made it appears that the Black Fortress I population was somewhat less prone to the development of craniovertebral bone anomalies than the people buried in the Vardbah cemeteries. These results are, however, preliminary.

Conclusion

This research is multi-faceted and addresses several important issues. Our findings offer a documented list of craniovertebral anomalies that ailed the people from the Late Antiquity period in their daily lives. The shape of occipital condyles has been classified into eight types.

Occipital condyles and foramina magna are affected by marginal osteophytosis. Most foramen magnum shapes are Oval and Diamond. The lateral cervical spine in two individuals from the Black Fortress I shows an ovoid, terminale ossiculum. The skeleton of a young adult woman, whose skull demonstrated remarkable degree of assimilation of the atlas, was found during an archaeological exploration in Beniamin. It is likely that both genetic and environmental factors would have contributed to the etiology of skeletal defects. Ethnohistorical and archaeological evidence suggests that the Shiraksky plateau villagers, who inhabited their sites during the Late Antiquity period, faced seasonal food shortages due to the unfavorable environmental conditions (Khudavedyan, 2000). These food shortages could have potentially contributed to an increase in the incidence of skeletal defects in the population. Paleopathological examination revealed weapon-related trauma, trephination, fractures, plagiocephaly, osteoarthritis, osteomyelitis, and dental diseases, such as dental abscesses, caries, and periodontal disease in the populations from the Black Fortress I and Vardbakh (Khudaverdyan, 2010a). It is therefore plausible that nutritional deficiencies and disease may have influenced the frequencies of skeletal defects at the Shirak plateau sites examined in this study. Bioarchaeological data from the historic population of Black Fortress I and Vardbakh are useful for understanding the lifestyles of the ancient population of area historically occupied by the Armenian people.

References

Al-Motabagani MA, Surendra M (2006) Total occipitalization of the atlas. *Anat Sci Int,* 81: 173-180.

Anderson PA, Montesano PX (1988) Morphology and treatment of occipital condyle fractures. *Spine,* 13: 731-736.

Anderson T (1996) Paracondylar process- manifestation of an occipital vertebra. *Int J Osteoarchaeol,* 6: 195-201.

Avagyan I (2003) “Sev Amroci” hushardcani dambaranadasht. Monument “Black Fortresses”

and a burial ground. In: Qalantaryan A, Badalyan R (eds). *The ancient culture of Armenia*. Yerevan.

Barnes E (1994) *Developmental defects of the axial skeleton in Paleopathology*. Niwot, CO, University Press, Colorado.

Bass W (1981) *Human osteology*. Columbia: Missouri Archaeological Society.

Bergman P (1993) The occurrence of selected non-metrical traits of the skull in relation to *cribra orbitalia* and grave equipment. *Variability and Evolution,* 2: 63-75.

Berry Ac (1975) Factors affecting the incidence of non-metrical skeletal variants. *J Anat*, 120: 519-535.

Berry AC, Berry RJ (1967) Epigenetic variations in the human cranium. *J Anat,* 101: 361-379.

Binatli O, Ersahin Y, Coskun S, Bayol U (1995) Ossifying fibroma of the occipital bone. *Clin Neurol Neurosurg,* 97: 47-49.

Bharucha EF, Dastur HM (1964) Craniovertebral abnormalities: A report of 40 cases. *Brain,* 87: 469-480.

Bret P, Lecuire J, Carlioz P, Deruty R (1980) Atlanto-axial dislocation due to ossiculum terminale persistens: Report of two cases treated by a new technique of posterior fusion. *Acta Neurochir* (Wien), 52: 105-112.

Broman GE (1957) Precondylar tubercles in American Whites and Negroes. *Am J Phys Anthropol,* 15: 125-135.

Brothwell D (1981) *Digging up bones*. London: British Museum of Natural History.

Buikstra JE, Ubelaker DH editors (1994) *Standards for Data Collection from Human Skeletal Remains*. Arkansas Archeological Survey Research Series No. 44, Fayetteville.

Das S, Chaudhuri JD (2008) Anatomico-radiological study of asymmetrical articular facets on occipital condyles and its clinical implications. *KUMJ,* 22, 6 (2): 217-219.

Deeb ZL, Rothus WE, Goldberg AL, Daffner RH (1988) Occult occipital condyle fractures presenting as tumors. *J Comput Assist Tomo,* 12: 261-263.

Gilbert BM, Mckern TW (1973) A Method for Aging the Female Os pubis. *Am J Phys Anthropol,* 38: 31-38.

Guidotti A (1984) Morphometrical considerations on occipital condyles. *Anthropol Anz,* 42: 117-119.

Gholve PA, Hosalkar HS, Ricchetti ET, Pollock AN, Dormans JP, Drummond DS (2007) Occipitalization of the atlas in children: morphological classification, associations, and clinical relevance. *J Bone Joint Surg*, 89: 571-578.

Eganyan LG (2010) *Shiraki hnagitakan ev patma-azgagrakan hetazotytyunner. Archaeological and historical - ethnographic research Shirak*. Yerevan-Gyumri.

Ingelmark BE (1947) Über das craniovertebrale Grenzgebiet beim Menschen. *Acta Anat,* 4 (Suppl. 6:1): 5-113.

Jayanthi V, Kulkarni R, Kulkarni RN (2003) Atlanto-occipital fusion - report of two cases. *Anat Soc India,* 52: 71-73.

Johnson MH, Smoker WR (1994) Lesions of the craniovertebral junction. *NCNA,* 4: 599-617.

Hauser G, Stefano GF (1989) Epigenetic Variants of the Human Skull. Stuttgart: Schweizerbart.

Hewsen RH (1997) The Geography of Armenia. In: Hovannisian RG (ed) *The Armenian People from Ancient to Modern Times*. St. Martin’s Press, New York.

Keith A (1948) *Human Embryology and Morphology*. Edward Arnold, London.

Katz D, Suchey JM (1986) Age determination of the male os pubis. *Am J Phys Anthropol,* 69: 427-435.

Khudaverdyan AY (2000) *Naselenie Armyanskogo nagora v antichnuiy epokhu (po antropolgicheskim dannim Beniaminskogo mogilnika. The population of the Armenian uplands during an antique epoch (on data of the Beniamin burial ground)*. Tigran Mec, Yerevan.

Khudaverdyan AY (2005) *Atlas paleopatologicheskikh nakhodok na territorii Armenii. Atlas paleopathological finds in territory of Armenia*. Van Aryan, Yerevan.

Khudaverdyan AY (2009) *Naselenie Armyanskogo nagora v epokhu bronzi. Etnogenez i etnicheskaya istoriya. The bronze population of Armenian highland. thnogenesis and ethnic history.* Van Aryan, Yerevan.

Khudaverdyan A (2010a) Paleopathology of human remains from V rdbakh and the Black Fortress I, Armenia. *Bioarchaeology of the Near East,* 4: 1-23.

Khudaverdyan A (2010b) Pattern of disease in three 1st century BC – 3rd century AD burials from Beniamin, Vardbakh and the Black Fortress I, Shiraksky plateau (Armenia). *JoP*, 22: 15-41.

Khudaverdyan A (2011) Artificial modification of skulls and teeth from ancient burials in Armenia. *Anthropos*, 106: 602-609.

Kollmann F (1905) Varianten am Os occipitale, besonders in der Umgebung des Foramen occipitale magnum. *Anat Anz,* 27: 231-236.

Lang J, Hornung G (1993) The hypoglossal channel and its contents in the posterolateral access to the petroclival area. *Neurochirurgia*, 36: 75-80.

Liang CL, Lui CC, Lu K, Lee TC, Chen HJ (2001) Atlantoaxial stability in ossiculum terminale: Case report. *Spine,* 95: 119-121.

Lakhtakia PK, Premsagar IC, Bisaria KK, Bisaria SD (1991) A tubercle at the anterior margin of the foramen magnum. *J Anat*, 177: 214-218.

Lovejoy CO, Memdl RS, Pryzbeck TR, Mensforth RP (1985) Chronological metamorphosis of the auricular surface of the ilium: a new method for the determination of adult skeletal age at death. *Am J Phys Anthropol,* 68: 15-28.

Marshall DD (1955) Precondylar tubercle incidence rates. *Am J Phys Anthropol*, 13: 147-151.

Martirosyan Aa (1964) Armenia w epokhu bronzi i rannego dzeleza. *Armenia during of Bronze Age and Early Iron*. Erevan.

Meindl RS, Lovejoy CO, Mensforth RP, Carlos LD (1985) Accuracy and direction of error in the sexing of the skeleton: implications for Paleodemography. *Am J Phys Anthropol*, 68: 79-85.

Merbs CF (1974) The effects of cranial and caudal shift in the vertebral columns of Northern populations. *Arctic Anthropology*, 6: 12-19.

Merbs CF, Euler RC (1985) Atlanto-occipital fusion and spondylolisthesis in an Anasazi skeleton from Bright Angel Ruin, Grand Canyon National Park, Arizona. *Am J Phys Anthropol,* 67: 381-391.

Moorrees CF, Fanning EA, Hunt EE (1963a) Formation and resorption of three deciduous teeth in Children. *Am J Phys Anthropol,* 21: 205-213.

Moorrees CF, Fanning EA, Hunt EE (1963b) Age variation of formation stages for ten permanent teeth. *JDR,* 42: 1490-1502.

Naderi S, Korman E, Çitak G, Güvençer M, Arman C, eno lu M, Tetik S, Arda MN (2005) Morphometric analysis of human occipital condyle. *Clin Neurol Neurosurg*, 107: 191-199.

Nayak S, Vollala VR, Raghunathan D (2005) Total fusion of axis with occipital bone: a case report. *Neuroanat,* 4: 39-40.

Nevell L, Wood B (2008) Cranial base evolution within the Hominin Clade. *J Anat,* 212: 455-468.

Nicholson JT, Sherk HH (1968) Anomalies of the occipitocervical articulation. *J Bone Joint Surg,* (50A): 295-304.

Oetteking B (1923) On the morphological significance of certain craniovertebral variations. *Anat Rec,* 25: 339-353.

Ohaegbulam C, Woodard EJ, Proctor M (2005) Occipitocondylar hyperplasia: an unusual craniovertebral junction anomaly causing myelopathy. Case report. *J Neurosurg,* 103: 379-381.

Oliver G (1975) Biometry of the human occipital bone. *J Anat*, 120: 507-518.

Pastor-Vazquez JF, Gil-Verona JA, Moro-Balbas JA, García-Porrero M, Barbosa-Ayucar E (1996) Tubercle at the foramen magnum. *Skull Base Surgery,* 6: 169-170.

Piotrovsky BB (1959) *Vanskoe carstvo (Urartu). Vansky kingdom (Urartu)*. East literature, Moscow.

Phenice TW (1969) A newly developed visual method of sexing the os pubis. *Am J Phys Anthropol*, 30: 297-302.

Putz R (1975) Zur Manifestation der hypochordalen Spangen im cranio-vertebralen Grenzgebiet beim Menschen. *Anat Anz,* 137: 65-74.

Saunders SR, Popovich F (1978) A family study of two skeletal variants: atlas bridging and clinoid bridging. *Am J Phys Anthropol,* 49: 193-204.

Scott JH (1958) The cranial base. *Am J Phys Anthropol,* 16: 319-348.

Smoker WRK (1994) Craniovertebral junction: normal anatomy, craniometry, and congenital anomalies. *RadioGraphics,* 14: 255-277.

See AW, Kaiser ME, White JC, Clagett-Dame M (2008) A nutritional model of late embryonic vitamin A deficiency produces defects in organogenesis at a high penetrance and reveals new roles for the vitamin in skeletal development. *Dev Biol,* 316: 171-190.

Stuart-Macadam P (1987) A radiographic study of porotic hyperostosis. *Am J Phys Anthropol*, 74: 511-520.

Stroobants J, Seynaeve P, Fidlers L, Klaes R, Brabnats K, Van Hoye M (1994) Occipital condyle fracture must be considered in the pediatric population: case report. *J Trauma,* 36: 440-441.

Tachdjian MO (1990) Congenital anomalies of the occiput and cervical spine. In: Tachdjian MO (ed). *Pediatric Orthopedics*. WB Saunders, Philadelphia.

Taitz C (2000) Bony observations of some morphological variations and anomalies of the craniovertebral region. *Clin Anat,* 13: 354-360.

Ter-Margaryan S (1991) Kumai tangarani Vardbakh dambaranadashti peghumner. Excavation of employees of a museum "Gumry" antique burial Vardbakh. In: Tiratsyan G (ed). *Scientific session devoting to results of field archaeological researches in Republic of Armenia*. Yerevan.

Ter-Margaryan S, Avagyan I (2000) "Sev Berd" hushardcani bnakatex ev dambaranadasht. Monument "Black Fortress" and a burial ground. In: Hairapetyan S (ed.). *Shirak's Historical and cultural heritage*. Gyumri.

Turek SL (1984) Craniovertebral region. In: Turek SL (ed). *Orthopaedics: Principles and their Application*. JB Lippincott, Philadelphia.

Ubelaker D (1989) *Human skeletal remains. Excavation, analysis,interpretation*. Taraxacum, Washington.

Vasudeva N, Choudhry R (1996) Precondylar tubercles on the basiocciput of adult human skulls. *J Anat*, 188: 207-210.

Warner WC (2003) Pediatric cervical spine. In: Canale ST (ed). *Campbell's Operative Orthopaedics*. Mosby, St. Louis, Philadelphia.

Williams JA (1982) An enlarged paracondylar process and associated anomalies in a plains woodland burial. *Plains Anthrop*, 28 (98 part 1): 323-326.

White TD (2000) *Human Osteology*. Academic Press, San Diego.