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HETEROTOPIC OSSIFICATION OF POSTERIOR ATLANTOOCCIPITAL MEMBRANE AS A COMPENSATORY REACTION OF THE ORGANISM WITH RANIOMANDIBULAR DISORDERS

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Abstract.

Relevance of this research arise from the fact that the diagnosis and etiology of ossification of the posterior atlantooccipital membrane is not only of academic interest, but also of great value in the practical work of clinicians. This study is focused on detecting positive correlations between craniocervicomandibular disorders and ossification of the posterior atlantooccipital membrane.

The presence and type of the ossification were examined via lateral teleradiography. The evaluation was made using Audaxceph advantage software programme. All the data was entered into Microsoft Excel 2010 and subjected to statistical analysis using IBM SPSS Statistics 23.

As a result of this study association between craniocervicomandibular disorders and ossification of the posterior atlantooccipital membrane was investigated. Obtained data can be used further as valuable material for future researches on the subject.

Keywords: ossification, atlantooccipital membrane, craniomandibular disorders, Kimmerle's anomaly, vertebral artery, craniocervical angles.

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INTRODUCTION:

The topic of bone formation at an abnormal anatomical site, i.e. in the non-skeletal tissues, is relevant in modern medicine. This phenomenon is commonly met in clinical practice. For example, ossification of ligaments and membranes, that can cause compression of adjacent anatomical structures, is developing different symptoms and defects [1]. This condition is commonly defined as heterotopic ossification.

The concern of researchers and clinicians on the subject is due to the fact that etiology and pathogenesis of this condition still remain not completely understood, it can significantly affect the patient's quality of life and also create a number of difficulties during surgical interventions [2].

The posterior atlantooccipital membrane that connects the posterior edge of the occipital foramen (foramen magnum) and the upper margin of the posterior arch of the atlas (arcus posterior atlantis) is often subjected to heterotopic ossification, transforming the vertebral groove (sulcus arteriae vertebralis) into a semicanal or a canal [3]. Hungarian physician A. Kimmerle was first to describe ossification in that area in 1930 and since then it has been called Kimmerle’s anomaly (AK) [4]. Kimmerle’s anomaly divides into ponticulus posterior atlantis – posterior bridge over a. vertebralis, between process articularis and arcus posterior atlantis, and ponticulus lateralis atlantis, i.e. lateral bridge, – between processus articularis and processus transversus [5]. Considering the limitations of two-dimensional radiography only ponticulus posterior, also known in scientific society as foramen arcuatum Atlantis, foramen retroarticulare superius, canalis Bildungi, ponticulus posticus and posterior bridge [4, 6, 7], will be discussed later-on in this study. The ossification can be unilateral or bilateral, however, clinical definition one from another is possible only using CT scan [6, 8]. There are different types of classifications of this process in specialized literature depicting ossification from pathoanatomical or radiological standpoints [16, 17, 18, 19].

Besides homonymous vessel, vertebral groove houses periarterial sympathetic plexus (Frank’s nerve), venous plexus, dorsal branch of the first spinal nerve - nervus suboccipitalis [2, 4, 7, 8]. Caliber inadequacy of the formed canal to the gauge of anatomical structures can lead to compression of these structures and development of various neurological symptoms, such as headache [9], vertigo [2], nystagmus [10], hearing loss and tinnitus [7] etc. Although an increased tention of dura mater can also be considered as an etiological factor [7].

Kulagin et al. [11] identified four common symptom groups depending on the main clinical sign: vertebral artery paroxysmal circulatory disorder syndrome, cephalgic syndrome, epileptic syndrome, radicular syndrome. The authors noted a paroxysmal tendency in neurological syndrome manifestations, as well as a connection between these conditions and contributing cause: sudden movements in cervical spine.

According to Musina G.M. [12], clinical manifestation of the ossification can occur even in childhood. Other alterations of the cervical spine among children with this abnormality were established: straightening cervical lordosis (51,2%), instability of spine segments (20,2%), localized angular kyphosis (4,8%). Prevalence of organ and system defects among such children is considered to be twice higher [12]. Alessandra Putrino et al. [13] found a positive association of ponticulus posticus in patients with dental agenesis.

All the aforementioned facts point out that diagnosis and analysis of the ossification of the posterior atlantooccipital membrane are not only of academic interest but also of a great value in practical work of clinicians. This condition is to be taken into account in case of planning a surgical manipulation on cervical spine [14] and in case of significant intense of clinical semiology is an indication for surgical decompression of vertebral artery [15].

Prevalence of Kimmerle’s anomaly among the population is considered to be within the range of 5,1% and 62,6% [8, 20] and significantly varies among different ethnicities not only quantitatively but qualitatively. Consequently, C.Taitz and H.Nathan [20] educed that incomplete ossification is more frequent among Middle Easterners (55,2% incomplete type; 7,4% full type), complete ossification is more frequent among African Americans (13,4%), complete ossification is the least commonly met among Indians (2,2%), however, partial ossification reached 37,4%.

Despite the presence of a relatively large number of publications related to the study of ossification of the posterior atlantooccipital membrane, the etiology and pathogenesis of this phenomenon are still not completely understood. Most studies focus on the prevalence and description of the ossification. In the available literature, we have not succeeded to find reliable information about the presence of a correlation link between the position of the head, orthodontic abnormalities, and ossification of the posterior atlantooccipital membrane. However, dentofacial anomalies are often combined with impaired posture and spinal deformity, being often primary in relation to the latter [21]. Above-mentioned facts determined the goals and methodology of this study.

MATERIALS AND METHODS:

A total of 170 randomly selected lateral cephalometric radiographs of patients undergoing orthodontic treatment based on Sechenov University were studied. 161 of which were selected from the age of 6 to 50 years (19.37 ± 10.582; mean ages ± standard deviation). The criteria for selection were: absence of injuries and operations carried out in the area of the craniocervicomandibular region, presence of informed voluntary consent to conduct the study and to publish the data in the open press.

The presence and type of the ossification, length and position of the mandible, the values of the craniocervical angles NSL-CVT, NSL-OPT, inclination of the lower incisors, the skeletal type and the direction of growth of the upper and lower jaws were determined according to cephalometric radiographs data. The gender and age of the patients were also taken into account in the study. All the data was entered into Microsoft Excel 2010 and subjected to statistical analysis using IBM SPSS Statistics 23.

Measurement of craniocervical angles (Fig. 1) [36]:

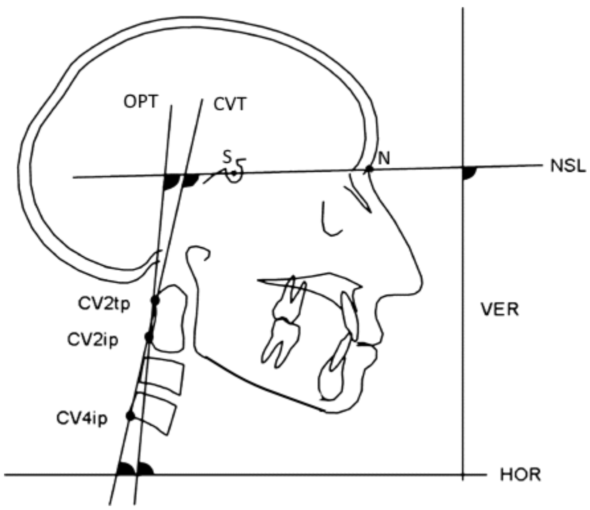


Figure 1. Craniocervical angles measurement

CVT-NSL angle –between CVT and NSL;
NSL- line, connecting nasion (N) and midpoint of sella turcica (S);
CVT- cervical vertebra tangent, line through the most postero-inferior point on the fourth cervical vertebrae (C4ip) and tangent to the odontoid process (C2tg).
CVT-NSL angle depicts cranium inclination in relation to the cervical spine (C2 – C4).
OPT-NSL – angle between OPT and NSL lines, depicts cranium inclination in relation to C2.
OPT: odontoid process (C2) tangent, the line through the most postero-inferior point on the second cervical vertebrae (C2ip) and tangent to the odontoid process (C2tg).

In this research, Miki et al. [16] classification was used, according to which there are three types of ponticulus posticus:
I. Full type (Fig. 4): It forms a complete bony ring (canal).
II. Incomplete type (Fig. 3): Some portions of the bony ring are defective (semi-ring).
III. Calcified type: There is a linear or amorphous calcification.

This particular classification was chosen as, from our poin of view, it is the most clinically suitable, since it is based on radiological research data, rather than pathomorphological analysis.

Figure 2. Image of truncated lateral cephalometric radiogram, which illustrates absence of ossification of the posterior atlantooccipital membrane

Figure 3. Image of truncated lateral teleroentgenogram illustrating partly ossified posterior atlantooccipital membrane

Figure 4. Image of truncated lateral teleroentgenogram showing fully ossified posterior atlantooccipital membrane

RESULTS:

Table 1

Ossification		Frequency	Percent (%)
Valid	Absent	120	74,5
	Incomplete	22	13,7
	Full	16	9,9
	Amorphous	3	1,9
	Total	161	100,0

Of the 161 patients (100%), partial ossification was observed in 22 (13.7%), complete in 16 (9.9%), amorphous in 3 (1.9%), in 120 (74.5%) ossification was not detected (Tab. 1).
Patients with amorphous ossification were excluded from further research due to insufficient number for calculation of statistically reliable links, as well as the complexity of differential diagnosis with other types of ossification by lateral radiographs.
While examining male patients (85 patients, 100%) partial ossification was observed in 11 men (13%) and complete - in 9 (6%), that was a bit lower compared to the distribution of ossification in female patients (73 patients, 100%), partial ossification was detected in 11 cases (15%), complete - in 7 (10%) (Fig.5). However, the correlation tests of Phi and Cramer's V showed that the development of ossification cannot be recognized as being reliably associated with sex (p = 0.526).

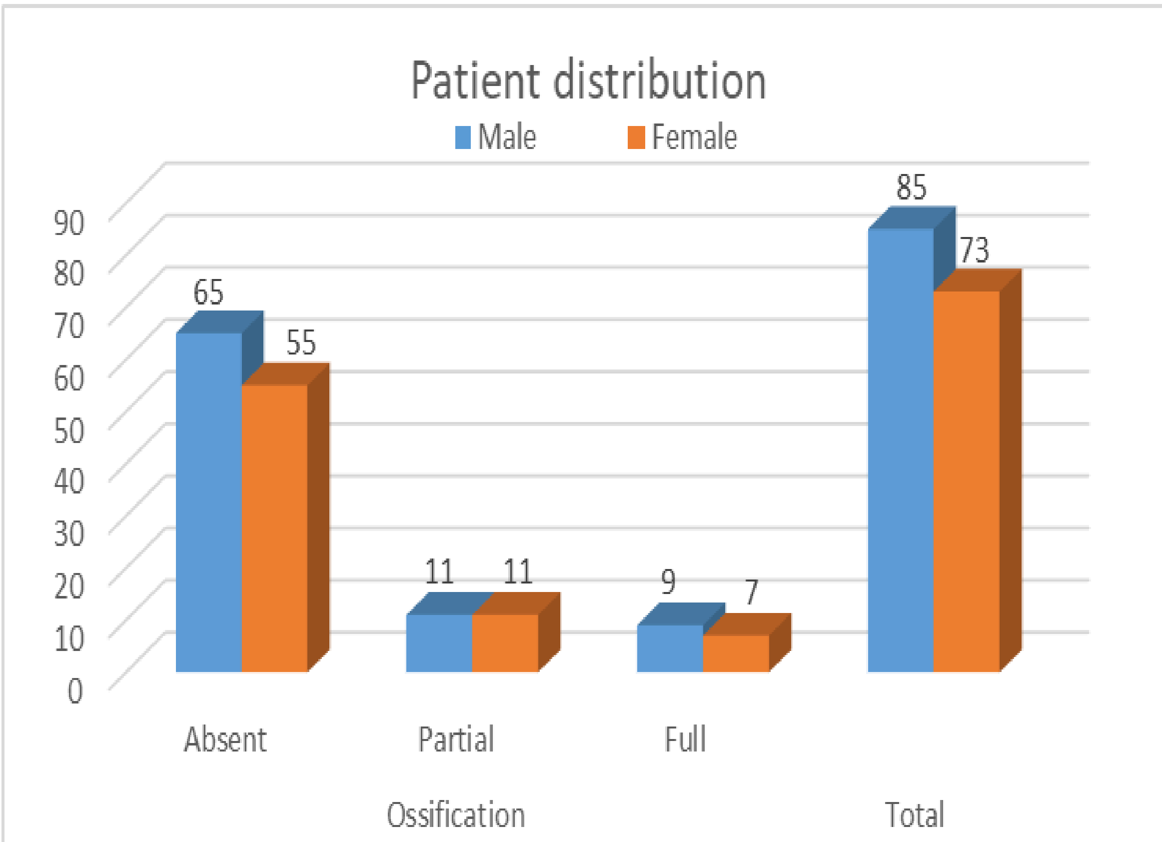


Figure 5

The presence of significant correlations between age and the presence of ossification was not also detected (p = 0.163).

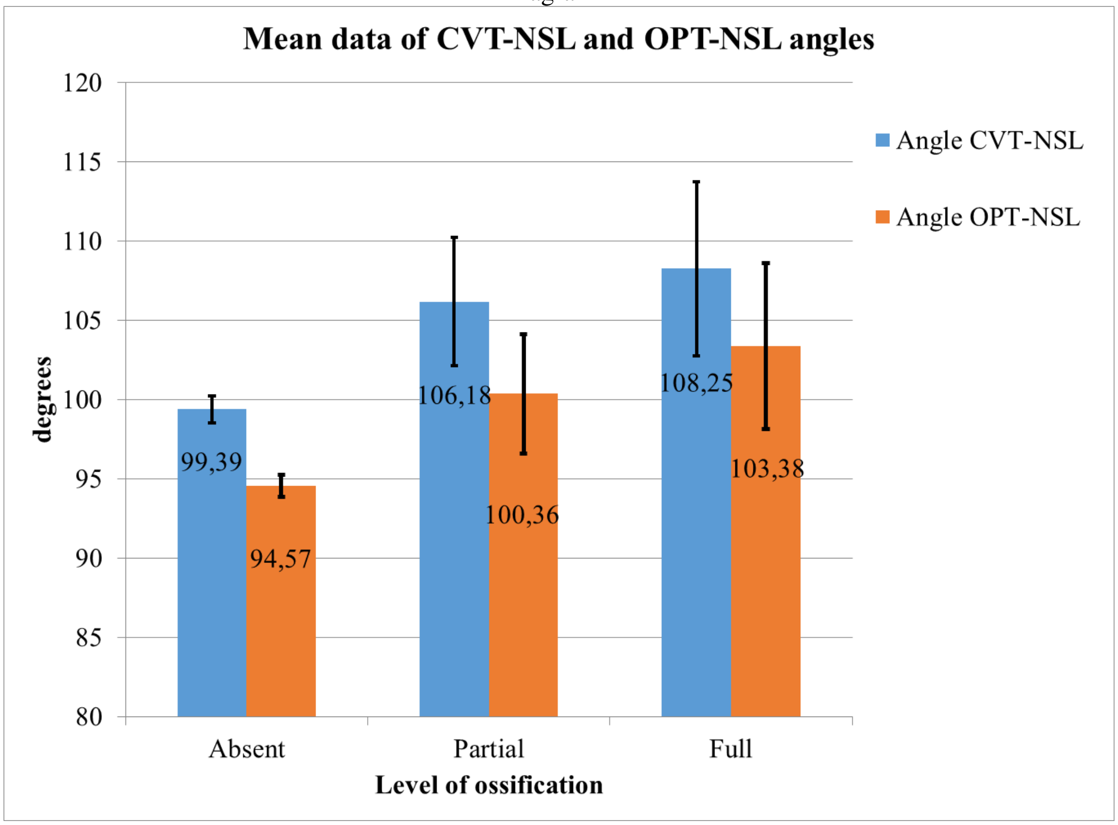
Connection between the CVT-NSL angle and the presence of ossification was revealed: r = 0.462 (p <0.001), the level of connection is moderate, statistically significant. A statistically significant correlation between the OPT-NSL angle and the presence of ossification was also detected: r = 0.489 (p <0.001), the level of connection is moderate.
The presence of correlations between ossification and length, the position of the mandible, the inclination of the lower incisors, as well as the skeletal type of the jaw relation and the direction of skeletal growth were studied.

Reliable connection between the length (p = 0.793), position of the lower jaw (p = 0.416), inclination of the lower incisors (p = 0.876), skeletal type (p = 0.386), direction of growth of the upper and lower jaws (p = 0.084) and the presence of ossification has not been detected.

Table 2

Ossification		CVT-NSL	OPT-NSL
Absent	Mean	99,39	94,57
	N	120	120
	Std. Deviation	4,668	3,828
	Maximum	114	110
	Minimum	76	82
	Std. Error of Mean	,426	,349
Partial	Mean	106,18	100,36
	N	22	22
	Std. Deviation	9,168	8,516
	Maximum	125	114
	Minimum	90	81
	Std. Error of Mean	1,955	1,816
Full	Mean	108,25	103,38
	N	16	16
	Std. Deviation	10,344	9,838
	Maximum	132	128
	Minimum	94	92
	Std. Error of Mean	2,586	2,459
Total	Mean	101,23	96,27
	N	158	158
	Std. Deviation	7,002	6,306
	Maximum	132	128
	Minimum	76	81
	Std. Error of Mean	,557	,502

Diagram 2



DISCUSSION:

The prevalence of ossification of the atlantooccipital membrane obtained as a result of our study correlates with the results published by J. Schilling et al. [6] (10.1% with partial ossification and 9.2% with full ossification). Despite the fact that there is a very large scatter of data in the literature, many modern researchers of the anomaly estimate its prevalence near 15% (15.5% [8], 15.8% [22], 15.5% [23], 14.4% [24]). Some publications state that ossification is more typical for women [24], though we did not get statistically reliable data confirming this distribution ($p > 0.05$).

In the scientific community, there is no consensus on the etiology and pathogenesis of the ossification of the posterior atlantooccipital membrane [18, 25]. There is an opinion about the congenial nature of ossification [6, 26, 27]. Arguments supporting this position are the detection of a cartilaginous posterior bridge in fetuses and in young children [28], the presence of complete and incomplete ossification in children under 10 years old [6], the lack of detection of a statistically significant association between age and ossification by a number of researchers [2 , 6, 13]. The correlation between the formation of ossification and pre- and perinatal factors, past diseases, gender was not detected [12]. A high incidence of family AK cases (66.7%) and its combination with other congenital malformations have been established [12]. Selby et al. [29] hypothesized that ponticulus posticus might be inherited as a dominant trait according to the laws of Mendel, Saunders and Popovich [30] suggesting that the inheritance of this trait is polygenic.

However, some authors [31] consider the ossification of the atlantooccipital membrane as a degenerative-dystrophic process that develops with age. So, Zadvornov Y.N. [31] contemplates the ossification of the atlantooccipital ligament to be an adaptation-compensatory reaction in response to the strain of the craniovertebral zone. G. Paraskevas [25], who found a statistically reliable difference in the membrane ossification among laborers and non-laborers, maintain a similar point of view. It can be assumed that hard physical labor contributes to the development of ossification. The author also comes to the conclusion that with age the incomplete type of ossification often becomes complete, which is consistent with the results of C. Taitz and H. Nathan [20], but differs from the results obtained by A. Putrino et al. [13], who claim that incomplete ossification often does not progress. In the literature, there is also evidence that the development of ossification can be caused by the occipitalization of atlas or proatlas remnants with the gradual calcification of the atlantooccipital membrane during microdamages, for example, by the type of "whip" [4, 32].

Despite the fact that ponticulus posticus in humans is considered to be an abnormal development, i.e. a pathological process, some researchers consider the posterior bridge to be a physiological variant of the structure of atlas [31, 33]. Keeping in mind the prevalence of concomitant neurological symptoms, published in the literature, this position seems to be not quite correct. Nevertheless, Le Double [34] noted the presence of a posterior bridge in normal conditions in many mammalian orders: Chiroptera, Eulipotyphla, Carnivora, Cetacean, Pinnipedia and others.

A study by J.M. Le Minor and O.Trost [33], revealed that the posterior bridge is a normal anatomical formation of adult monkeys. Moreover, it is much more common among less highly organized primates than higher apes. An interesting fact is that in Japanese macaques the development of the lateral bridge, like that of the posterior, is the norm, but begins much later in the postnatal period and ends much later than the development of ponticulus posticus, which can sometimes be registered already at birth [35]. Thus, there is some connection between the formation of ponticulus posticus in humans and in Japanese macaque: its formation and complete ossification often takes a long period of time despite the fact that initiation occurs immediately after birth [6]. According to A. Yamamoto and Y. Kunimatsu [35], in monkeys the prevalence of both variants of the "anomaly" is very high, and the decrease in the frequency of occurrence of the posterior bridge in the Hominids may be due to the peculiarities of their locomotion, a gradual transition of quadrupedal posture to the bipedal one.

These facts can indicate on the evolution of atlas with the gradual loss of the posterior and lateral bridges in the phylogenesis. Consequently, its appearance in modern people can be considered as an option of atavism.

J. Schilling et al. [6] suggested that the presence of the ponticulus posticus is a condition independent of age and this formation should not be considered a gradual calcification or an ossification of the lateral segment of the posterior atlantooccipital ligament, but rather as a functionally significant formation developed in primates to protect the vertebral artery at its bend, where its damage or compression is most likely.

Considering the data obtained as a result of the study, and having reviewed the literature, it can be assumed that a change in locomotion and the associated change in craniovertebral angles could contribute to the loss of functional value in the process of phylogenesis by the lateral and posterior bridges. The change in the localization of the vertebral artery in the craniovertebral region and the displacement of the foramen magnum anteriorly in the course of evolution led to the fact that such a variant of atlas in humans is considered to be an anomaly [35].

There are all reasons to believe that the increase of the craniocervical angle will contribute to the development of this anomaly. The reason of the increased inclination of the head with the cervical spine may be hypertonus of some muscles (trapezius, splenius, etc.).

Of course, an approach like this looks very mechanistic, and a serious argument against it is that the ossification has not developed to all patients with relatively large craniocervical angles. It is quite probable that at the heart of initiation of its development lay much more complex processes described by other authors and briefly commented above.

It can also be suggested that the increase of craniocervical angles is a secondary phenomenon in relation to ossification. However, to confirm or refute this position purposeful researches are required.

According to F.Y. Khoroshilkina [21], the head lag to 20 degrees changes the position of the vertebra - atlas increases the lordosis of the cervical spine and the cross-section of the pharyngeal space. The change of the position of the head is interrelated with the hyoid bone's location and defects of muscle functions of the supra and infrachioidal groups, that affects the formation of the occlusion. Thus, it can be assumed that there is a correlation between the high values of the craniocervical angles and the retrusion of the lower jaw, however, a reliable relationship was not obtained during this study. Probably, it can be explained by the fact that the absolute majority of the examined patients had retrusion in spite of the presence of the anomaly.

CONCLUSION:

An increase of craniocervical angles (NSL-CVT; NSL-OPT) is statistically reliably associated with the development of ossification of the posterior atlantooccipital membrane.

Some of the proposed assumptions in this article were not confirmed as a result of the study for one reason or another. However, that does not indicate their incorrectness. The study was pilot and its purpose was to establish possible correlated relationships between various craniocervicomandibular disorders and ossification of the posterior atlantooccipital membrane. To confirm or refute a number of suggestions a research with large samples is required. However, already received information is of a great value. The method of calculating the craniocervical angles is described in detail above and is not difficult for a practicing orthodontist what may involve other researchers in the study of this problem.

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