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Treatment of odontoid fractures: A clinical challenge and reality

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Abstract
Of all the injuries to the spine, the cervical spine injuries have been the most feared because of its potential to lead to deleterious complications. It has been noted that there is a correlation between the level of spinal injury and morbidity / mortality. The higher the level of cervical injury, the higher will be the morbidity / mortality. Injuries of the craniocervical junction are the deadliest. It has been observed practically that approximately 10% of patients who present in an unconscious state to the emergency department following a motor vehicle accident have a pathology in the cervical spine. Motor vehicle accidents and falls are seen to be responsible for C2 fractures [1]. Clinically, the manifestations may range from asymptomatic to frank paralysis. Among adults, odontoid fractures have been accounted for 9% to 15% of cervical spine fractures [2]. These fractures are usually a result of low energy impacts like falls in elderly people or of high energy impacts like motor vehicle accidents in the young and middle aged people [3, 4, 5]. Odontoid fractures are the most common cervical spine fractures among the elderly aged between 70 - 80 years [5]. The male to female distribution is equal for both populations. This article describes in brief the most common types of C2 fractures and its present treatment, the advancements to me made in the treatment of odontoid fractures and the challenges a surgeon faces in the day to day clinical practise in treating different types of odontoid fractures.

Keywords: Spine, odontoid injuries, anterior – posterior fixation

Introduction
Clinical Features
The mechanism of odontoid fractures includes hyperextension or hyperflexion of the cervical spine. The patients complain of pain and inability to move the neck actively. In addditon, patients with odontoid fractures describe that they feel the head being unstable on the spine – a sensation of instability. Such patients are seen to be holding their head with their hands in a way to support so as to prevent any motion. Range of clinical findings on examination may be from quadriplegia with involvement of the respiratory centre to motor and sensory deficits of the upper extremity due to secondary loss of one or more cervical nerve roots [4, 5]. Neurologic injury is variable between 2% to 27% among multiple studies. The type of fracture can be diagnosed by radiographic findings [6].

Classifications
Anderson and D'Alonzo Classification [7] of odontoid fractures based on the anatomic location of the fracture (Figure 1):

3 types of C2 odontoid fractures:
Type I: An oblique fracture through the upper part of the odontoid process.
Type II: Fracture at the base of the odontoid as it attaches to the body of C2.
Type III: When the fracture line extends through the body of the axis.

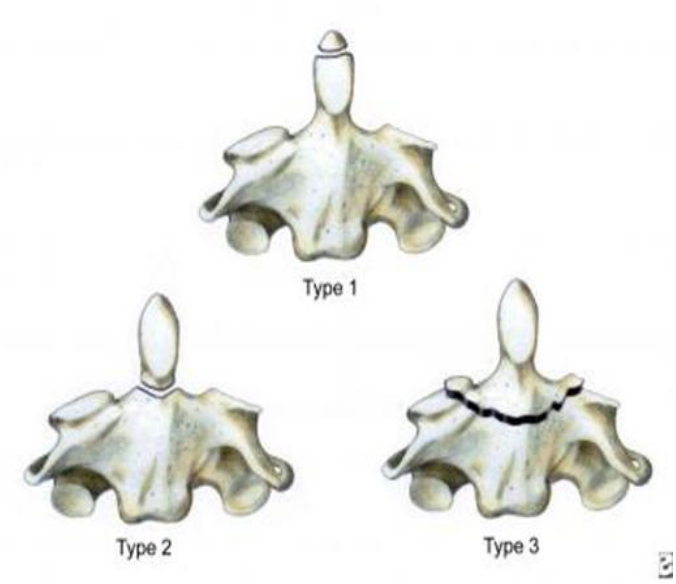

Fig 1: Anderson and D'Alonzo Classification of Odontoid Fractures.

A type I fracture is seen is less than 5% of cases. It is defined as an oblique fracture through the upper part of the odontoid process. Due to traction forces applied to the apical and / or alar ligaments, and its subsequent injury, the Type 1 fracture is associated with gross instability occasionally. This fracture is an avulsion injury of the tip of the odontoid process and is stable. But, if there is a bilateral avulsion of the alar ligaments in Type 1 odontoid fractures or if there is the presence of a contralateral occipital condyle fracture, the type 1 fracture can permanently cause an unstable occipital - cervical dislocation [8, 9].

A Type II fracture is seen in more than 60% of the cases. It occurs at the base of the odontoid between the level of the transverse ligament and the C2 vertebral body. It is relatively unstable and is the most common type of odontoid fracture [8, 9].

A Type III fracture is seen in about 30% of the cases. It extends into the vertebral body and are relatively stable unless severely displaced [8, 9].

The Classification systems are helpful to decide the type of treatment to be chosen. The Type I and Type II fractures can be managed conservatively by immobilization with a collar or a halo [10, 11], or surgically by anterior or posterior fixation [12 - 14]. However, the treatment of Type II fractures yet does not have a definite general agreement. The rate of union of the fractures is negatively affected by age of the patient, the extent of fracture displacement, commination of the fracture and delay in diagnosis [15]. The decision to be made as to what treatment needs to be chosen becomes difficult when a Type II fracture extends inferiorly to consider a Type III fracture. Such intermediate fractures have been referred to as ‘shallow’ or ‘high’ Type III fractures. Therefore, these fractures are considered to be in a grey zone between Type II and Type III fractures, for which some surgeons advice fixation as the choice of treatment [14]. Thus, this difference in opinion leads to confusion.

For this limitation, in order to distinguish Type II fractures from Type III fractures, more precise definitions have been suggested [11]. Type II fractures are those in which the fracture is present between the inferior aspect of anterior C1 ring with no extension into the superior articular facets of C2. Hence, oblique fractures in the anterior / posterior plane with minimum C2 vertebral body extension and no involvement of the C2 facet are considered as Type II fractures. But, if the fracture extends to atleast one of the superior articular facets of C2, it is considered as a Type III fracture [16].

Another limitation of the Anderson and D’Alonzo Classification is a lack of distinction between the wide range of morphologies of the fractures and their associated treatment considerations. To address this limitation, Hadley *et al.* [17] introduced a subclass of Type II fracture which he named as Type II-A fracture which is defined as a Type II fracture complicated by an additional chip-fracture fragment at the anterior or posterior aspect of the odontoid. This type of fracture was observed to progress to non-union regardless of the age of the patient, neurologic status or fracture displacement. Therefore, surgical intervention for such fractures was recommended.

However, there are many types of fracture patterns which are classified as Type II fractures. Grauer *et al.* [11] proposed a classification system for Type II fractures – Types II-A, II-B, II-C, (Figure 2), which is treatment oriented.

Type IIA is defined as a minimally or nondisplaced Type II fracture with no com-
minution. These fractures are generally treated with external immobilization.

Type IIB is a displaced fracture extending from anterior-superior to posterior-inferior, or a transverse fracture. These fractures are to be treated with anterior screw fixation following fracture reduction, assuming adequate bone density.

Type IIC is a fracture line extending from anterior-inferior to posterior superior or a fracture with significant comminution. These fractures are generally treated with posterior atlantoaxial stabilization.

Type II
Subclass A
(Nondisplaced)

Type II
Subclass B
(Displaced transverse or
ant superior to post inferior)

Type II
Subclass C
(Comminuted or
ant inferior to post superior)

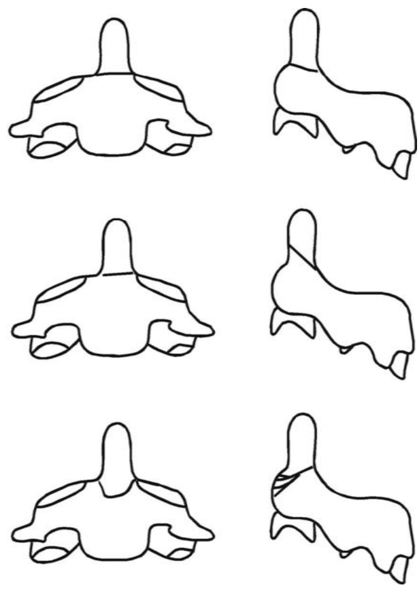

Fig 2: Classification of Type II fractures by Grauer *et al.*

Treatment

As already described, there are many different types of odontoid fractures and each type of fracture has its specific treatment options and considerations. However, there are general treatment considerations which have to be followed. The medical comorbidities of the patient is the most important consideration for developing a treatment plan. Elderly patients are more prone to these fractures and the older population is generally associated with decreased bone density, does not tolerate halo immobilization well and surgical intervention is less effective. These limitations therefore, alter the decision making of the treatment choice in the older population. It has been proved that when these fractures in population less than

40 years of age are compared with population older than 65 years of age, following treatment, there was earlier mortality by 35% in the elderly population [3, 5, 18, 19, 20]. Chronic medical conditions like Diabetes Mellitus, Hypertension, Coronary Artery Disease, Rheumatoid Arthritis, etc. have not beem noted to be directly associated with increase in mortality, though comparative information on this is limited [21]. To find the right balance between fracture healing and treatment complications, many factors need to be taken into account, as mentioned earlier.

Treatment Options

Type II and Type III fractures can be conservatively managed by rigid immobilization with halo vest or Minerva vest, or non-rigid immobilization with cervical collar or cervico-thoracic orthosis.

1. External Immobilization

Type II and Type III fractures can be conservatively managed by rigid immobilization with halo vest or Minerva vest, or non-rigid immobilization with cervical collar or cervico-thoracic orthosis.

For Type II fractures, if collar immobilization is chosen as a treatment option, occipital-cervical dislocation needs to be excluded as a rule. This can be noticed effectively on a sagital reformatted CT to assess the alignment of the facets/occipital condyles or ny MRI to observe any edema at the occipital-cervical junction [22]. A posterior occipital-cervical fusion is performed if these findings are observed [23-26]. Occipital-cervical dislocations are mostly stabilized surgically. However, halo vest immobilization is considered if the neurologic status of the patient is intact. This is however, not a definite treatment, and close monitoring is definitely required [27].

Collar immobilization can be chosen for treatment of Type III fractures, although, immobilization with a halo vest may also be considered [15, 28-31]. Nonetheless, if Type III fractures are associated with anterior displacement, in order to prevent further displacement and to achieve stability, internal fixation may be required. Also, 'shallow Type III' fractures function more like Tye II fractures and need internal fixation and stabilization [32].

Type II odontoid fractures are generally less stable. As compared to Type I and Type III fractures, the rate of union is lower in Type II fractures. Immobilization externally with a cervical collar has shown inconsistent results [29, 33]. The rates of non-union are higher in Type II fractures because of higher instability in the different patterns of this fracture. Decreased vascularity at the base of the odontoid leading to delayed or decreased healing potential may also be related to the higher non-union rates in this type of fractures [34]. Though a number of clinicians recommend halo vest immobilization for Type II odontoid fractures [33], but, this choice of treatment is associated with a significant rate of non-union observed in a number of series, between the range of 26% to 80% [18,35,36, 29,32,37-40]. There are many factors which are associated with increased non-union of Type II odontoid fractures, like, displacement of posterior fracture, a displacement of 4-6 mm and an angulation of 10 degrees, fracture comminution, mal-alignment of fracture during follow up, delayed treatment, and patients older than 40-65 years [31, 38, 41, 42]. It has been shown in many epidemiological and retrospective studies that the elderly population has higher prevalence of type II odontoid fractures [18, 19, 20, 43]. This fact makes it of particular concern as treating Type II odontoid fractures with external immobilization has increased incidence of non-union [20,33,44,45]. Therefore, primary internal fixation has been suggested in elderly patients with Type II odontoid fractures [20, 33, 44, 45]. Multiple studies have been performed which have documented higher rates of complications like decreased tolerance in the elderly patients, unstable pin fixation and Broncho pulmonary difficulty. Also, external immobilization such as a halo vest is not a good treatment option. Complications like poor maintenance of reduction, wound infection, pneumonia, Cerebra Spinal Fluid leakage and even death, have been reported. After external immobilization, if a stable non-union is achieved, the treatment becomes controversial. Surgical stabilization to prevent a potential catastrophic decline with a traumatic event may be considered in young patients. In the elderly population, however, this may pose to be an acceptable risk [38] against the rate of morbidity due to surgical intervention.

2. Posterior Odontoid Stabilization

When external immobilization is ineffective, insufficient or intolerable, surgical intervention needs to be considered to treat odontoid fractures. In conditions in which a patient has neurological deficit or a poly-trauma patient, this treatment comes into play. The main goal of a posterior approach is to achieve a solid fusion between C1 and C2. The main disadvantages of this approach are: loss of rotational motion after fusion at this cervical level and the morbidity associated with this approach [46]. There are a number of techniques available for stabilization of odontoid fractures by the posterior approach. There has been a gradual evolution of techniques from wire constructs to screw constructs which are more stable. The first posterior C1-C2 wiring technique was described by Galie [13]. In this technique, a single central wire was placed in the sublaminar position, under the C1 ring and around the C2 spinous process. The wire thus, provided stability and helped to secure a structural autograft in position. Later, another wiring technique was devised by Brooks and JERKINS [14] in which bilateral sublaminar C1-C2 wires with two structural autograft blocks were used (one on each side). The Brooks construct was biomechanicaly [4] times more stable than the Gallie fusion. Though this technique was proven to achieve effective internal ixation of odontoid fractures with higher fusion rates as compared to non-operative treatment [28, 42, 47] this technique has many disadvantages such has higher risk of injury to the spinalcord during passage of the sublaminar wires and inability to use this technique in cases of concurrent C1 arch fractures. The use of transarticular screws is an alternative method of C1-C2 stabilization [48]. In this procedure, the upper cervical spine is posteriorly exposed, screws are placed percutaneoulsy along the isthmus of C2 and into the lateral mass of C1. The placing of the screws percutaneously allows an appropriate screw trajectory. In this procedure, an adjunctive posterior wiring fixation is combined. On biomechanical point of view, there has been a ten times increased rotational stiffness and lateral bending stiffness in transarticular screw fixation compared with that of the posterior wiring techniques [49,50]. As compared to a halo vest, because of the increased stability, these patients are treated with a collar after surgery. By this protocol, the rates of fusion have almost approached to a 100% [16, 48, 51, 52]. There, however, are many limitations to this procedure- adequate reduction of C1 on C2 prior to placement of the screw, risk of injury to the vertebral artery and severe bleeding from C2 pedicle surrounding dissection [53]. For consideration of transarticular screws, an evaluation of CT scan preoperatively should be done to have sure that an appropriate and safe screw trajectory exists. This can be evaluated by parasagittal CT images. In order that the limitations of transarticular screw fixation can be avoided, Harms and Melcher [53] proposed another technique of screw fixation using posterior C1 lateral mass and C2 pars polyaxial screws. In this technique, after the placement of the screws, adjustment of C1 reduction relative to C2 can be done before application of a short rod contruct for securing the screws.This procedure had no neurological, vascular or implant complications, and produced a fusion rate of 100%.On comparing the biomechanics of this procedure with bilateral C1-C2 transarticular screws, there was a significantly decreased motion in axial rotation as well as in lateral bending in both the procedures [54]. In addition, there have been no other significant differences between the transarticular screw fixation and the Harms and Melcher methods.

3. Anterior Odontoid Fixation

The posterior techniques for odontoid stailization is commonly needed for C1-C2 fusion, but, this causes the elimination of about 50% of cervical rotation [46]. For this reason, an alternative technique for the stabilization of Type II odontoid fractures has been developed. This is named as the direct osteosynthesis with anterior screw fixation [15, 46]. Though the complete motion of C1-C2 is preserved or no still remains a question 70. The direct anterior odontoid fixation was first described by Bohler in 1982 [15], which has later on been modified. Prior to surgery or intra operatively, the fracture has to be reduced. Around the C5-C6 level, a standard low cervical approach is made. In order to allow access to the C2-C3 disc space, the prevertebral plane is then developed. The entry point of the screw is at the anterior-inferior corner of the endplae of C2, and this step is crucial in deciding the success of this technique. To ensure an adequate trajectory of the screw, which is very important, an entrance is made through the C2-C3 disc space; although it is ideal to preserve the C2-C3 disc space. Specially designed retractors and biplanar fluoroscopy would be helpful in this process. Initially, two screws were suggested, however, there has been no significant difference in non unin rates or biomechanical stability between the use of one or two screws [40, 55] .Also, it is difficult to safely place two screws in a single odontoid. Therefore, for this procedure, only a single screw is recommended [55]. Compared to the posterior fixation, the anterior approach has many distinct advantages. As already mentioned, the motion of C1-C2 is spared in the anterior approach. This technique does not require a bone graft, is less traumatic, and thus, decreases postoperative morbidity. This method can also be used to treat concomitant C1 ring fractures, provided the transverse ligament is intact. Nonetheless, there are some conditions when the anterior fixation cannot be used. Geometry of the fracture is one such condition. This technique can be used only for Type II odontoid fractures which are reducible and have correct obliquity in order to allow compression across the fracture region and to avoid displacement with lag screw fixation (Grauer *et al* Type II-A injuries, previously described) [56]. Also, this approach should not be used in an osteoporotic bone, a pathological fracture, or cases of non-union; as fixation of screws and/or fracture healing will be impaired. Hence, in the older population, as the bones will be osteoporotic, the anterior approach should not be used and posterior approach would be a better option. Patients with short and thick necks, and with thoracic or cervical kyphosis; the appropriate trajectory for placing the screws may not be achieved. Inspite of all these contraindications, it has been documented by multiple clinical studies that the rates of fusion of odontoid fractures after the anterior fixation technique range between 83% to 100%, for the patient who has been appropriately selected [11, 12, 32, 51, 57].

Conclusion

Odontoid fractures, commonly seen in the elderly population, have been posing a challenge in the clinical practise. There are different types of odontoid fractures. Type I and Type II fractures have been able to be treated with simple collar immobilization. But, Type II fractures have created a lot of controversy on deciding the type of treatment to be chosen. Though there have been advances in the types of fixation techniques, yet, there is no ideal treatment option for the different odontoid fractures to be treated. The lack of consensus on the ideal treatment option for odontoid fractures potentially reflects the reality that these fractures pose to be a serious clinical problem. Because of this reason, a definite decision cannot be made for treating this type of fracture. This fact was highlighted in a study in which 35 experienced spine surgeons were made to answer a questionnaire regarding the specific treatment of different spinal injuries [56]. Though there was a lot of commonality in the treatment options for the majority of spine injuries, a Type II odontoid fracture would be treated by the anterior approach by 50% of the spine surgeons questioned and by posterior approach by the remaining 50%. As of now, there have not been well controlled trials and studies to describe the true merits and demerits of the different treatment options; and hence, no single ideal universal treatment option is yet proved for the treatment of mainly Type II ododntoid fractures.

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