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Technical Notes

Determination and optimization of ideal patient candidacy for anterior odontoid screw fixation

Brian Fiani[1], Thao Doan[2], Claudia Covarrubias[3], Jennifer Shields[4], Manraj Sekhon[5], Alexander Rose[6]

[1]Department of Neurosurgery, Desert Regional Medical Center, Palm Springs, California, [2]University of Texas Medical Branch at Galveston, Galveston, Texas, United States, [3]School of Medicine, Anahuac Querétaro University, Santiago de Querétaro, México, [4]College of Human Medicine, Michigan State University, East Lansing, Michigan, [5]William Beaumont School of Medicine, Oakland University, Rochester, Michigan, [6]School of Medicine, University of New Mexico, Albuquerque, New Mexico, United States.

E-mail: *Brian Fiani - bfiani@outlook.com; Thao Doan - tmdoan@utmb.edu; Claudia Covarrubias - claud.cova@gmail.com; Jennifer Shields - shield68@msu.edu; Manraj Sekhon - msekhon@oakland.edu; Alexander Rose - msekhon@oakland.edu

***Corresponding author:**
Brian Fiani, D.O.
Department of Neurosurgery, Desert Regional Medical Center, Palm Springs, California, United States.

bfiani@outlook.com

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ABSTRACT

Background: Odontoid process fractures are one of the most common spine fractures, especially in patients over age 70. There is still much controversy over the ideal candidate for anterior odontoid screw fixation (AOSF), with outcomes affected by characteristics such as fracture morphology, nonideal body habitus, and osteoporosis. Therefore, this systematic review seeks to discuss the optimal criteria, indications, and adverse postoperative considerations when deciding to pursue AOSF.

Methods: This investigation was conducted from experiential recall and article selection performed using the PubMed electronic bibliographic databases. The search yielded 124 articles that were assessed and filtered for relevance. Following the screening of titles and abstracts, 48 articles were deemed significant for final selection.

Results: AOSF is often utilized to treat Type IIB odontoid fractures, which has been shown to preserve atlantoaxial motion, limit soft-tissue injuries/blood loss/vertebral artery injury/reduce operative time, provide adequate osteosynthesis, incur immediate spinal stabilization, and allow motion preservation of C1 and C2. However, this technique is limited by patient characteristics such as fracture morphology, transverse ligament rupture, remote injuries, short neck or inability to extend neck, barrel chested, and severe spinal kyphosis, in addition to adverse postoperative outcomes such as dysphagia and vocal cord paralysis.

Conclusion: Due to the fact that odontoid fractures have a significant morbidity in elderly population, treatment with AOSF is generally recommended for this population with higher risk for nonoperative fusion. Considerations should be made to achieve fracture stability and fusion, while lowering the risk for operative and postoperative complications.

Keywords: Cervical fusion, Odontoid fracture, Odontoid screw fixation, Spinal fixation, Traumatic spinal injury

INTRODUCTION

Anterior odontoid screw fixation (AOSF) is a cervical spine surgical procedure that usually utilizes an anteromedial approach to implement one or two screws for fusion of primarily Type II odontoid fractures.[31] Being the most common cervical spinal fracture for patients over age 70, and the most common spinal fracture for patients above 80,[14] odontoid fractures make up over 20% of all fractures of the cervical spine, and within this, 65–74% are Type II fractures.[4,43] The Anderson and D'Alonzo classification system is the most common, which characterizes odontoid fractures

based on anatomic location. Type I fractures are rare and stable occurring on the apex of the odontoid process, while Type III fractures are through the body of the axis and are sometimes unstable. Type II fractures are the most common and produce atlantoaxial instability occurring at the base, with much remaining controversy surrounding the ideal treatment for Type II fractures.[4]

Approaches to intervention for odontoid fractures have varied from nonoperative management with cervical collar, Minerva, cervicothoracic orthoses, and halo orthosis to operative management such as AOSF or posterior atlantoaxial stabilization.[12,13] Introduced in 1980 by Nakanishi[41] and Bohler,[6] anterior screw fixation has gained prominent acceptance as an osteosynthetic cervical procedure providing immediate spinal stabilization, motion preservation of C1 and C2, and quickened return to normal activities of daily living.[13,17] Grauer *et al*. proposed a modified classification system for odontoid fractures, stratifying Type II fractures. Within this classification, AOSF has been the surgical treatment of choice for Type IIB odontoid fractures, which pass from anterior superior to posterior inferior or displaced transverse fractures >1 mm.[20]

However, different parameters must be considered for predicting success of fusion for Type 2 odontoid fractures utilizing the anterior screw fixation approach. For example, displacement <4 mm and those >6 mm have been associated with improved and lowered fusion rates, respectively.[22] Children appear to have better fusion with halo immobilization versus adults who fare poorly with external immobilization.[19] In a multicenter prospective, geriatric, and odontoid fracture GOF study, they found increasing age, nonoperative treatment, male gender, and neurological comorbidity as factors for dying, 9.5-point drop in NDI scores, and major complications.[15] Anatomic considerations such as the degree of displacement, angulation, anatomical location of the fracture, and body habitus, in addition to postoperative outcomes such as dysphagia, voice hoarseness, pneumonia, and others need to be considered.[20,48] Therefore, this review seeks to examine the indications, ideal patient candidates, and potential adverse complications when deciding to pursue AOSF and provide adequate patient counseling.

PATIENT SELECTION

Determination of appropriate surgical candidates for AOSF must take into account many individual, clinical, and radiological features. Based on current literature, a proposed algorithm for the patient selection process [Figure 1] has been constructed to guide treatment in conjunction with clinical judgment. Odontoid fracture morphology, including fracture type, comminution, fracture gap, fragment angulation, odontoid

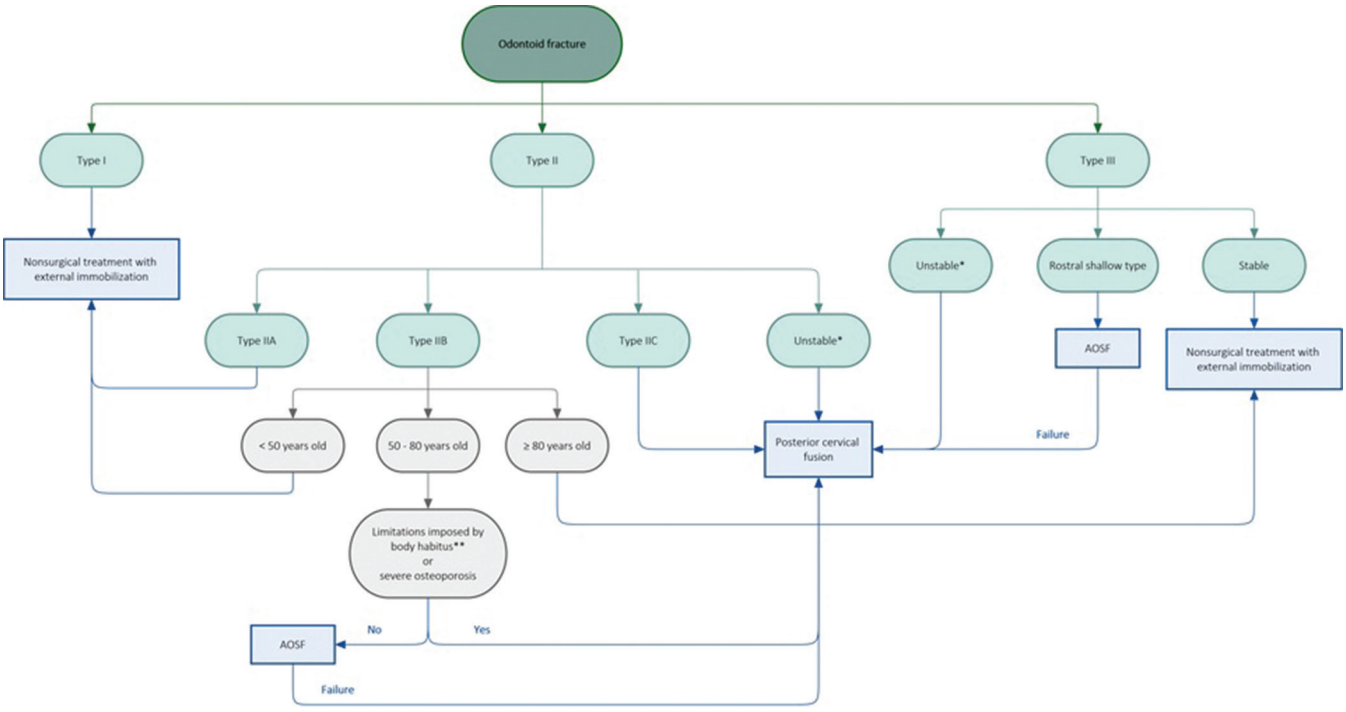

Figure 1: Proposed algorithm for the patient selection process to guide treatment of odontoid fractures for use in conjunction with clinical judgment. *Criteria of instability: fracture age greater than or equal to 6 months post-injury, fracture comminution, concomitant disruption of transverse ligament, nonreducible or malaligned fracture, dens displacement greater than or equal to 6 mm, angulation greater than or equal to 10 degrees, or fracture gap greater than or equal to 2 mm. **Criteria for body habitus limitations: fixed cervical or thoracic kyphosis, short neck, or barrel-shaped chest imposing restrictions for proper patient positioning and anterior neck access in AOSF. AOSF, Anterior odontoid screw fixation.

displacement, and preservation of adequate reducibility and alignment, affects the union rate and, therefore, the type of treatment proposed.[4,8,20,28] Based on the odontoid fracture classification systems proposed by Anderson and D'Alonzo, as well as Gauer *et al*., which take into account fracture line anatomy, angulation, displacement, and comminution, Type I fractures that maintain occipital-cervical stability, stable Type III fractures, and Type IIA minimally or nondisplaced fractures are effectively treated with external immobilization, such as a hard cervicothoracic orthosis or halo-vest rigid bracing.[4,5,8,12,20,25,28] Halo-vest immobilization can successfully be utilized in patients under 50 years of age with no other known risk factors for nonunion; however, patients ≥50 years old have higher complication rates and significant risk for nonunion with halo-vest treatment.[13,34] In patients over the age of 50 and under 80, Type IIB fractures that are displaced and extend anterosuperior to posteroinferior, transverse fractures, or rostral shallow Type III fractures qualify for AOSF.[5,8-10,13,16,20,34] Type II odontoid fractures in patients 80 years and older are associated with significant morbidity and mortality irrespective of operative or nonoperative management.[25,44,46] The outcomes of conservative treatment have fewer complications to that of surgical repair and are, therefore, often the preferred option. In the 80 or older patients, it has been shown that halo-vest immobilization poses a risk for increased morbidity and mortality with worse outcomes to internal fixation.[8,13,25,34,39,44,46] Therefore, treatment preference for patients ≥80 years old is a rigid cervical collar.[25,39,44,46] However, posterior cervical fusion may still be performed to increase stability and prevent prolonged immobilization.[8,13] In contrast, posterior internal atlantoaxial fixation and fusion are indicated for Type IIC fractures that extend anteroinferior to posterosuperior, comminuted fractures, concomitant disruption of the transverse ligament, fractures that are nonreducible or do not maintain adequate alignment, and as a salvage procedure for inadequate healing following conservative treatment or AOSF failure.[5,8,10,13,20-22,25,28,29,33,36,40] Displacement of the dens of ≥6 mm and angulation of ≥10° has been associated with a higher rate of nonunion after conservative treatment, as well as AOSF surgical failure, and, thus, is also indications for posterior surgical treatment.[12,20,22,24,25,28,44] Additional risk factors for AOSF surgical failure include fracture age postinjury of 6 months or greater, as the chance of success for stabilization and osteosynthesis decreases, as well as a fracture gap of >2 mm.[5,8-10,29,33] In these cases, posterior cervical instrumented fusion is the preferred treatment approach, providing more rigid stability for higher union rate, in contrast to external immobilization.[5,8,29,33]

Beyond age, other patient factors, such as comorbidities and functional dependence, bone quality, and especially body habitus, may influence medical suitability for surgery and postoperative outcome and, thus, should be considered when performing a clinical assessment to determine the best treatment approach for odontoid fractures. In patients with significantly reduced bone mineral density, strength, and healing potential, as seen in patients with severe osteoporosis, attaining adequate fixation and fusion are challenging and considered a contraindication given the high possibility for nonunion.[1,8,23,29,40] Body habitus must also be heavily considered, as obesity and structural deformities can impose limitations that may interfere with surgical execution and outcome. A fixed cervical spine with inability to impose neck extension or moderate-to-severe thoracic kyphosis, a short neck, or a barrel-shaped chest restricts proper patient positioning and access to the anterior neck, contraindicating AOSF as a surgical approach.[1,5,8,10,13,27,29]

Postoperative complications may occur as a result of surgical technique that has the potential to affect quality of life. Primarily, these are dysphagia or inability to swallow, as well as damage to the recurrent laryngeal nerve, causing dysphonia or vocal cord paralysis.[7,11,13,18,29,47,48] Although these complications are more commonly seen in elderly patients, it is necessary to weigh the benefits against the risks of the procedure and to consider additional, individual parameters in a case-by-case manner, such as the patient's career type. A chef requires the ability to sample food, while a singer necessitates a voice to harmonize; in these circumstances or similar where there are concerns for postoperative complications, a posterior technique may be indicated instead.

BRIEF OVERVIEW OF TECHNIQUES

Patients are placed under general anesthesia and positioned supine on the operating table. Anterior-posterior and lateral fluoroscopy are used to visualize the C2 vertebral body, odontoid process, and lateral masses of C1. Reduction is achieved using skull traction and flexion or extension maneuvers to position the head before stabilizing with a halter and assessing with fluoroscopy. The C5-6 level is identified and marked using the thyroid and cricoid cartilage preoperatively, then a transverse skin incision is made. The standard Smith-Robertson method is used to expose the prevertebral space by retracting the carotid sheath laterally and the trachea and esophagus medially. The anterior-inferior margin of C2 is exposed, and a Kirschner wire is drilled down the anterior-inferior edge of C2 to the midline of the dens on the opposite apical cortical bone using fluoroscopy. A guide wire is inserted centrally then a cannulated screw is inserted along the guide wire into the C2 body and posterior odontoid process. Fluoroscopy is used to confirm spinal stability.[30,33,37,45]

Careful selection of patients is necessary for surgery success. The integrity and grade of atlantal transverse ligament damage must be assessed, because atlantoaxial stability cannot be achieved with a single odontoid screw fixation if the ligament is damaged.[45] In addition, the type of fracture is another important factor that can impact success rate. An anterior fixation surgery is indicated if a fracture line faces downward obliquely and posteriorly (from anterosuperior

to posteroinferior) but is contraindicated if the line faces downward and anteriorly. This is due to possible torsional forces when inserting the screw that may cause poor alignment. Good fracture alignment and reduction are important factors to consider, because unstable fractures can be easily relocated or displaced.[5,30] Patients with upper thoracic lordosis, cervicothoracic kyphosis, short necks, severe osteoporosis, late fractures, or cervical stenosis cannot be treated due to limited range of motion or instability in the bone.[30,45]

TRIALS, OUTCOMES, AND EFFECTIVENESS

Current available data have demonstrated that AOSF is a feasible treatment for Type II and shallow Type III odontoid fractures, providing immediate stabilization with high fusion rates and preserved C1-2 rotation [Table 1].[35] A systematic review and meta-analysis published in 2020 compared the outcomes of single-screw fixation through the anterior lip of the C2 vertebra to other techniques such as insertion through

Table 1: Overview of anterior odontoid screw fixation studies and outcomes

Study	Indication	Number of patients	Patient demographics	Number of screws	Reported complications	Radiological outcomes	Outcomes
Harrop *et al*., 2000[26]	Type II odontoid fractures	10	≥65 years old	8; single screw 1; two screws 0; one screw removed intraoperatively due to osteopenia	Two cases of pneumonia	88.9% fusion rate 11.1% nonunion	Odontoid screw fixation can be safely performed in elderly patients, and frequent bone union is demonstrated. However, osteopenia may preclude adequate screw fixation in some patients
Alfieri, 2001[3]	Acute Type II odontoid fractures	9	24–75 years old	9; single screw	One case of transient dysphagia	100% fusion rate	Internal screw fixation gives immediate direct fixation of the fracture, offers a high rate of fusion without requiring prolonged halo immobilization, it gives a reduction of the cervical pain and preserves the normal mobility of C1-C2
Lee *et al*., 2004[32]	39 Type II odontoid fracture 9 rostral Type III fracture	48	16–78 years old	48; single screw	Three cases of screw malposition one case of screw cutout x	95.8% fusion rate 4.2% nonunion	Fixation technique was associated with a relatively high fusion rate and low complication rate for the management of acute Type II and rostral Type III odontoid fractures. Single-screw cutout event was attributed to inappropriate patient selection
Agrillo *et al*., 2008[2]	9 remote Type II axis fractures y	9	≥65 years old	9; single screw	Two cases of residual cervicalgia	77.8% fusion rate 11.1% stable fibrous fusion 11.1% nonunion	The technique appears to be feasible for remote axis fractures within 12 months of trauma, and it seems to be safe for elderly patients
*Lin *et al*., 2014[35]	29 Type II odontoid fracture Three rostral Type III fracture	32 (17 randomized to AOA group)	17–65 years old	17 (AOA); single screw	Three cases of transient dysphagia (AOA group)	100% fusion rate	Microendoscopic discectomy system for odontoid fracture treatment with cannulated screw is a safe, reliable, and minimal invasive procedure compared with traditional open surgery. Transient dysphagia symptoms resolved spontaneously within 1–3 months

*Randomized clinical trial, x Type II odontoid fracture, y Delayed fixation at ≥6 months after the trauma. AOA: Anterior open approach screw fixation

the C2 lower endplate in an indented point from the anterior edge of the C2 body. This study pooled a total of 83 articles and revealed a significant advantage with single-screw fixation. The authors concluded that the development of screw-related complications did not depend on the method of intraoperative head fixation, selection of the implant entry point for odontoid screw fixation, type of the used screws, or cannulated instruments application.[38] In [Table 1], we summarize a selection of studies that have been conducted particularly on AOSF and their outcomes.[2,3,32] Notably, only one of those clinical trials was randomized.

Higher incidence of nonunion is observed in both fractures that are displaced by more than 6 mm, particularly posteriorly, as well as in geriatric patients.[26] Finally, there are certain fracture patterns that do not allow interfragmentary compression using one or two screws. These fracture patterns include Type II odontoid fractures with anterior oblique fracture lines, comminuted fractures, or pathological fractures of the odontoid seem to be unsuitable for anterior screw fixation. In these fracture patterns, Platzer *et al*. recommended the techniques of posterior atlantoaxial arthrodesis and posterior transarticular screw fixation as favorable treatment options for operative stabilization.[35,42]

CONCLUSION

AOSF requires appropriate patient selection to minimize morbidity, maximize fusion rates, and avoiding reduction of range of motion. Because odontoid fractures have a significant morbidity in elderly population, treatment with AOSF is generally recommended for this population with higher risk for nonoperative fusion. Contraindications of anterior screw fixation mentioned in the literature include short neck, concomitant thoracic kyphosis, severe osteopenia, barrel chest deformity, disrupted transverse atlantoaxial ligament, and significant cervical kyphosis. Other factors that can be considered as contraindications include an unfavorable fracture plane angulation from anterior caudal to posterior rostral and inability to obtain an anatomical fracture reduction. Considerations should be made to achieve fracture stability and fusion, while lowering the risk for operative and postoperative complications especially those in relation to functionality and quality of life. Future studies, in particular randomized controlled trials and observational studies with larger patient sample size, should be conducted to further clarify appropriate patient selection and operative technique.

Declaration of patient consent

Patient's consent not required as there are no patients in this study.

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Conflicts of interest

There are no conflicts of interest.

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