Introduction

Injuries to the atlanto-occipital joint (AOJ) (Figure 1) make up 15–30% of all cervical spine injuries and 19% of such injuries are fatal. These injuries are more common in children due to the laxity of surrounding ligaments around the AOJ. The AOJ connects the occipital condyles (OC) (Figure 2) and the superior articular surfaces (SAS) (Figure 3) of the lateral mass of the atlas. The mean length, width, and height of the OC are 23.6 mm (a range of 16.7–30.6 mm), 10.5 mm (a range of 6.5–15.8 mm), and 9.2 mm (a range of 5.8–18.2 mm), respectively. The long condylar axes converge medially, forming the sagittal intercondylar angle, which ranges from 22 to 103° (mean of 59.3°). The SAS of the atlas is concave (Figure 5), forming a framework for the convex OCs, and is on the superior aspect of the lateral mass, which is trapezoid in shape and higher laterally (22 mm; a range of 17.5–28.5 mm) than it is medially (11 mm; a range of 8.2–14.6 mm). The SAS slopes medially with a mean angle of 22.4° (a range of 16.5–29.2°) and converges medially with a mean horizontal angle of 18.6 mm (a range of 15.5–21.8 mm). The surface of the AOJ has a C-shape and is concave medially. The AOJ is reinforced by a joint capsule.

Atlanto-Occipital Ligaments

The ligamentum nuchae (LN) is a continuation of the supraspinous ligament, which spans from the occipital protuberance to the vertebra prominens (C7). The LN...
limits excessive neck flexion.\(^5\) The alar ligament (AL) (Figure 6) limits axial rotation and lateral flexion, stabilizing the AOJ. The AL is the primary ligament for the stabilization of the joint when the transverse ligament is damaged.\(^5\) The AL also anchors the dens to the OCs and is very tough.\(^6\) The anterior and posterior atlanto-occipital membranes attach to their respective surfaces on the atlas and the foramen magnum.\(^6\) The apical ligament (Figure 6) joins the tip of the odontoid process to the basion (the most anterior point of the foramen magnum in the median sagittal plane) and has no mechanical role and is absent in 20% of the bodies studied by Tubbs et al.\(^5\)

The AOJ allows 11–13° of freedom, allowing for 25° of flexion and extension, 5° of axial rotation, and combined motions.\(^7\) Flexion is limited by the contact between the foramen magnum and the dens.\(^7\)

According to Tubbs et al., the tectorial membrane (TM) (Figure 6), a mean thickness of 1 mm, firmly attaches cranial base and body of the axis.\(^8\) The TM stabilizes the head in flexion and extension of the neck.\(^8\) It also carries a function of limiting the posterior movement of the odontoid process and prevents the process from intruding into the cervical canal and compressing the spinal cord.\(^8\)

The lateral atlanto-occipital ligament (LAO) is situated right against the rectus capitis lateralis bilaterally and is limited excessive neck flexion.\(^5\) The alar ligament (AL) (Figure 6) limits axial rotation and lateral flexion, stabilizing the AOJ. The AL is the primary ligament for the stabilization of the joint when the transverse ligament is damaged.\(^5\) The AL also anchors the dens to the OCs and is very tough.\(^6\) The anterior and posterior atlanto-occipital membranes attach to their respective surfaces on the atlas and the foramen magnum.\(^6\) The apical ligament (Figure 6) joins the tip of the odontoid process to the basion (the most anterior point of the foramen magnum in the median sagittal plane) and has no mechanical role and is absent in 20% of the bodies studied by Tubbs et al.\(^5\)

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in a close contact with the jugular foramen anteriorly and the vertebral artery posteriorly. The ligament originates from the anterolateral aspect of the transverse process of the atlas and inserts onto the jugular process of the occiput. LAO has a mean angle of 26° from the midline and a mean length and width of 2.2 and 0.5 cm, respectively. This ligament limits lateral flexion of the neck and partially limits neck rotations bilaterally at the AOJ.

The alar ligaments (AL) (Figure 6) are dense structures that connect the odontoid process to the medial aspect of the OCs. The ALs join the superior half of the lateral aspect of the dens and the medial surface of the OC, at which the distal insertions of the ligaments are limited. They limit the axial rotation, lateral flexion, and sagittal flexion at the AOJ. The alar ligaments are some of the most important structures around the AOJ, which not only protects but also allows mobility of the neurovascular bundles which run within the cervico-cranial junction.

**Injuries to the AOJ**

In a traumatic injury involving the AOJ, its supporting ligaments may be torn and dislocate the atlas from the occiput. Such an injury is classically associated with a high-energy impact trauma in a road traffic accident or a fall from a height. According to Horn et al., the presence of an atlanto-occipital dislocation must be assessed in all traumatic brain injuries. Most cases of dislocation require immediate stabilization.

There are two types of atlanto-occipital injuries: atlanto-occipital dislocation (Figure 1) and OC fractures. A damage to the ligaments in this region may cause vary-
ing degrees of atlanto-occipital instability and subluxation or luxation of the joint between the atlas and the axis.\textsuperscript{[13]} Traynelis et al. classified atlanto-occipital injuries according to the direction of the dislocation: type 1 – anterior dislocation, type 2 – vertical displacement, and type 3 – posterior dislocation.\textsuperscript{[13]}

The radiologic diagnosis of atlanto-occipital injuries is challenging. The basion to dens interval (BDI), the distance between the basion and the tip of the dens, and the basion to axial interval (BAI), the distance between the basion and a line drawn at the posterior border of the body of the C2 and dens extended cranially, should be less than 12 mm in a lateral cervical radiograph to rule out an atlanto-occipital dissociation.\textsuperscript{[14]}

The intraarticular fluid sign is shown by the magnetic resonance imaging (MRI) and indicates a disrupted AOJ capsule and an injury to the surrounding ligaments.\textsuperscript{[15]} The revised OC to C1 interval (CCI) shown by the computed tomography (CT) is highly sensitive and specific for an atlanto-occipital injury and is measured from the bottom of the OC to the deepest point in the valley of the SAS of C1 in the parasagittal plane.\textsuperscript{[15]} A CCI of greater than 2.5 mm is considered diagnostic of unilateral or bilateral AOJ dislocation.\textsuperscript{[15]}

A fracture of the OC is relatively rare and two classification systems are utilized. Anderson and Montesano developed three categories of OC fractures: type I – impaction fracture of the OC, which is considered stable, type II – fracture of the skull base in which the fracture line crosses the OC, type III – avulsion fracture of the OC resulting in ligamentous instability.\textsuperscript{[16]} Types I and II fractures are stable while type III fracture is unstable.\textsuperscript{[16]} Tuli et al.\textsuperscript{[17]} reported a classification system in regards to the presence of dislocation, which is defined by more than 2 mm of separation, or occipito-atlantoaxial instability: type 1 – OC fracture without dislocation and type 2 – dislocated OC fracture. Type 2 is further subdivided into 2a, which is a case of a stable occipito-atlantoaxial complex, and 2b, which is a case with any signs of occipito-atlantoaxial instability. A surgery is required only in cases of presence of an instability or a compression of the neural structures, both of which are rare.\textsuperscript{[17]}

Conclusion

The AOJ (Figures 7 and 8) is the articulation point of the OC and the SAS of the atlas. The structure of this joint is maintained and reinforced by multiple surrounding ligaments, which allow the spinal cord to pass through the foramen magnum without any bony interference. Contact sports and high-impact collisions are the common mechanisms of injury to the AOJ and may be fatal. A timely diagnosis of AOJ injuries increases the likelihood of survival.\textsuperscript{[1]} In addition, subluxations can also be caused by ligament laxity and muscular atrophy in osteoarthritis.\textsuperscript{[5]}

\textbf{Figure 7.} Posterior view of the craniovertebral junction noting the articulation between the occipital condyles and superior articular facets of C1. [Color figure can be viewed in the online issue, which is available at www.anatomy.org.tr]

\textbf{Figure 8.} Lateral view of the craniovertebral junction noting the articulation between the occipital condyles and superior articular facets of C1. [Color figure can be viewed in the online issue, which is available at www.anatomy.org.tr]
References

Correspondence to: Paul J. Choi, MD
Seattle Science Foundation, 550 17th Ave, James Tower,
Suite 600, Seattle, WA 98122, USA
Phone: +1 206 732 65 00
e-mail: paulchoi92@gmail.com
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