Acta Orthopaedica et Traumatologica Turcica xxx (2016) 1–4

Contents lists available at ScienceDirect

Acta Orthopaedica et Traumatologica Turcica

journal homepage: https://www.elsevier.com/locate/aott

Occipital bone thickness: Implications on occipital-cervical fusion. A cadaveric study

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ARTICLE INFO

Article history:
Received 25 February 2015
Received in revised form
8 March 2016
Accepted 20 April 2016
Available online xxx

Keywords:
Occipital bone thickness
Occipital-cervical junction
Occipital bone
Occipital-cervical fusion

ABSTRACT

Objective: The aim of this study was to create a map of the occipital bone using a cadaveric morphometric analysis.
Material: Twelve heads, from seven male and five female cadavers, were studied. The thickness of the occipital bone was measured with a digital vernier caliper within a coordinate system.
Results: The maximum thickness of the occipital bone could be measured at the external occipital protuberance (mean 15.4 mm; range 9–29.3 mm). All male individuals had higher bone thickness around this point. Further lateral a steady decrease of bone thickness could be observed. Same could be observed in craniocaudal direction. However, values above the superior nuchal line were on average thicker than below.
Conclusion: The measurements demonstrated a great individual variability of bone thickness of the occipital bone. The results emphasize the role of preoperative planning for the feasibility of placement of an occipital screw.

Introduction

The occipito-cervical junction is the most cephal portion of the axial skeleton, connecting the cranium and the spine. It is a functional unit including the occiput, atlas and axis. The osseous complex allows significant mobility while maintaining biomechanical stability. However numerous conditions can affect the stability of the occipitocervical junction and may manifest as disabling pain, cranial nerve dysfunction, paralysis or even sudden death.[1–3] The most common reason for acute presentation of instability is the result of trauma with dislocation of the atlantooccipital joint as well as a complex fracture of the atlas and axis. Other common pathological findings include rheumatoid arthritis, infection, tumors, and congenital malformation. In all mentioned conditions occipitocranial fusion is indicated when the craniocervical junction has proved as unstable.

In general, internal craniocervical fixation methods are the vital treatment of choice and can be divided in anterior, posterior and combined anteroposterior approaches.[3–5] All of them have to fulfill the biomechanical needs and the kinematics of the craniocervical junction. However, every technique presents a challenge to the attending surgeon. Due to the anatomic complexity of this area a thorough understanding of the bony elements and about the involved soft-tissue elements is essential. Especially when using rigid posterior fixation techniques with rods, screws and plates-a technique which provides superior biomechanical stability and higher fusion rates-knowledge about bone thickness at different occipital points is essential to avoid intracranial injuries.[6,7] In this context previous investigations have performed cadaveric or CT based measurements of the occipital bone.[8–11] The aim of the present cadaveric morphometric investigation was to create a complete map of the occipital bone to illustrate the position of greatest bone thickness for safe and effective internal fixation as well as to determine if significant variability exists concerning this matter.

Methods

Twelve cadaveric heads, seven male and five female, were harvested from fresh cadavers and dissected to the level of the cranial

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Peer review under responsibility of Turkish Association of Orthopaedics and Traumatology.

http://dx.doi.org/10.1016/j.aott.2016.04.003

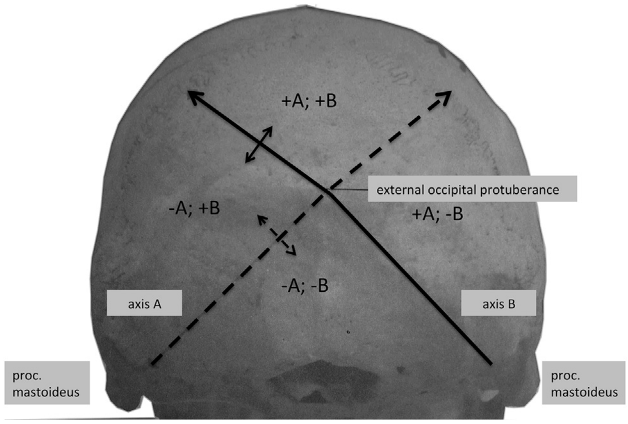

Fig. 1. Construction of a coordinate system of the occipital bone. The axis A and B defines four quadrant (+A; +B/−A; +B/−A; −B/+A; −B).

bone. Only heads without evidence of an occipital fracture, craniotomy or other abnormalities were used. Each head was freed of all soft tissue, leaving intact only the bony structures. Afterward the calotte was removed from the skull base through a horizontal cut.

To secure a unitary coordinate system for each head we define three benchmarks, which can be reliably determined: the right and left processus mastoideus and the external occipital protuberance. Using these landmarks the first axis (axis A) of the coordinate system was positioned between the left processus mastoideus and the external occipital protuberance. Axis B was positioned between the right processus mastoideus and the external occipital protuberance. From the external occipital protuberance both axis were scaled every 5 mm. Starting at every of these points we reconstructed to the perpendicular axis points every 5 mm. Following this procedure a coordinate systems results with defined points every 5 mm (Fig. 1). All points below the axis A and B were represented with negative sign, above with a positive sign (Fig. 1).

The thickness of the occipital bone was measured with a digital vernier caliper with an accuracy of ±0,002 mm (Digimatic, Mitutoyo, Japan). Due to the round surface of the occipital bone minor errors of this technique appear to be possible. However, previous investigations have demonstrated the accuracy of this technique.[12,13]

Beside descriptive analysis, Box-plots were created to visualize the thickness of the bone at defined points. Analysis was carried out using SPSS package software (SPSS Inc, Chicago, IL, USA).

Results

The maximum thickness of the occipital bone could be measured at the external occipital protuberance located midline on the superior nuchal line with a mean value of 16.1 mm (SD 3,9). Individually a wide range could be measured with values between 9 and 29.3 mm. Gender differences were obvious, too. In woman the mean thickness was 15.3 mm (SD2.8) with a range of 9–20.3 mm, in men 17.0 mm (SD 4.9) with a range of 9.9–29.3 mm.

Along the axes a decrease of bone thickness could be observed. Table 1 presents the thickness for the quadrant on the right side. As demonstrated, distinct changes appeared within the first 2 cm descending from the protuberance externa. Same could be observed along the axes A starting from the protuberance in cranial direction (Fig. 2).

An overview of occipital bone thickness in the generated coordinate system is demonstrated in Fig. 3. The diameter of the circles corresponds with the thickness of the bone at a ratio of 1:2. The thinnest spot was located in an area within the cerebellar fossa between the foramen magnum and the inferior nuchal line. The thickness below the superior nuchal line ranged between 10,5 and 1,7 mm. In cranial direction the occipital thickness increased gradually to higher values at the superior nuchal line with a maximum at the protuberance externa. In a further cephaled direction thickness gradually diminished. However, values above the superior nuchal line were with a range of 11,6 to 4,3 mm on average thicker than below.

Discussion

Based on the present investigation we concluded in accordance with previous cadaveric and radiographic studies a great individual variability of bone thickness of the occipital bone. In cases were craniocervical fixation is indicated for instability of the craniocervical junction, like rheumatoid disease, tumor, or trauma, preoperative CT scans appear to be essential.

There are many different techniques of internal fixation in order to accommodate the increased spectrum of anatomical variations, to avoid certain adverse events like loss of spinal alignment and to achieve more rigid stabilization in a wider variety of spinal diseases.[5] Within this context the Luque rod has to be mentioned where intracranial and sublaminar wiring is used.[14]

During the last years alternative procedures, which use rigid plates with screw fixation to the occiput and to the lateral mass of the cervical spine, have been developed.[15,16] Biomechanical investigations of these different fixation techniques demonstrated comparable levels of stability within the craniocervical junction. Nevertheless the mentioned plate-screw construct provides better maintenance of stability under repetitive loading conditions.[17] Especially fixation of the plate in the midline region of the occiput provides more rigid fixation than a plate fixed laterally.[18]

Regardless of the technique, understanding of the 3D anatomy of the cervical spine as well as of the occiput is necessary. Due to the anatomy, vertebral fixation is normally more problematical than occipital one. However, last mentioned should not be underestimated, due to the variability of occipital bone thickness. Inadvertent puncture of the underlying sinuses is one of the most serious complications within this technique. Thereby puncture of

Table 1
Overview of mean thickness (in mm) for the quadrant on the right side.

Axis B\A	0	5	10	15	20	25	30	35	40	45
0	12.3	10.9	9.3	7.2	6.0	4.9	4.4	4.2	4.2	4.7
−5	10.2	10.1	8.6	7.1	6.1	4.6	4.2	4.0	4.0	4.4
−10	9.0	7.9	7.2	7.0	6.1	5.0	4.5	4.0	4.0	4.0
−15	6.7	6.1	5.7	5.8	5.9	5.1	4.6	4.2	4.0	4.0
−20	4.7	4.8	4.8	4.8	5.2	4.9	4.7	4.6	4.2	3.7
−25	4.0	4.1	4.2	4.4	4.5	4.9	5.1	4.4	4.2	3.7
−30	3.1	3.6	3.9	3.9	4.3	4.8	4.9	4.5	4.2	3.7
−35	2.2	2.7	3.2	3.4	3.9	4.7	4.9	4.5	4.4	4.3
−45	1.7	2.0	2.9	3.1	3.7	4.3	4.9	5.0	4.7	4.9

Please cite this article in press as: Zarghooni K, et al., Occipital bone thickness: Implications on occipital-cervical fusion. A cadaveric study, Acta Orthop Traumatol Turc (2016), http://dx.doi.org/10.1016/j.aott.2016.04.003