Avoiding pitfalls in anterior screw fixation for Type II odontoid fractures

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Anterior screw fixation of Type II odontoid fractures provides immediate stabilization of the cervical spine while preserving C1–2 motion. This technique has a high fusion rate, but can be technically challenging. The authors identify key points that should be taken into account to maximize the chance for a favorable outcome. Keys to success include proper patient and fracture selection, identification of suitable screw entry point and correct screw trajectory, achieving bicortical purchase, and placing 2 screws when feasible and applicable. The authors review the operative technique and present guidance on appropriate patient selection and common pitfalls in anterior screw fixation, with strategies for avoiding complications. (DOI: 10.3171/2011.7.FOCUS11135)

Key Words • anterior odontoid screw fixation • odontoid fracture • complication

Ondontoid fractures account for 5%–15% of all cervical spine injuries and are seen more frequently in elderly patients. Anderson and D’Alonzo’s Type II fractures—at the base of the dens—are the most common odontoid injury and produce atlantoaxial instability. Such fractures compromise the integrity of the atlantoaxial complex, allowing abnormal movement that may result in compression of the cervical spinal cord and possible spinal cord injury. Nonoperative management with immobilization in a rigid brace or halo vest is associated with high morbidity and significant failure rates, particularly in high-risk populations. Several surgical stabilization options are available; however, there is no consensus on the best treatment management. Posterior atlantoaxial fusion techniques, such as placement of C1–2 transarticular screws, have a high fusion rate; however, these options can be technically demanding. Furthermore, fusion of the atlantoaxial complex, which provides the largest amount of rotation in the cervical spine, restricts this movement more than 50%. In contrast, direct anterior screw fixation provides immediate stability, relatively high rates of fracture healing, and preserved C1–2 motion. We review this operative technique and present guidance on appropriate patient selection and common pitfalls of anterior screw fixation, with strategies for avoiding complications.

Abbreviations used in this paper: TAL = transverse atlantal ligament; VB = vertebral body.

Surgical Technique

Anterior screw fixation of odontoid fractures is typically completed via an anterior retropharyngeal approach. This technique has been previously described in detail by Apfelbaum et al. Presurgical positioning and planning is critical for optimal screw placement. The patient is positioned supine on the operating table and placed in cervical traction to maximize fracture reduction, which is confirmed by fluoroscopy. An incision is made at the C-5 level along a natural skin crease. Dissection is completed carefully through anatomical tissue planes to the anterior aspect of the C-5 and C-6 VBs. Blunt dissection is continued in the retropharyngeal space to fashion a tunnel to the C-2 VB. A self-retaining retractor system is then positioned to facilitate rostral retraction. Under fluoroscopic guidance, a K-wire is inserted into the inferior aspect of the C-2 VB, with entry planning based on whether 1 (midline entry site) or 2 (paramedian entry sites) odontoid screws will be used. A hollow, 8-mm, hand-rotated drill is placed over the K-wire to burrow a path through the face of C-3 and the C2–3 disc space to the inferior aspect of the anterior lip of C-2. The drill guide system is then placed over the K-wire, and the outer guide tube is firmly set into C-3. This allows for gentle manipulation to align the C-2 and C-3 vertebrae relative to the odontoid and C-1 for an accurate screw trajectory. The K-wire is removed and replaced by the drill bit. The site is drilled and tapped, and a lag screw of appropriate length is placed.
All critical maneuvers should be monitored closely by using biplanar fluoroscopy (Fig. 1). After screw placement, dynamic flexion and extension fluoroscopic images should be obtained to confirm atlantoaxial stability.

Alternatives to and variations on the above approach for anterior fixation of odontoid fractures have been described. Image guidance in combination with neuronavigation provides an alternative to fluoroscopy for real-time intraoperative data acquisition and accurate placement of instrumentation. Technical reports have been published on minimally invasive surgery, including endoscopic and percutaneous techniques. The theoretical advantages of a minimally invasive procedure include the following: reduced operating time; less surgical exposure, manipulation of soft tissues, and blood loss; and better preservation of anterior anulus, disc, and bone. These techniques, however, are technically challenging. Because the percutaneous procedure is performed without direct visualization, familiarity with cervical anatomy is vital for avoiding injury to soft tissues during drilling and tapping. Endoscopically assisted surgery provides operative field visualization with a small skin incision, but evidence on the efficacy of using an endoscopic approach is lacking. Moreover, neither percutaneous nor endoscopic techniques allow for drill guides that can be affixed to the spine, thereby limiting manipulation of the C-2 VB for alignment of fracture fragments.

**Patient Selection**

Anterior screw fixation of odontoid fractures provides a much higher rate of fusion (82%) than nonoperative management with a rigid cervical collar (51%) or halo vest (65%). Patients in whom anterior fixation fails often have similar injury types, baseline characteristics, and courses of disease progression; thus, careful patient selection can ensure better outcomes. The following factors have been associated with poor outcomes after anterior screw placement.

**Morphological Features of the Fracture**

Anterior odontoid screw placement is ideal for a Type II fracture that courses obliquely from the anterosuperior to the posteroinferior portion of the dens, because the screw can be inserted perpendicular to the fracture. This fracture pattern is classified as a Grauer Type IIB injury. An oblique fracture line from posteroinferior to anterosuperior that would parallel screw trajectory is a contraindication to anterior fixation, because interfragmentary compression by the odontoid screw cannot occur. Some authors have also cautioned against anterior screw fixation for oblique fracture lines in the coronal plane, because tightening of the lag screw could cause lateral drifting of the apical fragment, resulting in atlantoaxial incongruency.

Bone quality at the fracture site should also be taken into account, because Type II odontoid fractures may be physiologically prone to poor healing. Cancellous bone heals faster than cortical bone, and fractured trabeculae are the sites for fracture repair. The base of the odontoid process is hypodense and contains 55% fewer trabeculae than the axis and the odontoid process itself. Patients with severe osteoporosis, comminution of the fracture, additional fractures of the body of C-2, or Type II odontoid fractures with severe angulation and displacement that cannot be completely reduced preoperatively may have insufficient bone quality to maintain screw fixation, and are poor candidates for anterior screw placement (Fig. 2). Proximal screw pullout and repeated fracture displacement...
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in osteoporotic individuals have been reported.\textsuperscript{1,56} Aebi et al.\textsuperscript{1} described anterior screw migration into the spinal canal in a patient with osteopenic bone that collapsed after odontoid screw placement. Apfelbaum et al.\textsuperscript{7} reported that screw pullout from the body of C-2 prior to development of fusion was the most common hardware-related failure, occurring in 5 of 117 patients. Each of these patients had a fracture extending into the body of C-2, and the authors recommended avoiding anterior fixation in patients with evidence of comminuted C-2 VB fractures.

Anatomical Considerations

Patient anatomy may preclude successful anterior screw fixation. It is critical that the patient’s body habitus allows for a direct screw trajectory that follows the curvature of the spine. Those with a barrel chest, short neck, subaxial cervical spondylolisthesis, or severe thoracic kyphosis may have anatomy that would impede appropriate drill and screw placement (Fig. 3). Perioperative positioning before surgery requires placing the patient in traction to extend the cervical spine and using fluoroscopy both to visualize fracture reduction and to verify an unimpeded trajectory for screw insertion. Such cervical manipulation may cause injury in some patients. Patients with severe spinal canal stenosis, such as those with posterior osteophytes of the cervical vertebrae, may be poor candidates for anterior screw fixation, lest placing the patient in the amount of cervical lordosis necessary for screw placement cause injury to the cervical spinal cord.\textsuperscript{31}

Some patients may have concomitant injuries at the atlantoaxial junction for which motion preservation would not be favorable. For example, injury to the C1–2 joints and intraarticular fractures may cause painful posttraumatic arthritis, and the presence of an unstable Jefferson fracture would result in persistent C1–2 subluxation.\textsuperscript{31} In these cases, posterior C1–2 fusion is preferable to anterior screw fixation.

Chronic Nonunion

Immediate fixation of odontoid fractures provides the best chance of fracture healing. Nevertheless, nonunion of odontoid fractures is a relatively common complication in patients treated nonsurgically and those in whom the diagnosis was delayed. Many authors have reported nonunion rates of 40% or greater in patients without operative stabilization.\textsuperscript{30,35,38} Persistent atlantoaxial instability is the primary concern when odontoid fractures fail to heal and pseudarthrosis develops. Patients may present with C-2 nerve root pain, neck stiffness, radiculopathy, or myelopathic symptoms, such as weak hands and difficulty walking,\textsuperscript{13,46} although some experience no neurological problems at all.

Outcomes vary in patients who undergo anterior fixation after remote odontoid fractures. Aebi et al.\textsuperscript{1} reported screw fracture in a 20-year-old patient who presented with a 22-month-old nonunion of the dens. Agrillo et al.\textsuperscript{2} reported on a series of 9 patients who underwent anterior screw fixation for nonunited odontoid fracture 6–12 months after the traumatic event. Bone fusion was observed in 7 patients (77%) 4–16 months after fixation. One patient developed a stable fibrous union 14 months after surgery. Anterior fixation failed in 1 patient for whom 11 months had elapsed from the traumatic injury until surgical intervention. Fracture diastasis was observed in this patient 6 months after anterior fixation, and subsequent posterior stabilization was performed. Apfelbaum et al.\textsuperscript{7} evaluated 16 patients who underwent anterior fixation 18 or more months after injury, and reported a technical complication rate of 25%, which was considerably higher than that of patients with fractures less than 6 months old (9%). Three patients in this series experienced screw fracture (Fig. 4), and 1 patient had screw backout. Moreover, the anatomical fusion rate in patients with remote fractures was significantly lower (25%) than that in patients with recent fractures (88%). From these data, the authors concluded that the rate of successful bone fusion inversely correlates with the age of the fracture.

Incompetence of the TAL

Incompetence of the TAL results in atlantoaxial instability regardless of whether the odontoid process remains intact. The TAL provides the most anterior stability of all the components of the atlantoaxial complex. If the TAL is ruptured, the auxiliary ligaments usually are inadequate to prevent anterior subluxation of C-1 on C-2.\textsuperscript{20} In cases of Type II odontoid fracture, instability will persist even after successful bone fusion is achieved.\textsuperscript{24} Therefore, disruption of the TAL is a contraindication for anterior
screw fixation for odontoid fractures. The incidence of concomitant TAL disruption and odontoid fracture is low. In a study of 30 patients with odontoid fractures, Greene et al.\textsuperscript{24} reported a 10% incidence of TAL injury and advocated the use of MR imaging to assess TAL integrity as a part of the initial evaluation of all odontoid fractures. In a study of 77 patients with odontoid fractures, however, Sayama et al.\textsuperscript{26} reported no cases of atlantoaxial instability, and these authors recommended MR imaging screening only if patients present with neurological deficits or widening of the atlantodental interval greater than 3 mm on radiographs or CT scans.

Pathological Fracture

Reports of anterior fixation of pathological dens fractures describe high morbidity rates and poor outcomes.\textsuperscript{33,34,41,54} The consensus considers a pathological fracture to be a contraindication to odontoid screw placement.\textsuperscript{15,21} Metastatic tumors involving the upper cervical spine are rare, involving <1% of patients with spinal metastases.\textsuperscript{37} When metastatic disease occurs at the atlantoaxial spine, the most common location is at the junction between the dens and the axial body.\textsuperscript{42} Patients typically report severe neck pain secondary to spinal instability.\textsuperscript{9,57} Neurological deficits, however, are not common,\textsuperscript{4,42,49} which may be due to the increased size of the upper cervical canal compared with other spinal levels. After tumor removal, rigid fixation is difficult to achieve technically by using anterior fixation alone, and subsequent posterior stabilization is often required.\textsuperscript{54} Furthermore, the goals of care often differ in cancer patients and in those who have a traumatic odontoid fracture. Rather than aiming toward preservation of long-term atlantoaxial mobility, in patients with cancer the surgery is palliative, with goals of decreasing mechanical neck pain and preventing neurological deterioration.\textsuperscript{21} Cancer patients may have limited life expectancy, and many require adjuvant chemotherapy or radiotherapy that compromises the chance of a successful osseous fusion.

Avoiding Complications During Anterior Screw Fixation

Anterior screw fixation of odontoid fractures is a technically challenging operation, but when performed correctly, atlantoaxial stability is restored immediately, the likelihood of fracture healing is high, and patients maintain anatomical motion along the C1–2 axis. Common pitfalls include poor patient positioning, improper screw trajectory, and inadequate screw purchase. Intraoperative complications may result in hardware failure, inability to reduce the fracture, or persistent atlantoaxial instability. When anterior screw fixation fails, posterior cervical fusion is usually performed as a salvage operation. We discuss strategies to avoid these pitfalls and maximize the chance for a successful result.

Perioperative Positioning

Proper perioperative positioning is the foundation of successful odontoid screw placement. Care must be taken to extend the patient’s head as much as possible without causing repeat dislocation of the fracture. Poor head positioning and inadequate fracture reduction at the time of surgery create a propensity for posterior malalignment of the dens.\textsuperscript{1} Adequate extension of C-2 enables the screw trajectory to be directed accurately along the axis of the odontoid process. Improper positioning or poor patient body habitus may render screw insertion difficult or impossible. The presence of a direct trajectory must be verified under fluoroscopy before surgery is started. If satisfactory positioning cannot be achieved, the attempt at anterior screw fixation should be abandoned and posterior fusion of C1–2 should be performed.

The surgical technique we describe calls for the use of a specific drill guide that can be affixed to the spine. These drill guides have spikes that attach to the C-3 VB, thereby enabling the surgeon to manipulate the C-2 VB and align the fracture fragments to further optimize screw trajectory. Certain minimally invasive endoscopic and percutaneous techniques for odontoid screw placement have been described that aim to minimize surgical exposure. Although the theoretical advantages are favorable, including reduced operating time and less manipulation of soft tissues, such techniques do not enable the use of drill guides that can be affixed to the spine. Because they do not allow for the same extent of manipulation and fracture reduction that the technique we describe, which is performed using a C-3 VB–affixing drill guide, affords, we do not recommend minimally invasive approaches to anterior screw fixation.
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Selection of Screw Entry Point

Before establishing a screw trajectory, it is critical to identify the precise entry point. Entry should be placed under the anterior lip of C-2 and not on the anterior body of the vertebra. Incorrectly positioning screw entry at the anterior body of C-2 predisposes to screw breakout, screw pullout, loss of fracture reduction, and subsequent nonunion. Furthermore, this trajectory increases the likelihood for posterior angulation, fragment malalignment, persistent anterior fracture gap, and prolonged healing time. Placing the entry point too close to the anterior surface of C-2 also carries the risk of causing breakout of the K-wire, drill bit, or odontoid screw through the anterior VB. This would result in inadequate screw purchase, resulting in immediate abandonment of anterior fixation and conversion to a posterior fusion, or risk potential nonunion (Fig. 5).

Proper K-Wire Use

A K-wire is used in cannulated screw systems to direct screw trajectory accurately, enabling continuous fixation and avoiding migration of unstable bone fragments during screw insertion. Hollow tools and hollow screws are inserted into the bone over the K-wires and are advanced to the tip of the dens, but once the K-wire engages bone, its position cannot be altered without it being removed completely by reversing the drill direction and then reinserting it at a new entry point to define a new track. Manipulation of the drill guide with the K-wire engaged may create excessive torque, causing the K-wire to break. Dickman et al. described the technique of attaching the end-threaded K-wire to a reversible pneumatic drill to advance the tip of the K-wire into the dens. Others recommend using a noncannulated bit to drill through the cortex at the tip of the odontoid so that breakage of the K-wire is avoided and the K-wire cannot be captured by the drill and driven through the distal cortex and beyond.

Bicortical Screw Fixation

Both unicortical and bicortical fixation have been described. Bicortical fixation maximizes interfragmentary compression, but is associated with a risk for guidewire or screw migration beyond the apex and associated neural or vascular injury. Because of this, some authors recommend unicortical fixation, in which either a fully threaded variable-pitch screw or a cannulated cancellous lag screw is used. Biomechanical studies have demonstrated a favorable comparison between unicortical and bicortical fixation. Clinical studies, however, describe complications associated with unicortical fixation, which suggests that bicortical fixation may provide a better result (Fig. 6). Apfelbaum et al. observed screw backout in 4 patients whose screws were only partially engaged in the apical odontoid cortex. One patient became quadriplegic and then died of respiratory causes after a screw backed out and fractured distally, causing displacement of the fragment. The authors concluded that ensuring adequate purchase in the distal fragments by having the screw threads cross the apical cortex is critical to optimize fracture healing.

If a bicortical fixation technique is used, care must be taken to drill through the distal cortex so the lag screw will engage the cortex and compress the distal fragment and proximal C-2 body together. Moreover, if a screw is placed that is too short to engage the distal cortex of the fracture segment, the operation can probably be salvaged with replacement by a longer screw that has bicortical purchase.

Single-Screw and Dual-Screw Fixation

Osteosynthesis via an anterior odontoid screw pro-
vides immediate stability to approximately one-half the strength of the intact dens.\textsuperscript{18,50} Either 1 or 2 screws have been used for fixation. Theoretically, 2 screws confer the advantage of preventing rotation of the odontoid relative to the body of C-2;\textsuperscript{7} and this may be the preferred technique in patients with poor bone quality, because of increased rotational stability.\textsuperscript{14} Dailey et al.\textsuperscript{14} found that placement of 2 screws resulted in a higher fusion rate in patients aged 70 years and older (Fig. 7); however, no difference in load-bearing strength, flexion-extension and rotational stiffness, or union rate has been demonstrated consistently in biomechanical or clinical studies.\textsuperscript{7,52} Moreover, placement of 2 screws can be technically challenging. Two 3.5-mm screws require at least 9 mm of space for appropriate placement,\textsuperscript{43} and many patients do not have an odontoid large enough in diameter to accommodate 2 screws.\textsuperscript{52} Given the small area of the odontoid tip, 2 screws reduce the surface area available for bone fusion to occur. This may be problematic for fracture healing, considering the decreased amount of cancellous bone present at the base of the odontoid.\textsuperscript{3}

Other Common Complications

The rate of site-specific complications and technical problems is comparable for anterior screw fixation and posterior arthrodesis.\textsuperscript{5,4,47} Major complications of anterior odontoid screw fixation include neural injury, esophageal or pharyngeal perforation, hemorrhage, and airway obstruction.\textsuperscript{7} There is a substantial incidence of airway complications in patients undergoing anterior screw fixation. Postoperative airway complications include tracheostomy, prolonged or repeated intubation, respiratory distress, airway edema, prolonged ventilator use, aspiration, pneumonia, and swallowing or vocal cord dysfunction. Smith et al.\textsuperscript{55} found that patients undergoing odontoid screw fixation were more likely to receive tracheotomies, contract pneumonia, and develop swallowing or vocal cord problems than those undergoing posterior procedures. Respiratory compromise due to retropharyngeal swelling adjacent to the surgical site has also been described.\textsuperscript{50} Dailey et al.\textsuperscript{14} found a relatively high incidence of postoperative dysphagia after anterior fixation in elderly patients with a mean age of 81 years. Thirty-five percent of the patients included required diet modification or nasogastric tube placement after surgery. Indeed, elderly patients are already predisposed to dysphagia, considering the fact that aberrant swallowing is a natural part of aging.\textsuperscript{53} Dysphagia after anterior cervical surgery is common in the initial postoperative period and decreases with time, but a minority of patients may continue to experience symptoms at 6 months after the procedure or longer.\textsuperscript{9} The risk of aspiration pneumonia, reported to be as high as 19\% in one study on elderly patients,\textsuperscript{14} increases in these patients with swallowing dysfunction. A postoperative swallowing study can help identify patients at risk for swallowing difficulty and may potentially decrease the risk for aspiration and subsequent pneumonia.

Conclusions

Anterior odontoid screw fixation is an excellent motion-preserving option for fixation of Type II odontoid fractures. Successful long-term management of these fractures relies on a multitude of factors. Based on review of the literature and the experience of the senior authors, we have identified crucial points to keep in mind when considering surgical fixation. The decision to place an odontoid screw should take into account the patient’s individual anatomy, the fracture’s morphological features, bone quality, and concomitant injuries. Keys to success include proper patient/facture selection, identification of suitable screw entry point and direct screw trajectory, achieving bicortical purchase, and placing 2 screws when feasible and applicable, such as in the elderly population. Attentive postoperative care is critical for addressing the more common complications, such as dysphagia. Close postdischarge follow-up can help identify persistent atlantoaxial instability, nonunion, and hardware-related complications that can arise, such as screw breakout, backout, or migration. Critical assessment of patient characteristics, sound surgical technique, and close clinical follow-up can dramatically increase success when performing anterior fixation for an odontoid fracture.

Disclosure

Dr. Schmidt is a consultant for Aesculap. The other authors do not report any conflict of interest concerning the materials or methods used in this study or the findings specified in this paper.

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Fig. 7. Plain radiograph demonstrating successful placement of 1 partially threaded lag screw and 1 fully threaded screw in an 80-year-old woman treated for an acute odontoid fracture from a ground-level fall.
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