Bony variations of the craniovertebral region

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The craniovertebral junction is a collective term that refers to the occiput (posterior skull base), atlas, axis, and supporting ligaments. Not only anatomists, but also clinicians are interested in these variations as they cause clinical symptoms.[1,2] A median occipital condyle (MOC) can be of various shapes and sizes.[3] The basilar (mamillar or papillar) processes are hemisphere-shaped bone projections located at the front rim of the foramen magnum. They show a surprisingly high degree of variance; they may be unilateral or bilateral.[1] The hypocondylar arch is a more or less complete arch, which is situated extracranially at the anterior margin of the foramen magnum.[4] An exostosis anterior to the foramen magnum, which has been described by Taitz,[4] is a structure very similar to the MOC, which might represent a manifestation of an occipital vertebra when it is found together with a hypocondylar arch.[4] We aimed to investigate the frequency of the MOC, the basilar processes and the hypocondylar arch in adult skulls.

Our study was performed in the Anatomy Departments of the Istanbul University Faculty of Medicine, Istanbul and Dokuz Eylul University Faculty of Medicine, Izmir in 2007. We evaluated 397 Caucasian specimens, including 115 separate occipital bones, occipital bones of 215 crania and occipital bones of 67 basicrania. The Local Research Ethics Committee confirmed that ethics approval was not needed for this study.

In our study, we observed MOC in 2 skulls (0.5%) (**Figure 1a**), exostosis anterior to the foramen magnum in 12 skulls (3%), bilateral basilar processes in 14 skulls (3.5%) (**Figure 1b**), unilateral basilar process in 5 skulls (1.3%) (**Figure 1c**), and hypocondylar arch in 26 skulls (6.5%) (**Figure 1a**). One of the specimens with bilateral basilar processes was interesting as it resembled an MOC. Nevertheless, as it had a sagittal directed canal at the midline, we decided that the bilateral basilar processes had united and imitated an MOC in this sample, and we concluded that it was a false MOC (**Figure 1d**).

When an MOC is present in the adult, it is in the region of a hypochordal bow.[5] The MOC is the medial residue of the hypochordal arch. In this variant, the lateral parts vanish, but the medial part persists. In contrast, the basilar processes are formed from the hypochordal arch of the proatlas so that the medial part of the hypochordal arch vanishes, but both lateral parts persist.[1] As the lateral parts persist to different

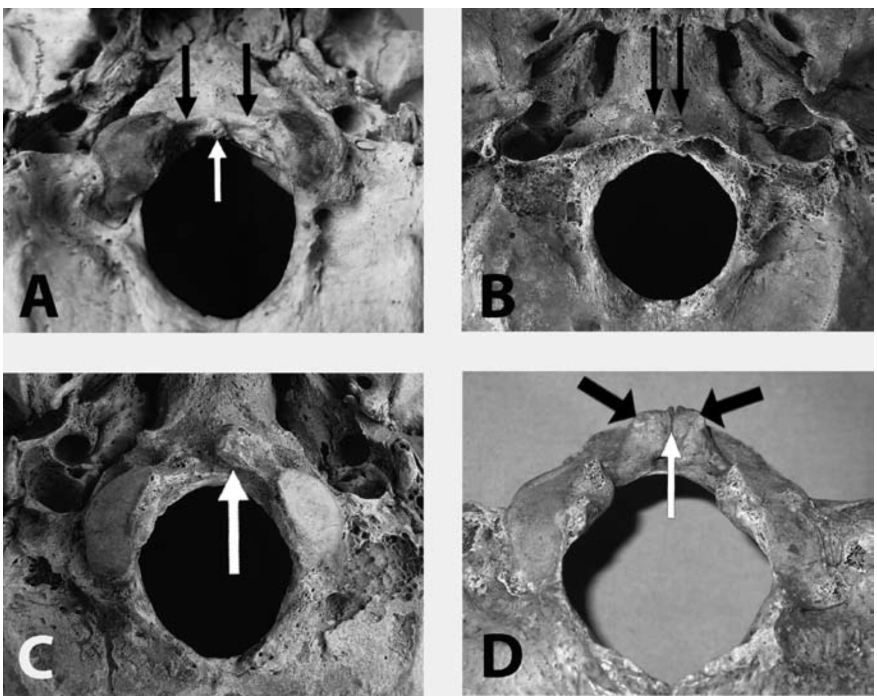

Figure 1 - Different bony variations of the craniovertebral region showing: **a)** White arrow shows the median occipital condyle, black arrows show the hypocondylar arch. **b)** Black arrows show the bilateral basilar processes. **c)** White arrow shows the unilateral basilar process. **d)** Black arrows show the bilateral basilar processes, white arrow shows the sagittal directed canal at the midline, proving that this occipital bone has a false median occipital condyle.

degrees, different morphologic manifestations of the basilar processes can exist. If only one lateral part of the hypochordal arch persists, the process will develop unilaterally.[1] The variations of the anatomic appearances of the MOC and the basilar processes can be explained by different degrees of persistence.[1] The hypocondylar arch is also considered as a manifestation of an occipital vertebra, which is situated extracranially at the anterior margin of the foramen magnum where it forms an almost complete arch.[4] The MOC may be either tightly attached or an isolated bony element, or it may be articulated with the tip of the dens axis or with the anterior atlantic arch.[1] The variable relationship of the MOC with the dens axis is unclear, as during the embryonic, and early fetal periods, the dens is at a very high level, and is almost continuous with the basilar part of the occipital bone.[5] Radiologically, the MOC has occasionally been recognized as a small or large bony element, either attached to the anterior margin of the basiocciput or unfixed between the occipital bone and the anterior arch of the atlas or the tip of the dens axis.[3] The radiologic diagnosis of an MOC is dubious when only anteroposterior or lateral x-ray photography is applied. Care must be taken to ensure the median location when diagnosing an MOC, which must be distinguished from an ossification of the apicis dentis ligament, which appears as a small peaked bony spur at the same place on the picture. If morphologic details are to be examined (for example whether a false MOC is present), a CT scan should be used.[1] The MOC seems to be a homologue of the single occipital condyle (in median location) in fish, reptiles, and birds. The MOC resembles the processus condyloideus impar, regularly found in reptiles and amphibians and occasionally in mammals.[3] The MOC can be regarded as a rare variation throughout the world.[1] In a study performed on 99 cadavers and 110 dry skulls by von Lüdinghausen et al,[3] the MOC was determined in 5 cadavers and 2 dry skulls. Of 214 skulls examined by Taitz,[4] only one skull showed evidence of a third occipital condyle. Rao[2] examined 153 skulls and reported only one MOC. In our study, 2 of 397 specimens had MOC (0.5%). Twelve out of 397 samples investigated in our study, had an exostosis anterior to the foramen magnum. Of 214 skulls Taitz[4] examined, exostosis was noted in one specimen, and stated that as this exostosis had appeared together with a hypocondylar arch, thus, it might represent a manifestation of an occipital vertebra. We determined bilateral basilar processes in 14 samples. Prescher et al[1] reported that large processes might fuse at the median line and can be called a false MOC. They added that unlike the real MOC, the false one had a sagittal directed canal. We evaluated one of the 14 specimens with bilateral basilar processes as a false MOC. We found the unilateral basilar process situated paramedially at the left side, in 5 samples.

At an early embryonic stage, a hypocondylar arch ventral to the developing vertebral body is found on each vertebral segment. All of these disappear with the exception of C1, which forms the anterior arch of the atlas. The hypocondylar arch may be retained after birth, and it is considered as a manifestation of an occipital vertebra.[4] Taitz[4] reported that evidence of a complete hypocondylar arch was found on the crania of 2 Caucasian men in a study including 111 adult skeletons of whites and 103 skeletons of blacks. In the present study, we found hypocondylar arch in 26 specimens. The MOC is of interest to the surgeons, because it may result in a 3-legged mechanism of head bearing, which can cause cervical stiffness, serious restrictions of head movement, and even a bone-derived torticollis.[1,3] Rao[2] explained that limiting of the rotation of the head was due to the fact that the MOC lied in the midsagittal plane. Moreover, Rao[2] also stated that when the abnormal osseous formations that originated from the arches of the proatlas fused with the base, they might narrow the foramen magnum and could cause compressive neurological symptoms.

In conclusion, an MOC is rare.[1] Although exostosis on the anterior margin of the foramen magnum, basilar processes, and hypocondylar arch are more frequent, they can also be evaluated as rare structures. Consequently, while evaluating imaging of the craniovertebral junction, making a distinctive diagnosis of its diseases and manipulating the disorders of it, the clinicians should be aware of the presence of these rare manifestations of the occipital vertebra. The limitation of our study was that we could not evaluate the corresponding cervical first and second vertebrae with our occipital bones. Future studies should observe the relation of the variations of the occipital bone with the atlas and axis for determining the possible clinical effects of contact between these structures.

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