Type I fractures of the odontoid process: implications for atlanto-occipital instability

Case report

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Only four cases of Type I odontoid fracture have been previously described in the English literature. Most authors consider this lesion to be stable, although the mechanism(s) of injury has not been clearly elucidated. A case of Type I odontoid fracture in association with atlanto-occipital and atlantoaxial dislocation resulting in death is presented. The normal ligamentous anatomy is reviewed and proposed mechanisms for this injury are discussed. The radiographic features of all reported cases of this type are reviewed. It is proposed that the Type I odontoid fracture is a likely manifestation of atlanto-occipital instability and rarely occurs as an isolated or stable injury.

KEY WORDS • atlantoaxial dislocation • atlanto-occipital dislocation • odontoid fracture • spinal injury

Many attempts have been made to classify odontoid fractures. The most widely accepted schema is that of Anderson and D’Alonzo, which divides odontoid fractures into three groups (Fig. 1). Type I injuries are described as oblique fractures through the upper part of the dens, thought to result from avulsion of the attachment of the alar ligament which joins the tip of the dens to the occipital condyle. This was classified as a “stable” injury; both of the cases they reported went on to fuse with only external immobilization. Subsequent reviews have also regarded these as stable injuries uncomplicated by nonunion and requiring only external immobilization, although neither of the later series gave specific results.

We report our experience with a patient with a Type I odontoid fracture. This entity is discussed in terms of the anatomy and treatment.

Case Report

This 23-year-old black woman was struck by an automobile and was noted to be unresponsive and apneic at the scene of the accident. She was intubated and resuscitated with administration of fluids.

Examination. Examination in the emergency room revealed a blood pressure of 70 mm Hg, pulse of 140 beats/min, and no spontaneous respiratory efforts. Con-
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Type I

Type II

Type III

Fig. 1. Schematic diagram of the Anderson and D'Alonzo classification of odontoid fractures. (Drawings adapted from Anderson LD, D'Alonzo RT: Fractures of the odontoid process of the axis. J Bone Joint Surg (Am) 56:1663-1674, 1974.) Type I = oblique fracture through the upper portion of the dens; Type II = fracture at the junction of the dens with the body of the axis; and Type III = fracture extending into the cancellous portion of the body of the axis.

Postmortem Examination. Autopsy revealed large right parieto-occipital and smaller left frontal scalp hematomas. There were no calvarial or basilar skull fractures. Examination of the brain showed diffuse subarachnoid hemorrhage, multiple basilar cortical contusions, and a crush injury at the juncture of the medulla oblongata and cervical spinal cord. There were associated atlantoaxial and atlanto-occipital dislocations. Extensive hemorrhage was noted in the submucosal pharyngeal soft tissues and in the prespinous soft tissues of the cervical spine.

Discussion

Type I fracture of the dens is a rare injury, and its validity as an isolated stable fracture has been challenged. Only two other cases, in addition to our own, have been described since the original two reported by Anderson and D'Alonzo. A review of several recent large series published in the English literature, totaling 434 cases of fractures of the odontoid, revealed not a single additional case of Type I fracture. The rarity of this injury precludes any statistically meaningful analysis of the associated incidence of other cervical-cranial injuries.

In an attempt to better define the clinical and radiographic characteristics of Type I odontoid fractures, we reviewed the four previously described cases. The anteroposterior open-mouth cervical spine radiograph included in the original report by Anderson and D'Alonzo is suggestive of an associated rotational injury. The C-2 spinous process is shifted toward the left and is not in alignment with the dens, although the occipital condyles are well aligned over the lateral masses of the atlas. Unfortunately, no lateral radiograph was provided. Their second case was not illustrated, although both fractures were reportedly not displaced and healed uneventfully with external immobilization with a collar/brace. Ryan and Taylor included a single Type I fracture in their series of 23 odontoid fractures but provided no clinical description or radiographs. The injury healed after 6 weeks of immobilization in a halo cast. Eismont and Bohlman described a 60-year-old man thrown from a vehicle who suffered a Type I fracture associated with a posterior arch fracture of C-1 and posterior atlanto-occipital dislocation. The extent of his injuries became apparent 24 to 48 hours later when he developed criculate paralysis and labile hypertension. These symptoms improved with skeletal traction and realignment. The patient subsequently underwent posterior wiring and fusion from the occiput to C-3.

Harris and Edeiken-Monroe suggested that the Type I fracture is unstable and should be considered a manifestation of atlanto-occipital dislocation. Our case and the report by Eismont and Bohlman provide
additional clinical and radiographic evidence for this postulate.

The atlanto-occipital joint is essentially a shallow "ball in socket" joint composed of two condyloid articulations with reciprocally curved "cuplike" surfaces. The cup is more shallow in the anteroposterior plane than in the sagittal plane and consequently more prone to anteroposterior displacement/dislocation than to lateral displacement. These bone articulations and their joint capsules provide only minimal stability for the atlanto-occipital joint, however. Stability is primarily supplied by the ligaments, which have traditionally been divided into two groups: those that connect the atlas to the occiput and those that connect the axis (or more precisely the dens) to the occiput (Fig. 3).

The first group is composed of the anterior and posterior atlanto-occipital membranes. The anterior atlanto-occipital membrane (the strong cephalad extension of the anterior longitudinal ligament) runs from the anterior margin of the foramen magnum to the anterior arch of C-1. The posterior atlanto-occipital membrane connects the posterior margin of the foramen magnum to the posterior arch of C-1. The second set of ligaments includes the tectorial membrane, the two paired alar ligaments, and the apical ligament which has minimal mechanical significance. The tectorial membrane (a continuation of the posterior longitudinal ligament) is a strong dense band of tissue running from the dorsal surface of the dens and dorsal aspect of the C-2 and C-3 vertebral bodies to the ventral surface of the foramen magnum.

The alar ligaments have traditionally been described as paired structures running obliquely from the tip of the odontoid to their respective occipital condyles. However, detailed studies by Dvorak and Panjabi have demonstrated that the alar ligaments consist of two portions, the occipito-alar and the atlanto-alar ligaments. The former connects the side of the dens with the occipital condyle and the latter connects the dens to the lateral mass of C-1.

Various authors have speculated on the mechanism(s) necessary to produce odontoid fractures. Hyperflexion, hyperextension, and horizontal shear have all been proposed as the primary force vectors. However, Althoff found that in controlled experimental studies, dens fractures were produced only by combining horizontal shear and vertical compression. Different types of odontoid fractures resulted from changing the direction of the impact in relation to the sagittal plane through the axis. The Type A fracture described by Althoff (Fig. 4) most closely (although not exactly) approximates the Type I fracture of Anderson and D’Alonzo. These oblique fractures pass through the isthmus of the odontoid process just above the base approximating the inferior border of the transverse ligament. In cadaver experiments, the Type A fracture could be produced only by a lateral impact applied 90° to the sagittal plane (blow above the ear). A change in the vertical component of the force varied the angle of the injury, with the fracture line always sloping downward in the direction of impact. A force directed from a slightly more anterior direction (blow to the lateral side of the forehead) resulted in decapitation with rupture of all ligaments between the occiput and cervical spine. A similar blow with less energy resulted in partial rupture of the anterior atlanto-occipital membrane and complete rupture of the contralateral alar ligament. There was no dens fracture in either case. In all instances, the skull was maintained in a neutral, flexed, or extended position prior to impact (with minimal tension on the alar ligaments). There were no studies incorporating a rotational component to the primary vector force.

In another series of cadaver experiments, Mouradian,
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et al., 21 found that lateral vector forces consistently produced odontoid fractures. Simultaneous rotation predisposed fractures of the dens by two mechanisms: 1) the ligaments and muscles were tightened, compressing the facet joints and minimizing disruption at other levels; and 2) in rotation, the alar ligament is already maximally stretched.

The role of the alar ligaments in the stability of the occipitoatlantoaxial joint has long been underestimated. A series of cadaver studies demonstrated that the alar ligament is the main restraint against axial rotation both at the occipito-atlantal and atlanto-axial levels.7,8 These ligaments are extended most while the head is rotated and flexed and consequently are at greatest risk for injury in this position. Failure always occurs at the insertions of the ligaments in an area of bone-cartilage interface resulting in fragments of mineralized bone or cartilage attached to the ligament — the oblique "avulsion" fracture characteristic of Type I injuries.9

Traumatic atlanto-occipital dislocation is a relatively common and usually fatal injury. In one autopsy series, it was present in 19% of fatal cervical spine injuries.1 Bucholz and Burkhead4 found it to be the single most common injury to the cervical spine in victims of fatal multiple trauma. These injuries almost invariably result from vehicular trauma and are particularly common in pedestrians. Traynelis, et al., 27 reviewed the clinical and radiographic manifestations of these injuries and classified them into three groups: longitudinal distraction; anterior dislocation; and posterior dislocation of the occiput relative to the atlas.

Werne11 first described the dynamics of the atlanto-occipital joint in a cadaver series. He demonstrated that sectioning of the alar ligaments and tectorial membrane allowed the cranium to dislocate anteriorly on the cervical spine. Traynelis, et al., 27 proposed that traumatic atlanto-occipital dislocation results from a complex combination of forces including hyperextension, lateral flexion, and possibly hyperflexion which would disrupt the tectorial membrane, alar ligaments, and posterior elements, respectively. A Type I odontoid fracture requires: 1) disruption of the occipital portion of at least one of the alar ligaments and 2) disruption of at least part of the tectorial membrane (Fig. 5). Traynelis, et al., suggested that Type I or Type II odontoid fractures should damage the alar ligaments and tectorial membrane sufficiently to cause atlanto-occipital dislocation, but they could find no association in their review of the literature. Our patient and the one described by Eismont and Bohlman10 provide this link.

The number of patients surviving atlanto-occipital dislocation appears to be increasing, which emphasizes the serious implications of overlooking such an injury.5,12,27,28,30,33 It is proposed that Type I odontoid fracture be considered a radiographic sign suggesting atlanto-occipital instability. Such patients may have unstable, potentially life-threatening injuries, and the capability for respiratory and hemodynamic support in treating these cases should be close at hand. Immediate halo immobilization is best in cases of longitudinal distraction alone. Patients with anterior or posterior displacement and neurological deficit may benefit from gentle (2- to 5-lb) skeletal traction to realign the bone structures and decompress the neural elements, followed by halo immobilization. Most patients require subsequent spinal stabilization and fusion.27

![Fig. 4. Schematic drawing of the various odontoid fracture types produced under experimental conditions by Althoff. (Drawings adapted from Althoff B: Fracture of the odontoid process: an experimental and clinical study. Acta Orthop Scand 177 (Suppl):1-95, 1979.) Type A = fracture through the isthmus of the dens; Type B = fracture extending down into the most superior part of the body of the axis; Type C = fracture extending through the superior part of the body of the axis to involve the medial portion of one of the superior articular facets of the axis; and Type D = fracture passing through the superior part of the body of the axis to involve the medial portions of both superior articular facets.](image)

![Fig. 5. Diagram showing proposed pathological findings in Type I odontoid fractures. Anterior view of a Type I odontoid fracture demonstrating disruption of the occipital portion of the alar ligaments and the tectorial membrane (not shown), allowing longitudinal distraction of the occiput from the atlas (arrows); that is, atlanto-occipital dissociation. The fractured tip of the dens is separated from the remaining portion of C-2, resulting in the characteristic "avulsion fracture" appearance on radiographs. The atlantal portion of the alar ligament remains intact.](image)
Addendum

Since this manuscript was accepted for publication, an additional case of Type I fracture of the odontoid has been reported by Francavilla, et al. (Francavilla TL, Melisi J, Chappell ET, et al: Type I odontoid fractures. Neurosurgery 25:481, 1989 (Letter)). These authors described a spiraling fracture of the upper and mid-portion of the dens with slight posterior displacement. The patient was treated with halo immobilization for 12 weeks. He remained neurologically intact and achieved adequate bone fusion.

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References


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