6 Anterior Odontoid Fixation

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INDICATIONS

Direct anterior odontoid screw fixation is indicated in patients with acute type II and high type III
Fig. 6-1 (with a shallow base) odontoid fractures (Fig. 6-1). The rationale for direct anterior fixation is the achievement of immediate fixation in anatomical alignment, stabilizing the atlantoaxial complex while providing the best environment for fracture healing. The construct preserves C1–C2 rotation while providing rigid internal fixation and avoids restrictive bracing and the complications associated with bone grafting techniques. It has a higher success rate than and reduces the morbidity associated with prolonged halo immobilization, which had been used preferentially in the past. Direct anterior osteosynthesis of the odontoid fracture with anterior odontoid screw fixation is often the preferred alternative to atlantoaxial arthrodesis for management of odontoid fractures. This technique has been shown to achieve a high healing rate, similar to that of posterior atlantoaxial arthrodesis (88% to 100%), with a similarly low complication rate (1,4,9,27,30,31), and has the advantage over posterior methods of achieving this without intentionally sacrificing atlantoaxial motion (2,27,30).

Polytrauma patients, in whom immediate mobilization has proved beneficial, are also good candidates for anterior odontoid screw fixation as they often are not candidates for halo-vest stabilization. Direct osteosynthesis also can be used in patients who refuse halo treatment and in those in whom fracture reduction can be obtained but not maintained in this apparatus.

CONTRAINDICATIONS

Caution should be used in osteopenic patients; many patients with odontoid fractures are elderly and will have decreased bone mineralization. There is less reason to be concerned about the bone density of the cancellous interior of the odontoid and the C2 body because healing occurs primarily across the cortical bone at the junction of these two. Therefore, if the cortical shell of C2 and the odontoid are reasonably well ossified and there is good apical bone at the tip of the odontoid, screw fixation maybe considered. The lag screw needs to have good purchase in the strongest region of the odontoid—the dense apical cortex—and have a good buttress at the strong anterior inferior aspect of the C2 body to be effective (Fig. 6-2).

A fixed kyphotic angulation of the neck or a barrel chest with a short neck may preclude obtaining the low trajectory needed to place a screw from the inferior edge of C2 to the odontoid apex. This can be checked before surgery using lateral fluoroscopy when the patient is optimally positioned. If the trajectory is not adequate, we will not proceed with direct odontoid screw fixation but rather reposition the patient and perform a C1–C2 instrumented fusion. Compromising the trajectory and accepting an entry site for the screw on the anterior face of C2 rather than the inferior one is not recommended.

Anatomic reduction of the odontoid fracture is imperative before the fixation screw is placed across the fracture. Inability to achieve reduction prior to commencing surgery was therefore previously considered to be an absolute contraindication to the procedure; however, intraoperative reduction and perfection of the alignment of the odontoid to the body of C2 can be obtained using the techniques and instrument system described in this chapter, so this is no longer a contraindication. An absolute contraindication to anterior screw fixation is (the relatively rare) concomitant transverse

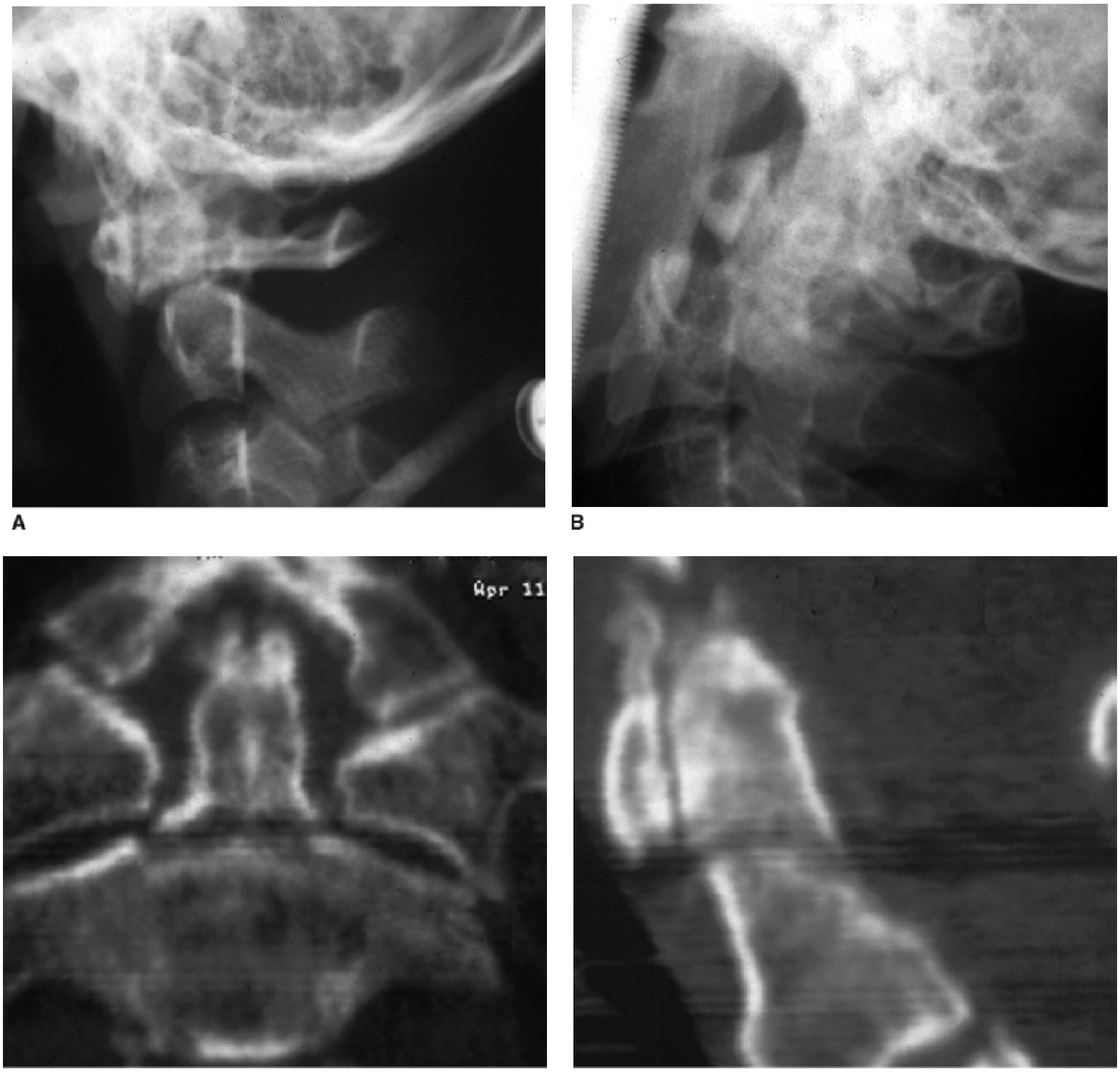

FIGURE 6-1
Type II odontoid fractures: with odontoid anterolisthesed **(A)** and retrolisthesed **(B)**. High Type III odontoid fracture **(C, D)**. (Copyright Dr. Ronald I. Apfelbaum).

atlantal ligament (TAL) disruption since, in such a case, fixation of the odontoid alone will not stabilize the C1–C2 complex.

Chronic fracture nonunions over 6 months old and oblique fractures in an anteroinferior-to-posterosuperior plane that could cause the odontoid fragment to shear anteriorly at the fracture site during lag compression are relative contraindications. The success rate of direct screw fixation for fractures over 6 months of age (25%) has been substantially lower than in those treated earlier. Fractures treated within the first 6 months, such as those treated after failure of a trial of halo immobilization, did as well as fresh fractures (4). This is similar to the experience in treating patients with nonunions of anterior cervical interbody fusions with posterior rigid fixation. Once the motion is eliminated, a high percentage of patients with anterior nonunions go on to achieve solid fusion. In regard to oblique fractures, if the overall bone quality is adequate, fixing them in a slight retrolisthesed position in anticipation of the translation of C1 anteriorly on C2 can result

FIGURE 6-2
Cryosection of a fatal odontoid fracture. Note the much thicker inferior cortex marked with *double asterisk*, as compared with the anterior cortex (*thick blue arrow*) and also the dense apical odontoid cortex (*thin blue arrows*) and much weaker cancellous bone below this and in the interior of the body of C2. (Image courtesy of Dr. Wolfgang Rauschning.)

in the final alignment being anatomic. In such a case, we would also use a hard collar for 6 weeks to restrict neck flexion. Others also have reported good success with shallower anterior oblique fractures (11).

PREOPERATIVE PREPARATION

Examination and Evaluation/Pathology

Odontoid fractures are relatively common upper cervical spine injuries, constituting nearly 60% of all fractures of the axis and 10% to 18% of all cervical spine fractures (6,24,30). Proportionally greater space is available for the spinal cord in the upper cervical spine than in the lower cervical spine. Therefore, the incidence of neurologic involvement in upper cervical spine injury is relatively low (18% to 26%) (12,38). Furthermore, when significant cord damage does occur in the upper cervical spine, patients frequently do not survive because of respiratory arrest. Modern immobilization and transportation techniques have reduced the incidence of secondary injuries at this level and resulted in more survivors with injuries that previously might have been fatal.

Although odontoid fractures occur in all age groups, the bimodal distribution observed in the past is changing. In younger patients, who represent the first peak incidence, these fractures are usually secondary to high-energy trauma; motor vehicle accidents are responsible for the majority of the odontoid injuries (6,13). Often, the injured patient was a nonrestrained passenger in the front seat whose neck was violently hyperextended when his or her head or face struck the windshield. Concomitant spinal injuries are present in up to 34% of patients; 85% of these associated injuries occur in the cervical spine, most commonly the atlas (12,23,38). These injuries have become much less frequent with the increased use of seat belts and the proliferation of passive restraints such as airbags. The second peak in the incidence of odontoid fractures occurs among the elderly (30). In fact, odontoid fractures are the most common cervical spine fracture in patients older than 70 years (34,35,37). These fractures, unlike those in the younger patients, tend to result from low-energy injuries, such as falls from a standing height. The mechanism of injury is often hyperextension that results in posterior displacement of the odontoid. Associated spinal trauma is much less common in elderly patients (7,12). With increased longevity, these injuries are being seen more frequently and make up the clear majority of odontoid fractures.

Preoperative Radiographic Evaluation

Which imaging studies should be obtained for a comprehensive, diagnostic approach in evaluating suspected upper cervical spine injuries remains a topic of controversy, particularly in the presence of polytrauma or for obtunded patients. The standard, initial cervical spine radiographic series in trauma patients includes a cross-table lateral view, an anteroposterior (AP) view, and an open-mouth view. The value of the AP view has been questioned because it provides little additional information (18). Although this three-view screening series can detect 65% to 95% of axis injuries (30), the C2 vertebra is often obscured by overlying bony maxillary, mandibular, and dental structures; therefore, C2 fractures may be missed. Thin-section computed tomography (CT) is the best study for evaluating C2 bony fractures (8). Sagittal reconstruction of CT images is important because axial images may not show a transverse odontoid fracture. These views can also provide valuable information about the cortical bone density, the status of the subaxial spine, and the presence of anterior osteophytes that may factor into the decision regarding choice of approach.

Although CT is excellent in demonstrating bony injuries, soft tissue and significant ligamentous injuries may not be apparent. Therefore, dynamic flexion/extension lateral fluoroscopic evaluation has been advocated for polytrauma patients to identify occult ligamentous instabilities and confirm that the cervical spine is uninjured (25). Magnetic resonance imaging (MRI) also is helpful in assessing the spinal cord in patients with and without neurologic deficits and gives important information about the subaxial spine. It also is becoming increasingly important in evaluating the status of ligamentous structures such as the TAL.

The assessment of TAL integrity in patients with odontoid fractures is an important consideration in selecting appropriate treatment options (15). Anterior odontoid screw fixation will not provide C1–C2 stability if the TAL is not competent. TAL disruption has been reported to occur in 10% of patients with odontoid fractures (22); however, in our experience, we have rarely noted instability when evaluating TAL integrity by flexing the patient's neck under fluoroscopy after odontoid fixation. This brings into question the accuracy of the MRI criteria. Nevertheless, the combination of MRI, CT, and plain radiographs is important for evaluating unstable C2 fractures and planning a rational treatment course. When a C2 fracture is identified, it is necessary to also evaluate the subaxial spine carefully because 16% of patients have a noncontiguous fracture (39).

TECHNIQUE

Positioning

Before beginning the operation, the surgeon must ensure that reduction of the odontoid to a more anatomic position is possible. Some prefer to do this by simple traction or manipulation while the patient is awake, with lateral fluoroscopic imaging. Typically, we will place the patient on the operating table with a folded blanket or other suitable padding under the shoulders and a similar padding under the head to keep the neck in a neutral position (Fig. 6-3). If the patient's odontoid in this position is anterolisthesed, we extend the patient's neck while observing the alignment under fluoroscopy and gradually remove the head pads. This may reduce the anterolisthesis of C1 and the odontoid process relative to C2 while also optimizing the patient's head position for both intubation and screw placement. If the patient's odontoid is retrolisthesed, the degree of mobility can be assessed under fluoroscopy when the neck is slightly flexed. These preliminary maneuvers help ascertain that reduction will be possible intraoperatively. Intubation should be done without moving the patient's neck in the direction that increases the subluxation. This may require fiberoptic intubation techniques.

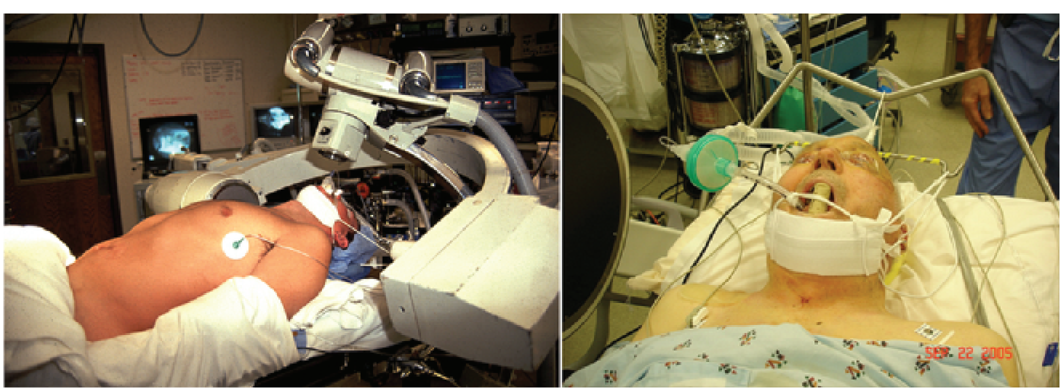

FIGURE 6-3 Patient positioning. Note padding under the patient's shoulders (**left**), radiolucent mouth gags, halter traction to allow head repositioning if needed during surgery, and biplanar fluoroscopes. (Copyright Dr. Ronald I. Apfelbaum.)

To achieve a proper screw trajectory and clear the anterior chest with the instrumentation, it is usually necessary to extend the patient's neck; however, unless this position results in optimal reduction and alignment, this is best done once the screw guidance tubes are in place as is described below. In essence, we will accept the best aligned position to begin the approach but prepare the setup to allow us to modify the patient's head position once the C1–C2 relationship is perfected intraoperatively. Therefore, "perfect" preoperative reduction is *not* required to proceed.

Once the patient is intubated, a radiolucent mouth gag is placed to allow for transoral imaging. A wine bottle cork notched for the patient's teeth or gums is excellent for this. We then use halter traction, with the patient's head resting on a foam donut rather than any type of pin fixation so further intraoperative position changes can be made. If C1 and the odontoid are in an anterolisthesed position, we can optimize the alignment as achieved in the preanesthetic evaluation described above, slowly removing any additional padding, other than the donut, and then dropping the head of the table if necessary under fluoroscopic control to maximize the reduction (Fig. 6-3, left). If C1 and the odontoid are in a retrolisthesed position, rotating the patient's head about a transverse axis approximately through the ear canals by placing one hand under the chin and the other on the occiput may reduce this completely or partially (Fig. 6-4). This occurs because the center of rotation is above the odontoid, so this motion brings the odontoid anteriorly. These maneuvers may result in full or partial reduction. Biplanar fluoroscopy using two C-arms is used not only for the initial reduction but also for tracking the progress of the operation and screw placement. Excellent visualization of the odontoid in both planes is mandatory. The recent application of fluoroscopic-derived CT imaging and stereotactic guidance systems allows for the use of this modality to substitute for the AP images once the reduction is obtained. Because the scan will only be accurate if no further motion has occurred, it must be used with caution and not relied upon until the final position is obtained.

Before the incision is made, the trajectory of the drill is ensured by placing a Steinmann pin or other long straight tool along the lateral aspect of the patient's neck while observing the lateral fluoroscopic image. If the surgeon's hand does not clear the chest, repositioning may be required. As noted above, this may be difficult in a large barrel-chested patient, one with a short neck, or a patient with a fixed kyphotic deformity in the subaxial spine. If an adequate approach path cannot be achieved, then the procedure should be converted to a C1–C2 posterior instrumented fusion.

Approach

A small 3- to 4-cm transverse skin incision is made at the C5–C6 level in the same manner as is done for an anterior cervical discectomy (3). The platysma muscle is then incised sharply but not undermined. The sternocleidomastoid muscle fascia is opened sharply, and this opening is carried cranially for several centimeters. Blunt dissection through the natural tissue planes medial to the carotid artery and lateral to the trachea and esophagus is then carried down to the anterior cervical spine at about the C5–C6 level. We then make an incision in the midline and elevate the longus colli muscles over about 1½ vertebral bodies. We use electrocautery for the midline incision but

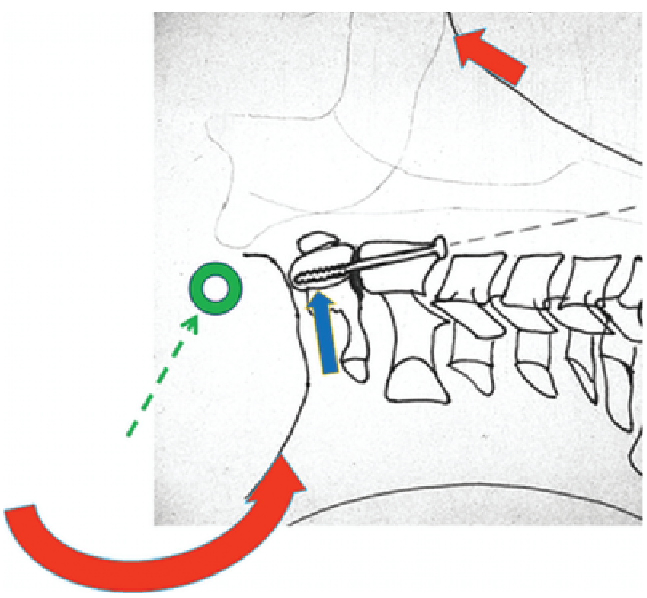

FIGURE 6-4
Maneuver to help realign a retrolisthesed odontoid: The patient's head is rotated in the sagittal plane by lifting up the chin and also rotating the occipital area as shown by the *red arrows*. This will rotate the head about a center of rotation indicated by the *green circle*, which is superior to the odontoid. The odontoid will therefore be translated anteriorly as a result (*blue arrow*), and the screw can then be placed to hold it in anatomic alignment. (Copyright Dr. Ronald I. Apfelbaum.)

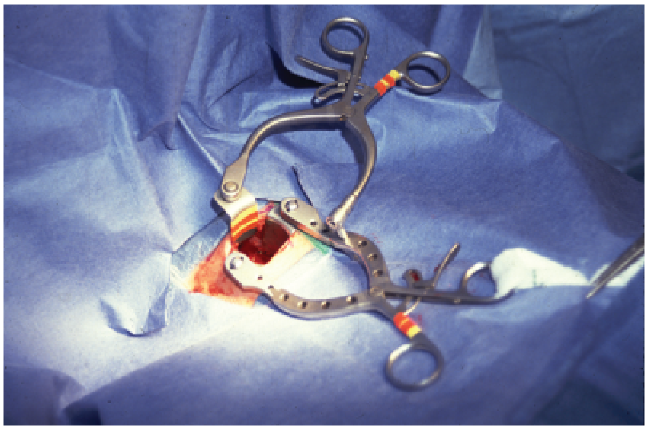

FIGURE 6-5
The retractor system creates a stable working tunnel and allows a midline approach through a small midcervical incision. Note that there is no inferior retractor blade that would interfere with the low trajectory needed to place the screw. (Copyright Dr. Ronald I. Apfelbaum.)

use a periosteal elevator to elevate the muscles to keep them intact. A modified Caspar retractor is placed with toothed blades fixed under the longus colli muscles to anchor it in place. This serves as a base for a special retractor used to keep open a tunnel to C2 in the midline (Fig. 6-5). Blunt dissection anterior to the longus colli muscles in the midline using a "peanut" or Kittner dissector held in an angled hemostatic clamp and swept side to side will quickly open the prevertebral space up to C1. An angulated retractor blade is placed to hold this plane open. It retracts the soft tissues including the esophagus and posterior oropharyngeal wall to keep them out of harm's way. It is mated to a special retractor that attaches to one side of the previously placed Caspar retractor to maintain the working tunnel up to C2 (17). In addition to creating a safe working tunnel up to C2 in the direction needed for the drilling and screw placement, approaching C2 in this manner rather than directly from the incision area avoids crossing structures such as the superior laryngeal nerve.

Screw Placement

The entry point for the fixation screw is on the anterior aspect of the inferior endplate of C2, *not on the anterior surface of C2.* To achieve this, we initially place a K-wire and optimize its position fluoroscopically (Fig. 6-6). If one screw is to be placed, we will insert it in the midline through the anterior annulus at C2–C3 and tap it into the bone. If two screws are to be placed, we will offset their entry points by about 3 mm from the midline. The K-wire is placed to create an entry point and to guide the placement of a guide tube system. *We do not drill with the K-wire*, as it is not rigid enough to maintain an accurate trajectory and any changes in the trajectory are hard to achieve because the K-wire will revert to the original hole.

Once the entry site is selected, we first remove a small amount of bone from the anterior surface of C3 inferior to the C2–C3 interspace to accommodate the guide tube system (5). To do this, a hollow 7-mm drill is placed over the K-wire and rotated by hand to create a shallow trough in C3 (not C2) up to the inferior edge of C2 without removing any bone from C2 (Fig. 6-7). We then place the guide tube system over the K-wire. The system has outer and inner components, the latter of which can be extended beyond the outer tube as needed. They are mated together, with the inner tube retracted, and placed over the K-wire until the spikes on the guide tube contact C3 (Fig. 6-8). The K-wire is cut off so only about an inch protrudes from the guide tube, and a plastic impactor sleeve is placed over the guide tube. Tapping on this with a mallet drives the spikes into C3 to secure the guide tube system. Once in place, the surgeon should maintain constant upward pressure on the guide tube system to keep the spikes engaged in C3. The inner guide tube can then be advanced until it is in contact with the inferior edge of C2 at the entry site, and then the K-wire is removed and replaced with a calibrated drill.

The guide tube is used not only to accurately direct the drill to the apical cortex of the odontoid but also to optimize the alignment of C2 and the odontoid. While keeping upward (cephalad) pressure on the guide tube at all times to maintain the engagement of the spikes in C3, it is possible to displace C3 and C2 posteriorly under a retrolisthesed odontoid (Fig. 6-9) or lift C2–C3 anteriorly to realign with an anteriorly displaced odontoid. Unless we need to correct the alignment to initiate the drilling, we find it easiest to start drilling first, aiming for where the apical cortex of the odontoid will be in the reduced position and then perfect the C2–odontoid alignment just before crossing the fracture. If, however, the patient has a retrolisthesed odontoid that could not be realigned during the initial positioning, we would start the surgery with the head in a neutral position and proceed until the guide tube was anchored. Then C3 and C2 can be displaced posteriorly under the odontoid

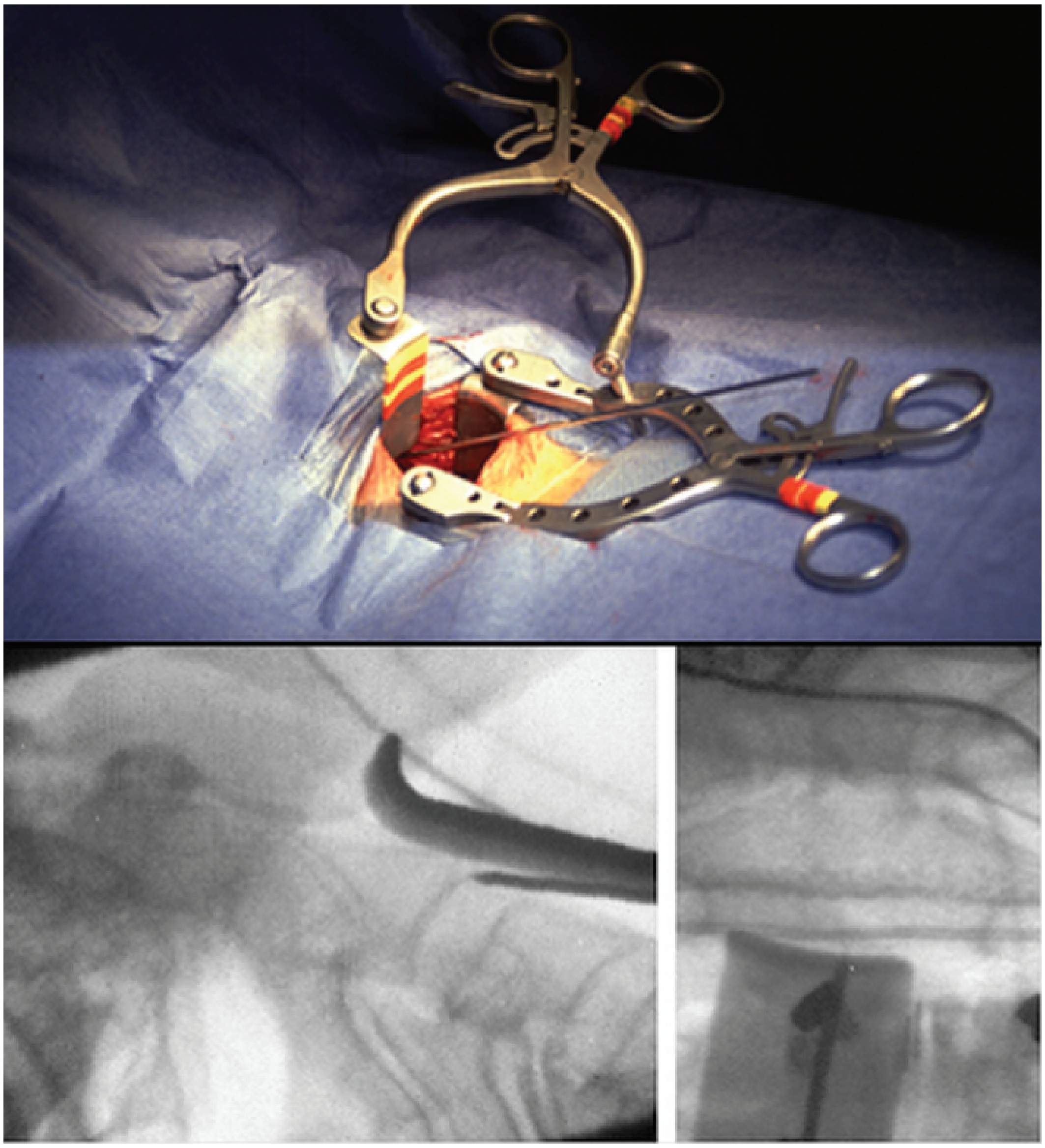

FIGURE 6-6 Placement of the K-wire to create a starter hole and align the guide tube system to the entry site for drilling on the anterior inferior aspect of C2, as seen on the lateral view (**lower left**). In this case, one screw was planned and therefore a midline entry site was chosen, as seen on the AP view (**lower right**). (Copyright Dr. Ronald I. Apfelbaum.)

(Fig. 6-10). The anesthesiologist then slowly removes the extra padding under the patient's head; when the head is lowered, the patient's neck is extended while the alignment is maintained with the guide system. This can give the needed chest clearance to proceed. We would not try this unless we were convinced we could achieve the position by initial maneuvers such as displacing C2 posteriorly by direct posterior pharyngeal wall pressure once the patient was anesthetized.

The drilling is accomplished by advancing the drill slowly and using frequent fluoroscopic views. If any changes are needed as the drill is advanced, these can easily be done by backing up the drill slightly, correcting the trajectory with the drill guide, and advancing it again. The drill, which is 3 mm in outer diameter, has excellent directional authority and will usually go as directed.

It is important to drill through the apical odontoid cortex (Fig. 6-10C). This is usually quite dense and, if not drilled, may be difficult to engage with the screw or may crack. If the drilling is accomplished in the correct trajectory starting in the C2 endplate at its anterior aspect, the drill can penetrate from several millimeters to a centimeter or more beyond the apical cortex without threatening the thecal sac. Since the drill is coming tangentially to the dura and is in front of it, drilling in this manner is safe as long as the drill tip is not allowed to progress posterior to the plane of the back wall of the C2 body. Before removing the drill, note its depth on the calibrated shaft and take an image in each plane and store it on the second screen of the fluoroscopes. These images make it very easy to match the alignment that was obtained and achieve the same trajectory when tapping the hole and placing the screw. The drill and the inner drill guide are removed, but the outer drill guide is kept securely fixed in C3. A tap is then used to cut threads in the drilled hole. As it is

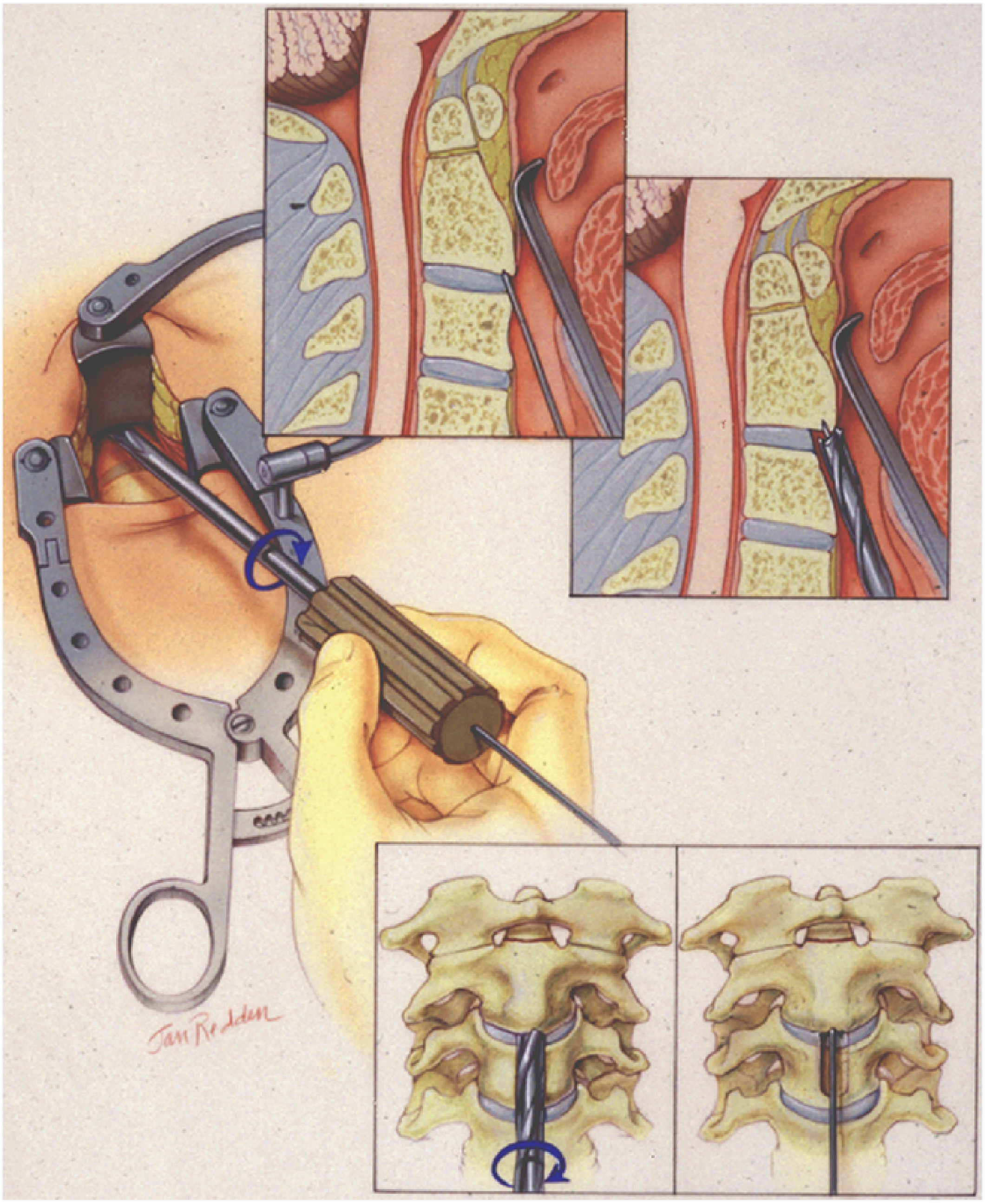

FIGURE 6-7
A shallow trough in the face of C3 is created with a hand drill to allow placement of the guide tube system to the inferior edge of C2. (Copyright Dr. Ronald I. Apfelbaum.)

advanced, it is easy to replicate the trajectory achieved with the drilling, making minor alignment corrections with the guide tube if needed to follow the same path in the odontoid (Fig. 6-11). In fact, the drill hole can usually be seen on the fluoroscopic images. The tap also is calibrated so the depth can be checked if needed. Tapping the screw hole allows the screw to engage the dense apical cortex instead of displacing the odontoid and ensures an optimal screw bone interface. Forcing a screw into an untapped bone hole can result in high interface pressures and subsequent bone absorption and possible screw loosening. Screws have been broken when attempts were made to force them into the dense, untapped apical bone of younger patients.

The tap is then removed, and a 4-mm cortically threaded lag screw, which has a minor diameter of 2.9 mm, is placed through the drill guide along the same path, its length chosen on the basis of the depth measurements. This smooth-shafted lag screw will engage the distal odontoid cortex and with its head buttressed against the inferior cortex of C2 can pull it down into closer approximation with the body of C2 (Fig. 6-11). If there is much of a gap between the odontoid and C2 and the fracture is recent, the lag effect will usually close this substantially. It is important to fully engage the odontoid cortex, so we strive for a screw length that will allow the tip of the screw to penetrate a 0.5 to 1 mm through the apical cortex. Deeper penetration is acceptable as long as the screw tip does not extend

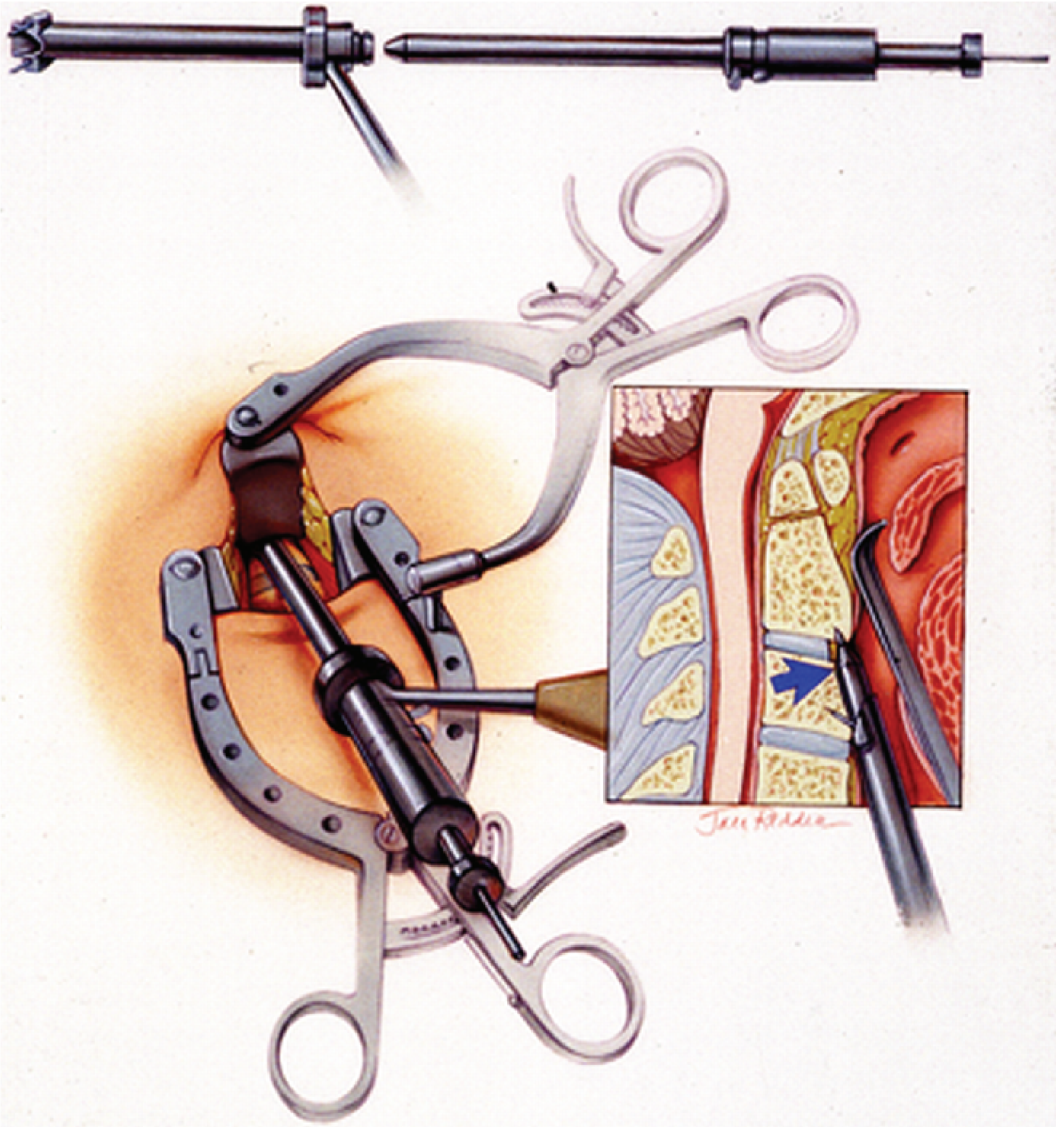

FIGURE 6-8
The outer and inner guide tubes are mated together and passed over the K-wire until the spikes on the outer guide tube can engage C3. After seating the spikes with the impactor, the inner guide tube is extended to the bottom of C2 (*blue arrow*). This provides a secure pathway to the selected entry hole and allows adjustment of the drilling trajectory as the drill is advanced. It also allows realigning C2 into an optimal relationship with the odontoid process (see Fig. 6-9). (Copyright Dr. Ronald I. Apfelbaum.)

posteriorly into the spinal canal. Because the drill hole is tapped, the screw can be removed and replaced if needed to optimize its length without damaging the bone pathway. This type of screw with a larger minor diameter has proven to be much stronger in resisting bending, and since it has been adopted we have not seen any screw breakage.

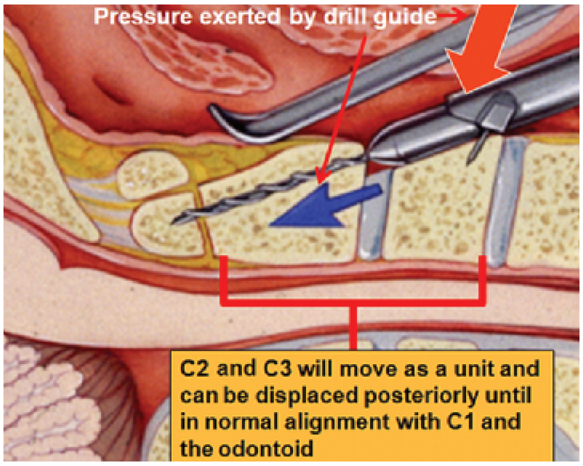

FIGURE 6-9
In the case of a retrolisthesed odontoid, the guide tube can be used to correct the alignment. Upward pressure is maintained at all times to keep the fixation pins engaged in C3 (*blue arrow*), and then C3 and C2 are displaced posteriorly by simultaneous posterior pressure on the drill guide (*red arrow*). When in optimal alignment, the drill is advanced across the fracture and into the apical odontoid cortex. (Copyright Dr. Ronald I. Apfelbaum.)

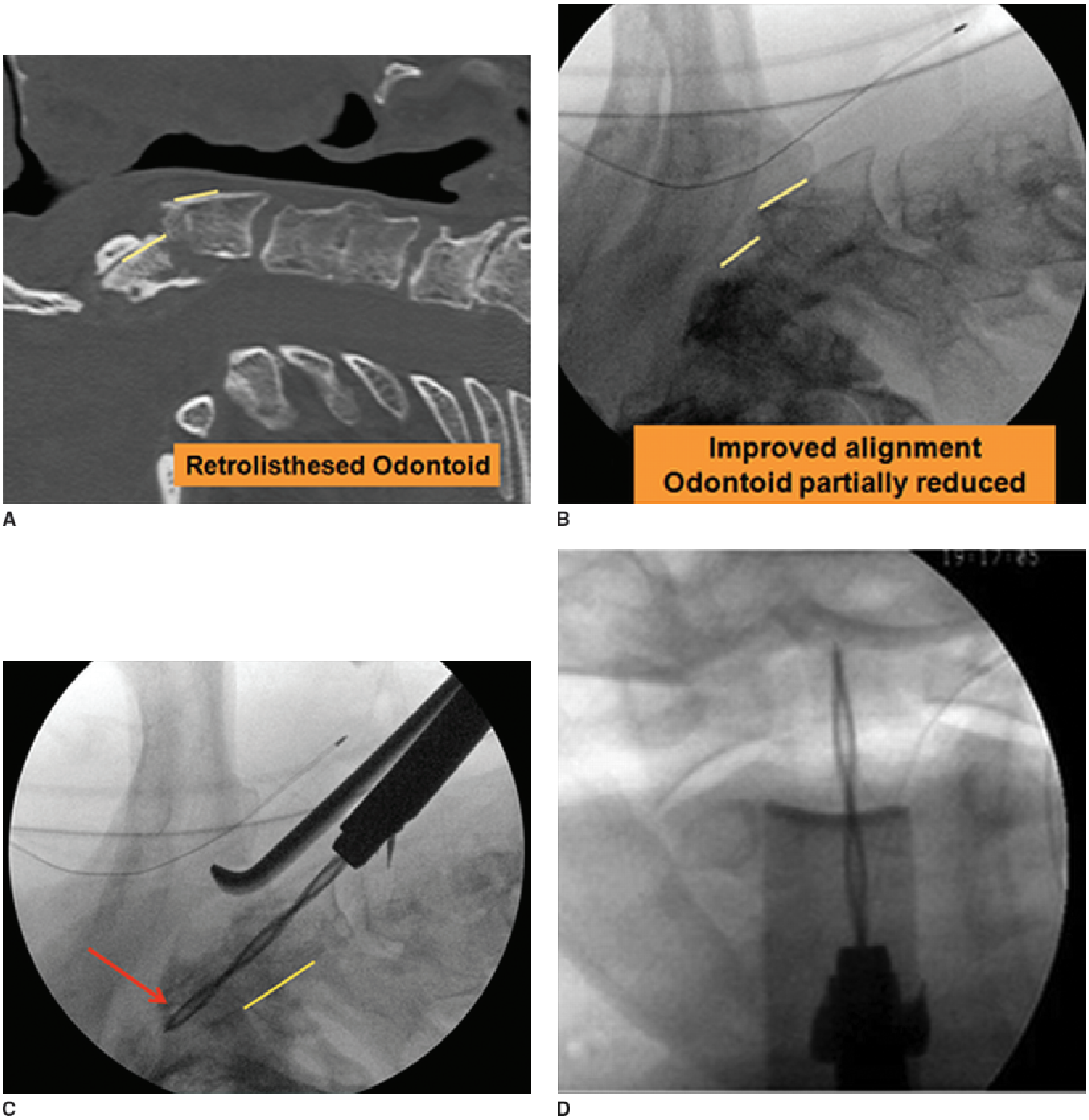

FIGURE 6-10
The alignment of this difficult retrolisthesed odontoid in an 80-year-old man **(A)** was improved **(B)** by the head-tipping maneuver (note less offset of the *yellow lines*), and we were then able also to further extend his neck (cf. **B** and **A**). This allowed us to proceed with drilling and achieve complete realignment (as indicated by the *yellow line*) **(C)** before crossing the fracture line. The final drill position **(C)** is through the apical cortex of the odontoid (*red arrow*). The AP view **(D)** just before penetrating the tip of the odontoid shows that we chose a paramedian position for the screw to accommodate a second screw. (Copyright Dr. Ronald I. Apfelbaum.)

PEARLS

The placement of two screws is usually not technically more difficult as long as the surgeon plans ahead and utilizes a paramedian entry site and a trajectory that does not cross the midline. The ability to precisely guide the screws to the desired location makes this possible in most patients. The second screw is placed using the identical series of steps and an entry site into C2 that is on

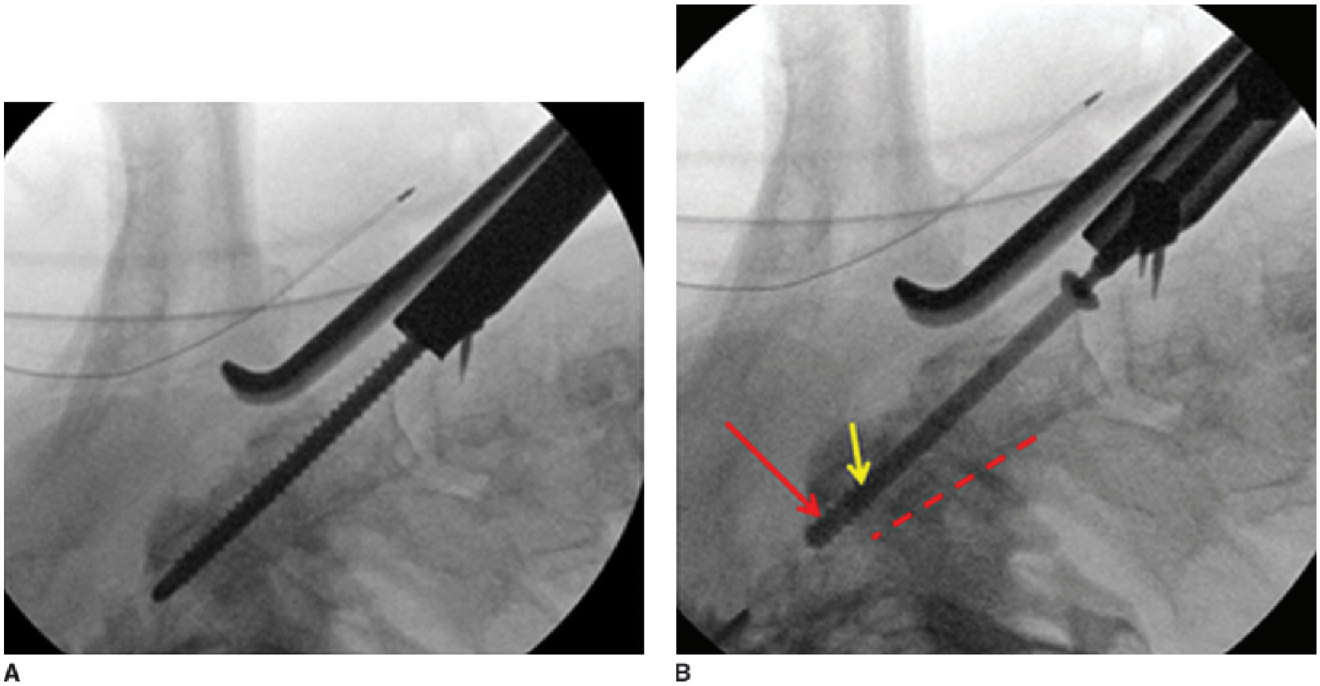

FIGURE 6-11
A: The pilot hole is tapped over its full length. **B:** The lag screw with threads extending only distally past the *short yellow arrow* is then placed. This lags (draws) the odontoid to the body of C2. Note also the apical penetration of the screw (*red arrow*). The head of the screw is against the inferior surface of C2, not its anterior surface, and the alignment is anatomic (*dashed red line*). (Copyright Dr. Ronald I. Apfelbaum.)

the opposite side of the midline (Fig. 6-12). The screws can converge toward each other to remain within the cortical shell of the odontoid. If the odontoid has a larger diameter in the AP plane, the screws can be placed so one comes to lie behind the other within the odontoid process. Only rarely is it not anatomically possible to place a second screw. While biomechanical testing has shown no biomechanical advantage of two screws in comparison with one-screw fixation in regard to stabilization of flexion and extension or resistance to screw fracture (16,26,27,33,36), this is not the complete picture. Two screws offer resistance to rotation of the odontoid relative to the body of C2 that is not achieved with one lag screw. This has not been addressed in studies such as that of Sasso et al. (36). Mechanically produced type II odontoid fractures were stabilized with either one or two 3.5-mm screws. Stability after internal fixation was 50% that of the unfractured odontoid. The use of two screws did not significantly enhance the stability in testing against re-failure. Graziano et al. (21) also found no difference between one and two screws in bending and torsional stiffness of the instrumented odontoid; however, the ability of one screw to limit rotation between the odontoid and C2 was not evaluated and is probably critical in achieving a solid fusion.

In younger patients with fresh fractures in whom the fracture line is often irregular, the lag effect alone may pull the irregular surfaces together and prevent rotation, but in fractures treated a few weeks or longer after their onset, such as after failure of a 3-month trial of halo immobilization, the single screw may not be adequate. This has not been adequately studied until recently when Dailey et al. (14) evaluated the results of odontoid screw fixation in elderly patients over the age of 70 years and found the difference between one and two screws to be highly significant. Fusion was achieved in only 56% of patients with one screw versus 96% when two screws were used. This likely is due to the weaker bone structure in older patients who may sustain smoother fracture surfaces. These may also not be able to be lagged as tightly, allowing rotation to persist when only one screw is used, thereby reducing the success rate. *In these older patients, we believe that two screws should always be placed unless anatomically prohibited*. In younger patients, we see no downside to using two screws when possible as it may be helpful in some, but we recognize it is not essential.

In some cases, especially in osteopenic patients, it can be difficult to positively identify the odontoid, and particularly its apex, on the lateral fluoroscopic images. In such situations, careful study of the CT sagittal reconstructions referencing the shape and height of the odontoid in relation to other better-seen landmarks, such as the top of the anterior arch of C1, can help define the actual borders of the odontoid on the fluoroscopic image.

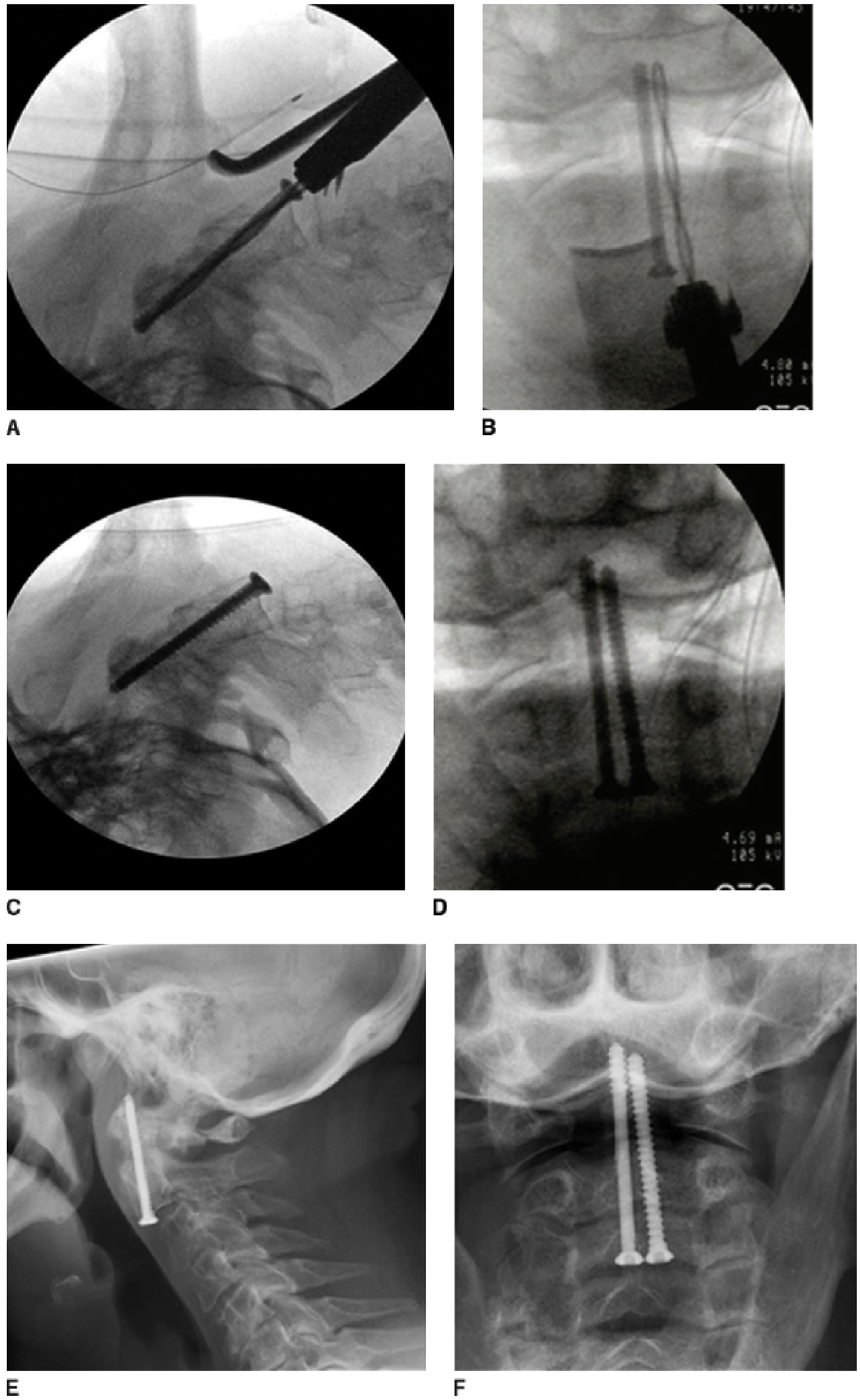

FIGURE 6-12
A, B: Drilling for the second screw. **C, D:** Final construct in the operating room. **E, F:** Two-month follow-up films. The second screw can be threaded screw because no further lag action is expected. (Copyright Dr. Ronald I. Apfelbaum.)

PITFALLS

Odontoid screw fixation has been considered to be a technically demanding procedure; however, the refinement of the instrumentation, as described here, and improved imaging have made it less so. The procedure requires thorough preoperative planning and adequate surgical training. Determining the correct entry point, at the anterior margin of the inferior endplate, is critical. If entry is started more cephalad on the anterior surface of C2, the angle of inclination for fracture fixation often cannot be achieved, and the purchase is weaker, which may allow the screw to cut out of or migrate

FIGURE 6-13
Poorly placed cannulated screw whose insertion was started on the anterior face of C2. The screw head has migrated into the body of C2, and the screw tip is within the neural canal, almost to the foramen magnum and in an uncertain relationship with the odontoid.

in C2 (Fig. 6-13). Poor odontoid purchase with subsequent screw back-out may also occur if the apical cortex of the odontoid tip is not fully engaged to ensure adequate purchase (Fig. 6-14). This is mandatory to achieve a lag effect between the fractured odontoid and the body of C2.

AP and lateral fluoroscopy are essential for constant monitoring during all stages of this procedure, and the procedure should not be attempted without adequate imaging equipment.

Clearly, choice of the proper screw length is also important for the screw to sit flush against the body of C2 proximally and not extend into the neural canal at its distal end. Failure to properly position the patient to achieve reduction and the needed trajectory to place the screws (both described in detail above) will make it difficult or impossible to achieve the desired result.

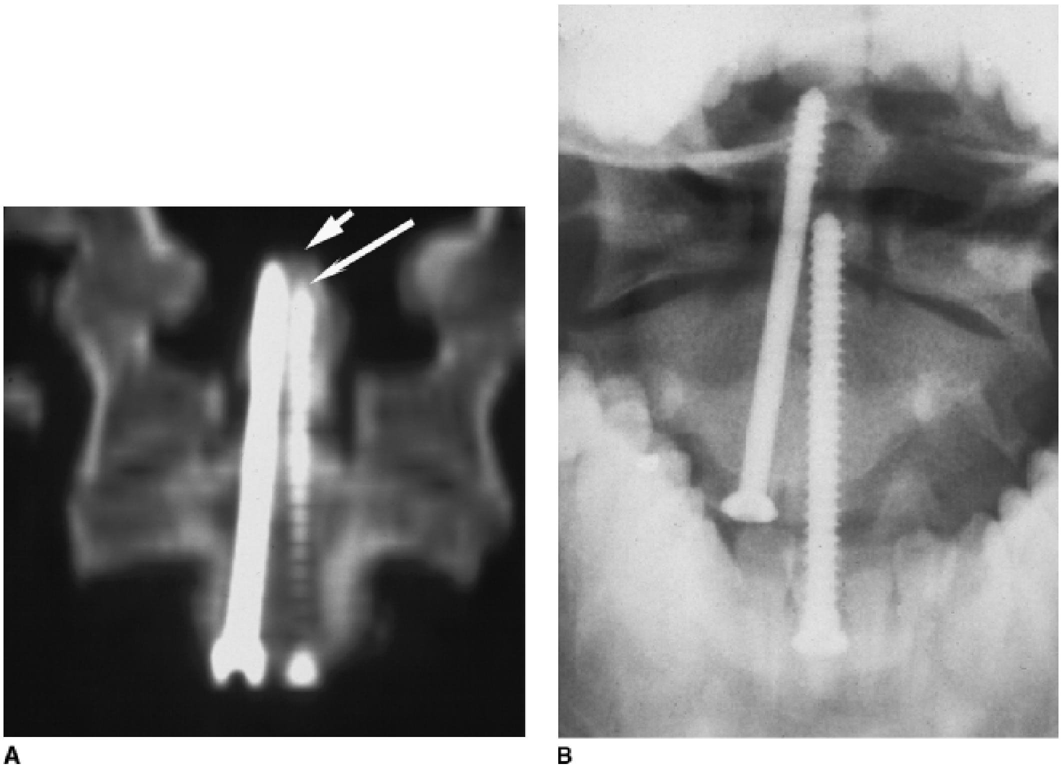

FIGURE 6-14
In another case, in an 18-year-old man, **A:** One screw went completely through the apical cortex (*short arrow*) while the other stopped a few millimeters short (*longer arrow*). That small difference was enough to prevent a firm grip and allow the second screw to back out within 6 weeks of the initial surgery. When revised with a longer screw, it held well. (Copyright Dr. Ronald I. Apfelbaum.) Q1

The surgeon must realize that the whole procedure is performed using fluoroscopic guidance. It is not useful to try to retract the neck soft tissues any more than is necessary to create a working tunnel. The fixed retractors assure this. Hand retraction is difficult to limit and may result in excessive pharyngeal retraction and postoperative dysphagia. Trying to look up the tunnel to see C2 is not useful. All guidance must be obtained from the fluoroscopic images. No placement of the guide tubes and other tools to C2 and through the bone should be done without fluoroscopic guidance.

SPECIAL CONSIDERATIONS

Several options exist for treating odontoid fractures, which by definition are always unstable unless C1 is fused to C2. For many years, and especially before the development of this minimally invasive technique, halo immobilization was the preferred method. Despite the morbidity of prolonged immobilization, successful odontoid fusion can be achieved in approximately two-thirds of patients with halo immobilization. The risk of nonunion in patients over the age of 50 years with type II odontoid fractures, however, was 21-fold greater with immobilization in a case-controlled study (28), and studies have also shown that type II odontoid fractures with more than 6 mm of initial radiographic displacement have a very high incidence of nonunion despite immobilization in a halo for 3 months (6). For patients with these fractures, it is reasonable and preferable to consider direct fixation of the fracture or C1–C2 fusion. There are no studies looking at the maximum possible displacement in patients with odontoid fractures on flexion and extension images (for obvious reasons), so many patients with "nondisplaced fractures" also may have much greater offsets if the images had been taken at a different time.

If halo treatment is chosen but fails, then anterior odontoid screw stabilization is still an option for patients within 6 months of injury, and the outcomes have been equal to those in fresh fractures (4). Chronically united fractures (over 18 months) have fared poorly, so for these established nonunions, the best surgical alternative is posterior C1–C2 arthrodesis, despite the accompanying loss of axial rotation. The morbidity and mortality of halo immobilization in the elderly is significantly higher than in younger patients, again suggesting that surgical fixation should be strongly considered (7).

The use of cannulated screws is controversial. In a prior version of this chapter, Dr. Sasso stated: "For three main reasons, I do not use this technique: First, it is very difficult to drive a K-wire exactly. It is much easier to make fine corrections to the trajectory of a 2.5-mm drill bit. It is imperative that the screw is perfectly placed in the odontoid fragment, and if the K-wire is not perfect, it is usually necessary to completely restart the drilling because the K-wire tends to follow the hole already made. Second, the K-wire may shear and break or may bind and drive into the spinal canal if the cannulated drill is not perfectly collinear. Finally, the bending and shear strength of the cannulated screw is less than a solid screw of the same diameter." Dr. Apfelbaum agrees and feels even more strongly about this technique. Having become aware of serious (but unreported in the literature) complications and fatalities from using a K-wire and cannulated screw technique, we feel even more strongly about this decision. These complications have resulted, in various instances, from not achieving the correct trajectory and/or from drilling or advancing the K-wire into the spinal canal, the spinal cord, and through the foramen magnum into the brain stem or vertebral artery. We are not aware of any such complications with properly placed solid screws.

If a partially threaded lag screw is used, concern has been raised that some circumstances such as a high fracture may not allow the threads to be completely contained in the dens fragment and that these threads crossing the fracture site would keep the fracture distracted. The currently used screws have only a 10-mm threaded portion, which will not cross the fracture site, but, even with longer threaded portion screws previously used, we saw no failure to lag or other ill effects because the central bone at the fracture site is structurally weak and does not hold the screw. For this reason, we have not found it necessary to overdrill the body fragment to obtain the lag effect as some have recommended.

Another concern has been raised that the anterior aspect of the C2–C3 disc space must be violated to obtain the proper entry point; however, this usually involves removing only a very small piece of the anterior annulus at the screw insertion site at the inferior endplate of C2. The nucleus should remain intact, as can the anterolateral annulus. No long-term ill effects at this level have been observed.

In elderly patients, osteopenia is a relative contraindication to anterior odontoid screw fixation. A perfectly placed screw, however, engages into the strongest bone at the tip of the dens (strengthened by the constant pull of the alar ligaments) and possesses a foundation in the very strong inferior endplate of C2. When good lag technique is implemented across the fracture, this construct may be quite stable even in osteoporotic patients. This strategy may be reasonable in the medically unstable geriatric population because the anesthetic morbidity is much less severe in the supine position than in the prone position required for a C1–C2 fusion. Also, surgical morbidity is much less severe with an anterior cervical approach than with a posterior approach, and the bone graft harvest site is eliminated.

POSTOPERATIVE MANAGEMENT

Progressive ambulation is initiated immediately after surgery. A hard cervical collar may be worn postoperatively when it is desirable to reduce a patient's motion or activity levels. In most of the older patients who are not very active it may be omitted or used for only a few days to weeks. If the patient is unstable on his or her feet and likely to fall again, it may be prudent to consider using a collar for a longer period of time, because, although the fixed fracture is stable, it is only 50% as strong as the intact odontoid (36). No correlation has been observed between collar usage and outcomes, so our preference is to not use them and to encourage gentle regular neck motion to preserve neck mobility as the fracture heals. We do advise against bouncing, jarring, or other strenuous activity and to delay return to work if such activities are required.

Mild dysphagia is common because of the retropharyngeal dissection and retraction. The latter can be minimized by using the self-retaining retractor system rather than handheld retractors. Most often the dysphagia will be mild and will resolve quickly, but occasionally it can be severe and require delayed feeding or the use of a feeding tube for a period of time. The incidence of dysphagia has been shown to be high in patients over the age of 70 years (14), so medical staff should monitor patients carefully, but if the patient is able, we will have the patient resume oral intake immediately after surgery and progress quickly from a soft to a normal diet.

Rehabilitation

Unless dysphagia is a problem or they have other limiting medical issues, patients can usually be discharged in a day or two after surgery. The patient is encouraged to be active immediately. In the elderly, who may be timid to be active, we recommend that they "get out of the house" and take a walk daily if the weather permits. Home exercise equipment if available can also be used. We also encourage gentle range-of-motion exercises, stretching, and strengthening the cervical spine to regain full function. Formal physical therapy can be used if the patient is not able to do this alone.

COMPLICATIONS

Complications of this procedure can be divided into approach-related ones and technical errors. The former group could involve injury to other structures in the neck, wound problems, and infections, but other than the dysphagia discussed above, these have rarely been observed or reported.

Technical problems include an inability to anatomically reduce the fracture, difficulty positioning the surgeon's hand for proper drill trajectory because of interference with the patient's chest, and poor visualization of the odontoid on fluoroscopy because of osteopenia. All of these can reduce the chance of a successful outcome; however, refinements in instrumentation and fluoroscopic devices have overcome many of these issues. With experience, we have learned that two screws are very important in older patients to get a successful fusion. We also learned years ago that using a larger-diameter, 3-mm solid screw virtually eliminated screw breakage. Finally, as noted, if a cannulated technique is used, the K-wire may shear, bind, and drive into the spinal canal, resulting in suboptimal screw placement at best and neurologic injury or death at worst.

A better understanding of methods to realign the spine preoperatively and intraoperatively and an understanding of the technique as described above can eliminate or minimize problems due to poor screw placement. Incorrect entry site selection, failure to engage the distal odontoid cortex, or using too long a screw to get the lag effect can all lead to a failed fusion and may require additional treatment.

With any biologic system, no treatment can be expected to be 100% effective; however, with careful preoperative and perioperative evaluation and careful attention to, and understanding of, the details of the procedure, anterior odontoid screw fixation has proven to be safe with a very high success rate and few serious complications.

RESULTS

Overall, studies reported in the literature have established this technique as an efficacious treatment of odontoid fractures (4,10,14,19,20,29,32). Complications and their incidences, reported in clinical series as results of direct anterior odontoid screw fixation, include screw malposition (2%), screw breakout (1.5%), and neurologic or vascular injury (less than 1%) (see comments above about nonreported serious complications). The procedure in several series has an aggregate fusion rate of 94.5% (9,31,32). If the fracture is morphologically appropriate and if the patient is not osteoporotic, then reliable fixation with minimal morbidity and quick return to function without a halo can be expected.

DISCLOSURES

The instrumentation described in this chapter was developed by ~~the~~ Dr. Apfelbaum in conjunction with Aesculap, AG and is available from the manufacturer. The author has no ongoing financial interest in this product and receives no remuneration in any form related to either the instrumentation or screws.

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Query

[Q1] Note that Part label B is mentioned in the Figure 6-14 but not mentioned in the caption. Please check.