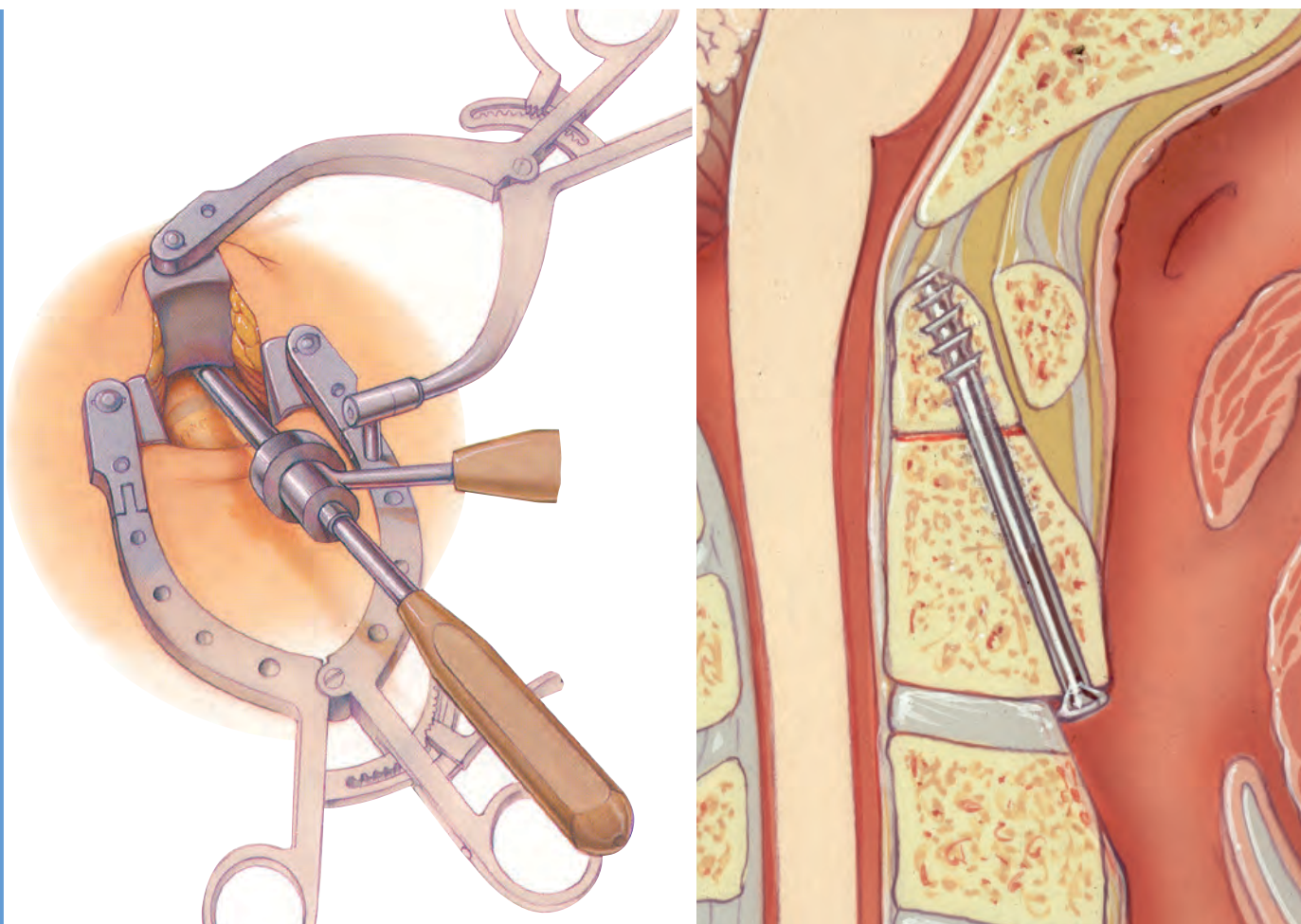# Apfelbaum Odontoid Fixation

Anterior Fixation of Odontoid Fractures Surgical Technique
According to Ronald I. Apfelbaum, M.D.

Aesculap Spine

AESCULAP®
Implant Systems

Apfelbaum Odontoid Fixation

Anterior Fixation of Odontoid Fractures Surgical Technique

Product Description, Indications, Materials, Warnings, Precautions and Contraindications

Product Description

The AIS Odontoid Fracture Fixation System is an instrument system that facilitates an anterior approach to the second cervical vertebra and allows reduction and direct screw fixation of odontoid fractures using titanium alloy screws.

Indications

For fracture fixation of small bones and small bone fragments including odontoid fractures.

Materials

The materials used in the implant are listed on the packaging:

- Titanium forged alloy Ti6Al4V according to ISO5832-3

Warnings

- Ensure that all necessary implants and instruments are on hand and inspected prior to use.
- For implants and instruments that are supplied non-sterile, they must be sterilized prior to use.
- The screws should not be re-used under any circumstances.
- Patients should be advised of the possible limitations of their implant(s), including postoperative mobility and load bearing stress.
- Patient behavior can affect surgical outcomes. Smokers and non-compliant patients should be advised of this fact and warned of the increased risk of potential complications.

Precautions

- The Odontoid Fracture Fixation System has not been evaluated for safety and compatibility in the MR environment, nor has it been tested for heating or migration in the MR environment.
- Based on the fatigue testing results, the physician/surgeon should consider the levels of implantation, patient weight, patient activity level, other patient conditions, etc. which may impact the performance of the system.
- Mixing of stainless steel implants with unalloyed titanium, titanium alloy and other cobalt alloy implants should be avoided for implants that are in contact with each other.

Contraindications

Do not use in the presence of:

- Fever
- Infection: systemic or localized in the spine
- Pregnancy
- Medical or surgical conditions that could negatively affect the outcome of the implantation
- Foreign body sensitivity to the implant materials
- Acute osteopenia
- Severe osteoporosis or similar loss of bone density
- Severe damage to the osseous structures preventing fixation of the implant components
- Bone tumors in the region of implant fixation
- Anticipated overloading of the implant
- Systemic or metabolic diseases
- Dependency on pharmaceutical drugs, drug abuse or alcoholism
- Morbid obesity (adiposity)
- Generally poor condition of the patient
- Inadequate patient compliance
- Cases not listed under indications

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I. Introduction

Fig. 1 A

Typical type II odontoid fracture. These are unstable and while they may appear to be in good alignment when the head is in a neutral position as shown here, the odontoid and C1 will often translate with head motion relative to C2 and below, as seen in figure 1B.

Odontoid fractures (Fig. 1 A, B) account for 10-15% of all cervical spine fractures. They have historically occurred in a biphasic distribution. Fractures in younger patients usually occurred after high energy trauma such as motor vehicle accidents while fractures in older patients occurred in low energy trauma such as ground level falls. The former group has become much less common due to improved active and passive motor vehicle occupant restraints; however, the latter group is increasing in frequency with improved longevity.

The most common odontoid fractures are the Anderson & D'Alonzo[1] Type II fractures at the base of the odontoid where it joins the C2 body or just above that location. Type III fractures involving the body of C2 include high Type III fractures at the base of the odontoid with the fracture extending to the medial aspect of the C1-2 lateral mass joints.

Treating these fractures is of great importance because they are always unstable using White & Punjabi's[2] definition of stability as being "the ability to protect the neural elements under physiological loads".

Many studies[3-19] have attempted to identify factors predisposing to non-union but most, looking at x-ray findings, are not valid as these images only represent a single point in time and not the maximum amounts of offset or angulation, nor even the only direction of offset, that may occur with further movement. The patient's age however does correlate well and a case controlled Type II study showed a 21 fold greater risk of non-union in patients greater than 50 years of age treated with Halo immobilization compared to surgery.[20]

Fig. 1 B
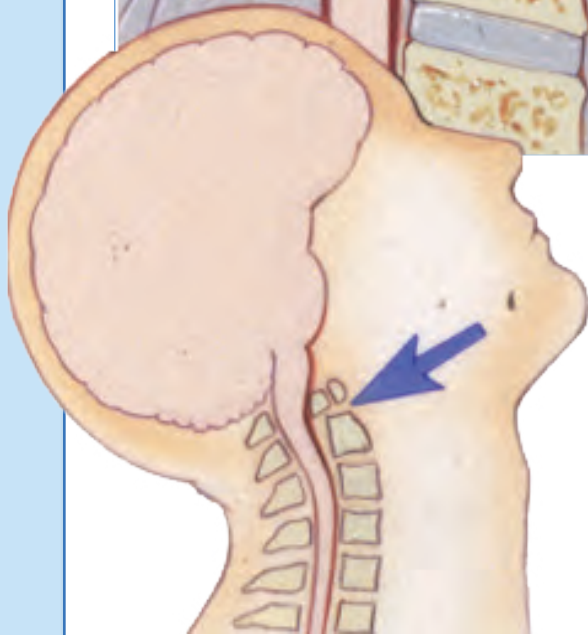
Conventional surgical treatment historically has included external immobilization with a halo-vest apparatus[21-23] and surgical stabilization, usually by C1-2 posterior fusion. However, a meta-analysis of results with non-operative techniques found only a 65% overall success rate. For this reason, surgery is often required. Posterior C1-2 fusion as a primary procedure or secondary to failure to unite the bone after a period of extended immobilization was often used.[24-29] While usually effective in stabilizing the C1-2 region, posterior fusion itself may require an additional period of extended immobilization unless internal fixation is used and can at times also fail to result in boney union.[30] More significantly it eliminates the normal rotation between C1 and C2 which accounts for 50% of the normal cervical spine rotation.[31]

A better surgical treatment is to place a fixation screw across the fracture site,[32-38] thereby reapproximating the fractured odontoid process to the body of C1-2 and stabilizing the C1-2 complex immediately while preserving full C1-2 functional capability.[39] This may be performed as a primary treatment or after failure of a trial of external immobilization.

To accomplish such a screw fixation in the past was difficult, involving extensive neck dissection[34,35] and potentially significant morbidity. The development of the instrumentation illustrated here, however, allows efficient screw fixation using an easily mastered minimally invasive approach which greatly reduces the risks to the patient and has a high rate of success.[37] It is accomplished through a small low cervical approach, similar to that used for an anterior cervical discectomy. Specialized retractors and drill guides allow easy access to the area of pathology, and biplane fluoroscopic control assures precise placement of the fixation screws.[38] The instrumentation also allows correcting the position of C2 relative to the odontoid, realigning them into a more optimal position.

Type II odontoid fracture exhibiting retrolisthesis in extension (Fig. 1B). In flexion anterolisthesis may occur at this unstable level.

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II. Patient Selection

The procedure has been employed in type II and high riding type III odontoid fractures of less than six months of age, as well as those with remote or obscure origins, although with substantially less success in the latter.[40] For this reason, we do not recommend it for chronic nonunions or fractures more than six months age. Patients should not have additional lesions which will reduce the chance of adequate fixation, such as fractures into the body of C2, which will not allow firm screw purchase. Nor should they have a disruption of the transverse ligament which will allow atlantoaxial translation even if the odontoid fragment is fixated. This can be suspected in Jefferson type atlas burst fractures with greater than 7 mm displacement of the lateral mass of C1[2] and evaluated by MRI imaging of the region.[41] In our experience, we have not encountered a case with both odontoid fractures and transverse ligament disruption. The presence of nonreduceable compression of the cord in this area would also be a contraindication and would best be treated by resection of the compressing lesion and subsequent C1-2 posterior fusion. Significant cervical kyphosis or a barrel chest also precludes obtaining the needed trajectory for screw placement.

Typically the central cancellous bone of the odontoid near its base is weak, even in the non-fractured situation. In addition there may be cystic degeneration at its base. This alone is not a contraindication to screw fixation. The quality and density of the bone at the inferior cortex of C2 and at the odontoid apex are the key factors since the screw needs to hold at these places to stabilize the construct. Bone healing at the fracture site will occur involving the cortical bone around the circumference of the odontoid rather than the central cancellous bone.

Advanced age alone is not a contraindication to the procedure. Indeed, with increased longevity, we are seeing more elderly patients with odontoid fractures, usually from minimal trauma such as ground level falls. If the patient's medical condition allows, and they are a functioning individual with reasonable mental status, this may be the procedure of choice. The surgery is shorter, less invasive and more easily tolerated than many other surgical procedures. The other options of prolonged rigid immobilization with a poor success rate or a more extensive and more risky posterior fusion are less desirable. If anterior odontoid screw fixation surgery is chosen, it is desirable to proceed as quickly as possible and mobilize the patient immediately. In elderly patients, it is important to minimize their time in the hospital. We strive to treat them within a day of admission and discharge them within 24-48 hours. Prolonging the hospital stay is often deleterious to them. In older patients, there is also an increased incidence of postoperative, usually temporary, dysphagia. This can be minimized by carefully minimizing retro-pharyngeal retraction and dissection. In this regard, the use of the self-retaining retractor is preferable to handheld retraction.

III. Surgical Technique
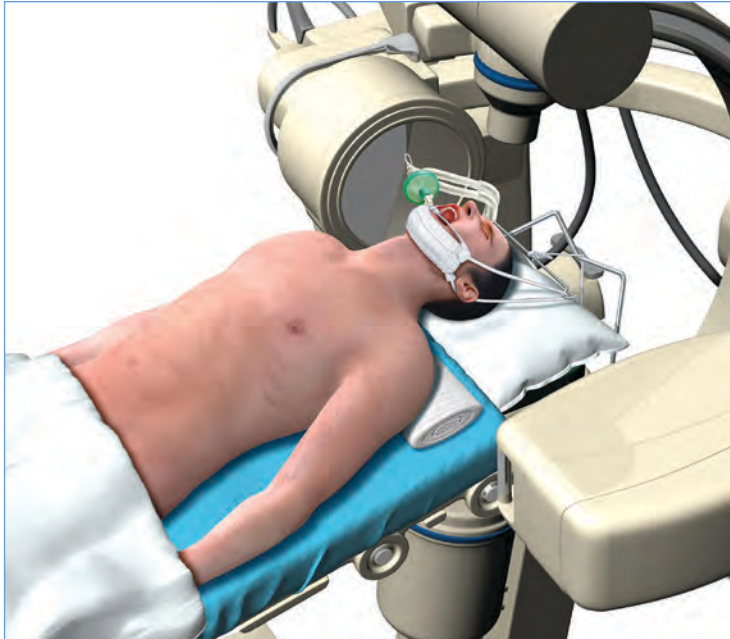
Fig. 2
Patient positioned on operating table. Note folded sheet under shoulders to increase neck extension in this patient whose fracture reduced in extension. Also note the placement of two C-arm fluoroscopic units for antero-posterior (transoral) and lateral fluoroscopic control.
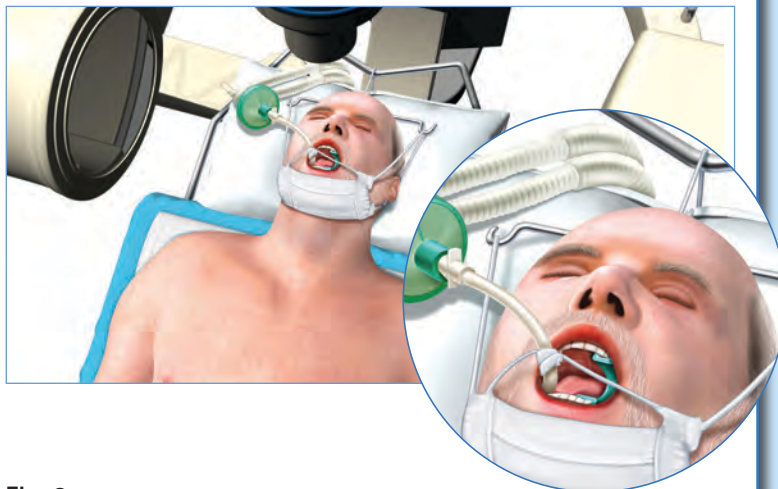

Fig. 3
Close up of fluoroscopic unit placement in another patient who is not as hyperextended. In each case, the best position that can be tolerated is selected based on the lateral fluoroscopic images. Note mouth gag to facilitate transoral AP fluoroscopic view.

The patient is positioned supine on the operating table, and the head is immobilized with gentle halter traction. Rigid skull fixation should be avoided as it will preclude often desirable intraoperative manipulation of the head position to optimize odontoid alignment. A folded sheet or blanket is placed under the shoulders and if the fracture reduces in extension, the head is extended (Fig. 2). If it is not reduced in extension, the head is initially held in a neutral position and will be extended once the guide tube is placed. The guide tube will control the alignment, placing the odontoid in its normal position and allowing proper angulation for screw placement. Instability in extension requires special anesthesia attention during intubation. Nasotracheal intubation or fiberoptic guidance are often employed in these cases.

Fluoroscopic imaging in both the lateral and AP (transoral) planes is required. Two C-arm units are ideal (Figs. 2, 3) and, if available, speed up the procedure. If two are not available, a single unit can be used, rotating it frequently from the AP to the lateral plane, but this is cumbersome and suboptimal. A radiolucent mouth gag is placed and, once the initial images are obtained, the patient´s neck can be placed in the best position. If the patient has a retrolisthesed odontoid, it can be translated anteriorly by rotating the patient's head about an axis through the ear canals. This is done by placing one hand on the patient's occiput and the other under his chin. The odontoid will be located below the axis of rotation and can be observed on the lateral fluoroscopic image to translate forward into better alignment. This will then help allow for further neck extension to be safely achieved without further loss of alignment.

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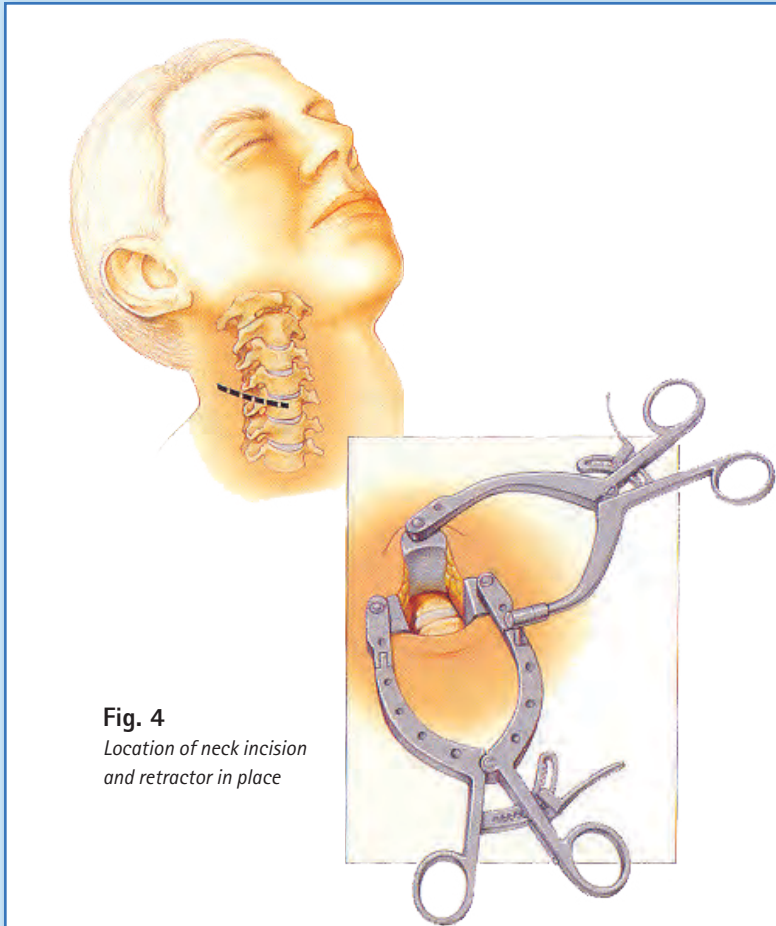
Fig. 4
*Location of neck incision and retractor in place*

Fig. 5
Special retractor blades for creating a working "tunnel" up to C2. These blades are made of titanium which is semiradiolucent for improved anterior-posterior imaging capability while still allowing the blade to be visualized to assure it is in proper position.

After routine prepping and draping, a small unilateral midcervical (approximately C5) natural skin incision is made (Fig. 4). Too high an incision prevents proper trajectory to achieve screw placement in C2 along the vertical axis of the vertebral body. Under fluoroscopy, a straight instrument placed along side the neck can help define the trajectory and anticipate the correct level for the skin incision. Local epinephrine injection aids skin hemostasis. A standard Cloward-type approach to the anterior spine is performed, dividing the platysma muscle horizontally, then sharply opening the sternocleidomastoid muscle fascia along the medial border of that muscle. Blunt finger dissection will then open natural planes medial to the carotid bundle and lateral to the trachea and esophagus to gain access to the prevertebral space.

The longus coli muscle fascia is incised in the midline, and the muscle bellies elevated from the anterior surface at approximately C5-6. Caspar sharp tooth cervical retractor blades are inserted firmly under these muscles and connected to the special retractor blade holder (Fig. 4). Firm fixation here is important, as the superior retractor will work against this fixation. Poor placement can result in the blades rotating out of optimal position.

Next, blunt dissection in the prevertebral facial plane (<u>anterior</u> to the longus coli muscle) using a side to side sweeping motion with a small gauze pad ("peanut" or Kittner dissector) held in an angled clamp will quickly open the tissue plane up to C1. The superior angled retractor blade is then inserted into this space. Its size is chosen from among the six available sizes (Fig. 5) to reach up to C1 and fit the patient´s geometry, especially the size of the mandible. The retractor blade mates with a special retractor that attaches to one side of the previously placed lateral retractor (Fig. 4 and 6 A). A spring loaded set of interdigitating teeth allows adjustment of the angle of retraction. This is changed by manually separating the interdigitating teeth, rotating the retractor to the desired position and allowing the teeth to re-engage.
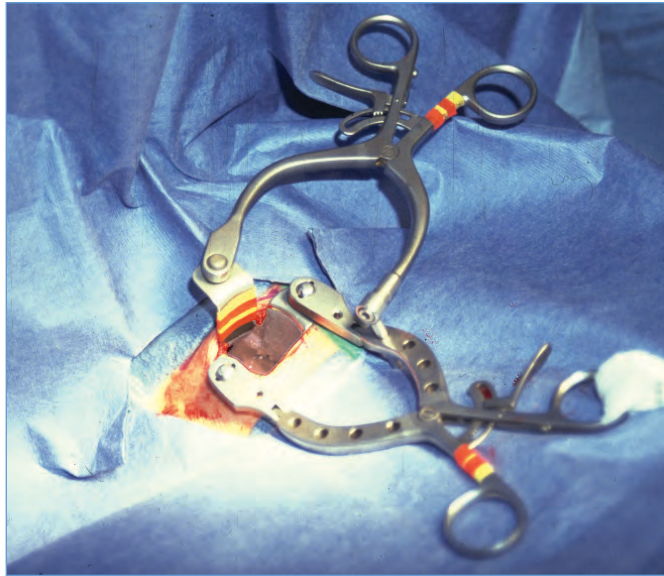
Fig. 6 A

Surgeon´s view with retractor in place. Note lack of any inferior blade, which allows flattest possible trajectory to C2.

Once set, the retractor creates a tunnel within which to work (Fig. 6 A). While it is possible to visualize up to C2 in this tunnel using a headlight, in reality, the majority of the operation is accomplished primarily by fluoroscopic guidance.

An entry site for the fixation screw is then chosen in the <u>inferior</u> anterior edge of C2. If one screw is to be placed, this is usually in the midline. A paramedian site about 2-3 mm off the midline is used if two screws are to be placed. Typically, two screws are used when there is adequate dimension to the odontoid process to accept two screws. <u>Recent analysis has shown that the success rate of odontoid screw fixation in patients over the age of 70 increased from 56 to 95 percent when two screws were used, so this should always be done if the anatomy allows in older patients.</u>

A 2 mm K-wire is then manipulated under biplane fluoroscopic control to the desired entry site, which should be on the <u>inferior</u> aspect of C2, not its anterior surface, and impacted 3 to 5 mm into the bone (Fig. 6 B). Care is taken to get this placed precisely as it will guide all the subsequent steps in the procedure. If necessary, a curette can help prepare an access path through the annulus of C2-3 to seat the K-wire properly.

Fig. 6 B

A guiding K-wire is inserted into the inferior edge of C2.

K-wire

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Once the K-wire is impacted into the inferior edge of C2 at the desired entry point (Fig. 7 A), a 7 mm hollow core drill is passed over the wire (Fig. 7 B) and rotated by hand (Fig. 7 C) to cut a shallow groove to accommodate the drill guide system in the anterior face of C3 and in the C2-3 annulus but not into C2 (Fig. 7 D). This too is monitored fluoroscopically.
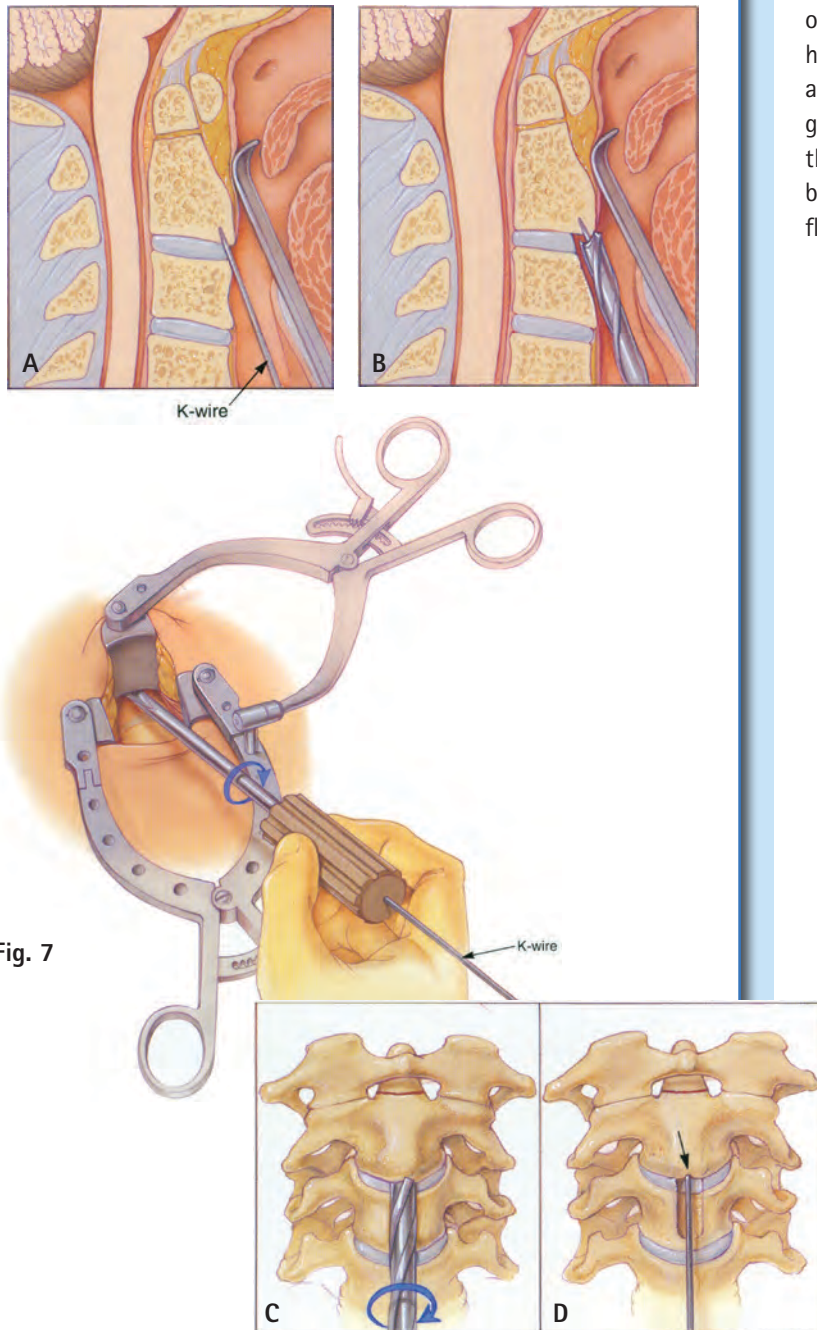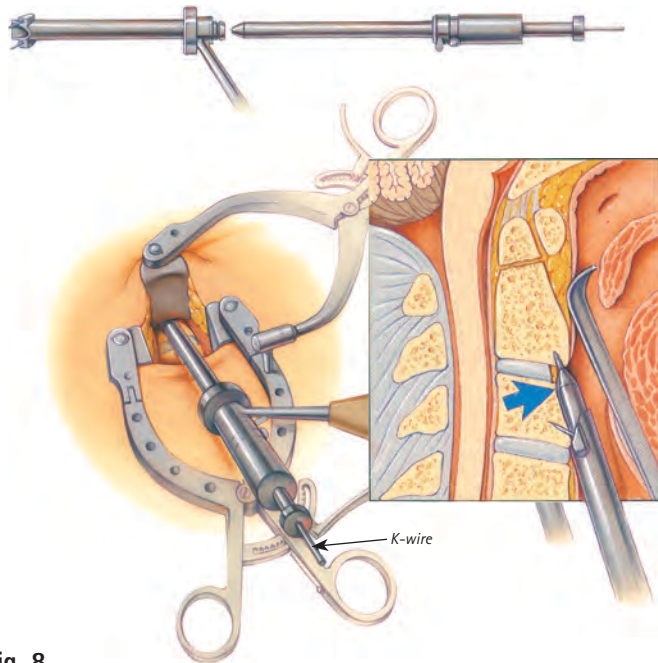
Fig. 7

Fig. 7 A–D
With the guiding K-wire in place (A), a hollow hand drill (B) is rotated by hand (C) to create a trough in face of C3 (D) and C2-3 annulus, up to but not into the inferior aspect of C2 (arrow in D). A midline position used for a single screw placement is shown. For two screws, the initial screw is placed in a paramedian position 2-3 mm from the midline.

Fig. 8

Drill guide system – Inner and outer guide tubes shown at top mate together and are placed over K-wire. The spikes are then "walked up" until over the body of C3.
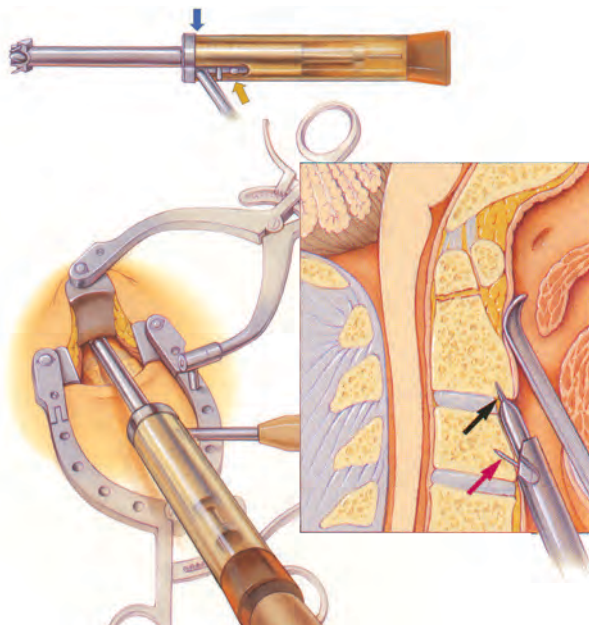
Fig. 9

Upper image: The handle and buttons are aligned in the slot of the impactor (yellow arrow) so the mallet impact is translated to the collar of the outer drill guide (blue arrow). The spikes on the outer drill guide (red arrow on image on the right) are impacted into C3 to stabilize the system. The inner drill guide is then advanced to the inferior edge of C2 (black arrow and blue arrow in Fig. 8 above) in the trough previously created in C3.

The inner and outer drill guides are then mated together and passed over the K-wire. The guide system is manipulated so the securing spikes are over C3 (Fig. 8). To accomplish this, lock the handle to the shaft by tightening the knob at the end of the handle, then "walk" the spikes up to the desired vertebral level by rotating the handle about 15-30 degrees to each side.. The K-wire is then shortened so less than 1 cm protrudes beyond the inner guide tube.

The plastic impactor sleeve is then fitted over the guide tube assembly. Ensure the various adjustment levers and drill guide handle nestle into the slots of the impactor sleeve (Fig. 9 top).

Several sharp taps with the mallet will impact the spikes into C3 and secure the system (Fig. 9). The inner guide tube is then advanced out from within the outer drill guide until it contacts the inferior edge of C2 by depressing (releasing) its locking button.

The surgeon should then reposition the handle of the guide tube system to a comfortable location. This will allow the surgeon to maintain constant upward pressure on the guide tube to keep it engaged in the bone. The K-wire can then be removed without loss of guide tube positional stability and alignment.

The alignment of C1 and the odontoid process relative to C2 and C3 can then be perfected by lifting or depressing the guide tube assembly while maintaining constant upward pressure. In the case of a retrolisthesed odontoid, depressing C2 under the odontoid allows further extension of the patient´s neck, while maintaining normal alignment. This allows drilling at an optimal angle. Manipulation to reduce a retrolisthesed odontoid can be safely accomplished by monitoring the changes in alignment fluoroscopically.

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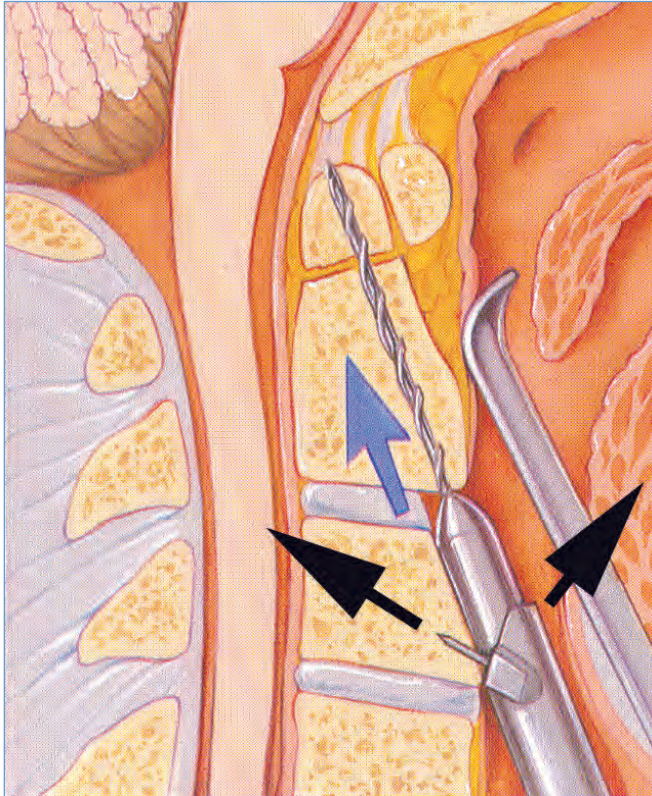
Fig. 10
The K-wire is removed and replaced with the drill, which is guided fluoroscopically through the apex of the odontoid after reducing the dislocated odontoid. Prior to crossing the fracture site, the alignment can be optimized by maintaining forward pressure on the drill guide to keep the spikes engaged (blue arrow) and displacing C2 and C3 either anteriorly or posteriorly as needed (black arrows).
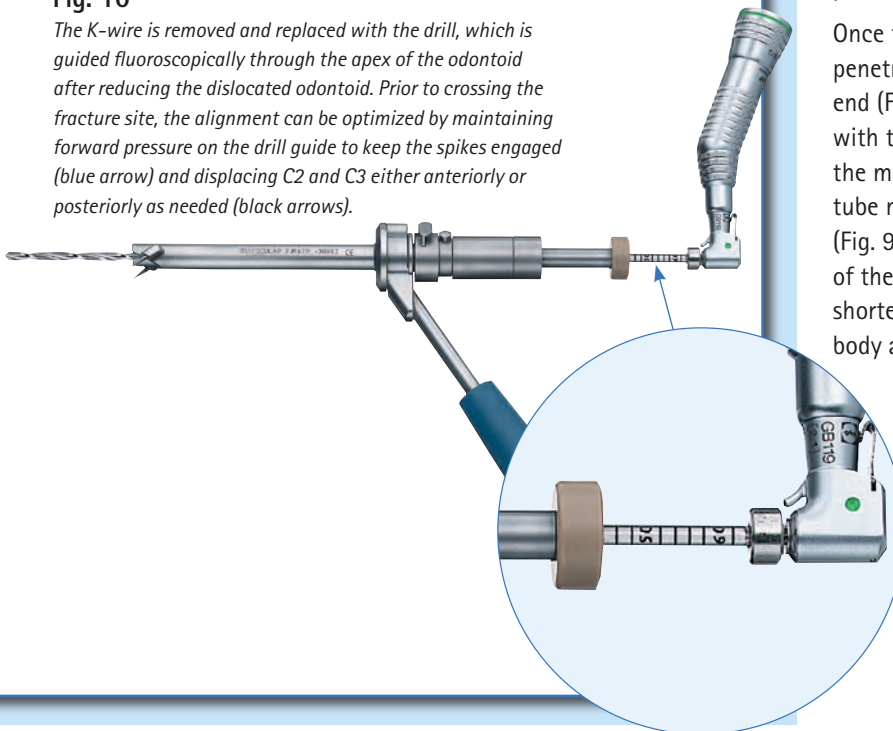
Attach the calibrated drill to the Microspeed® drill driver and insert it through the guide tube into the entry hole created by the K-wire (Fig. 10). Drill a pilot hole into C2 while making fine adjustments to optimize its trajectory in both the AP and lateral planes. When placing two screws, maintain a paramedian trajectory to allow room for second screw. The drill is then advanced into the odontoid process and through its apical cortex by cautiously advancing it up through the bone while monitoring its progress on biplane fluoroscopy.

Prior to crossing the fracture site, additional manipulation can be performed using the drill guide to either depress or elevate the C2-3 complex relative to the odontoid (black arrows, Fig. 10) until the perfect alignment is achieved. If needed, the head may also be manipulated to further optimize the odontoid–body of C2 relationship.

The pilot hole is drilled to <u>and through</u> the apical cortex of the odontoid. The odontoid is firmly attached by its investing ligaments and will neither rotate nor be significantly displaced by this or subsequent maneuvers. The apical cortex is very dense, and failure to penetrate it with the drill may preclude proper screw placement.

Once the drill is fully seated, note the depth of penetration on the calibration marks at its proximal end (Fig. 10, 11 D). Each mark represents 2 mm with the 40 and 50 mm depths so labeled. For the measurement to be accurate, the inner guide tube must be touching the inferior end of C2 (Fig. 9 - right image, 10). A partially threaded screw of the measured length or a millimeter or two shorter to account for the gap between the odontoid body and body of C2 is chosen.
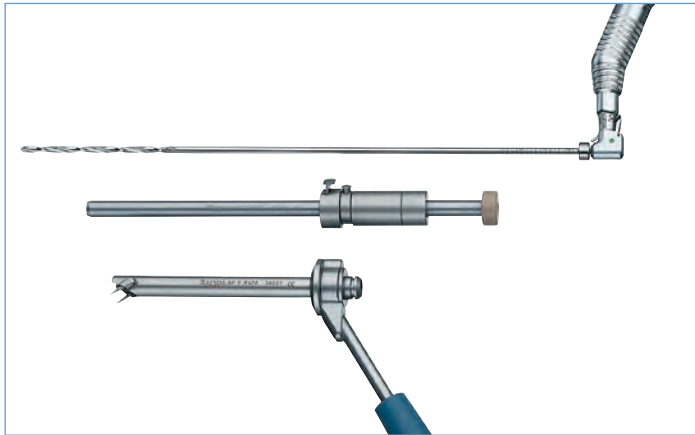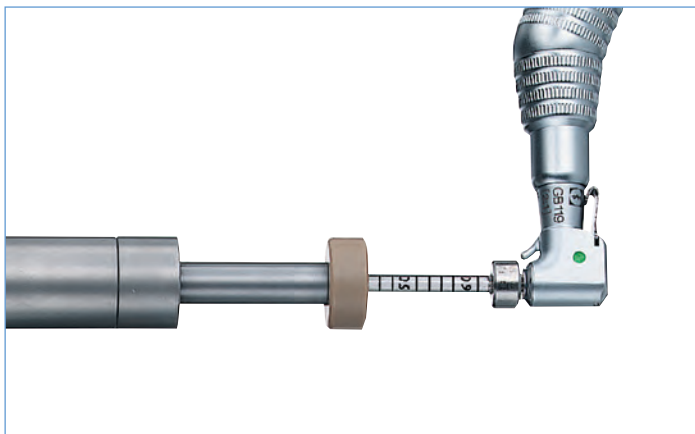
Fig. 11 A
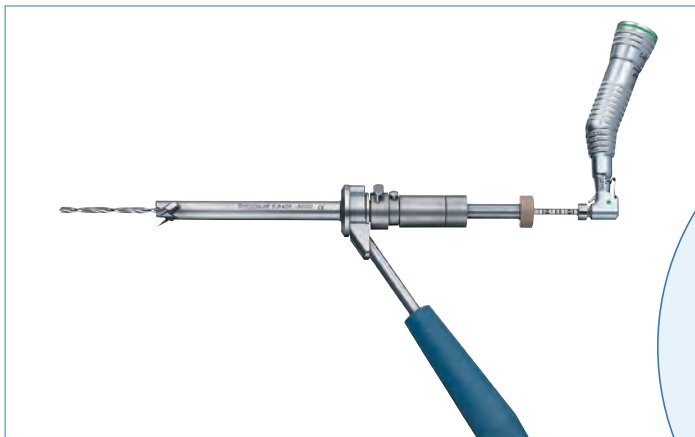
Fig. 11 B
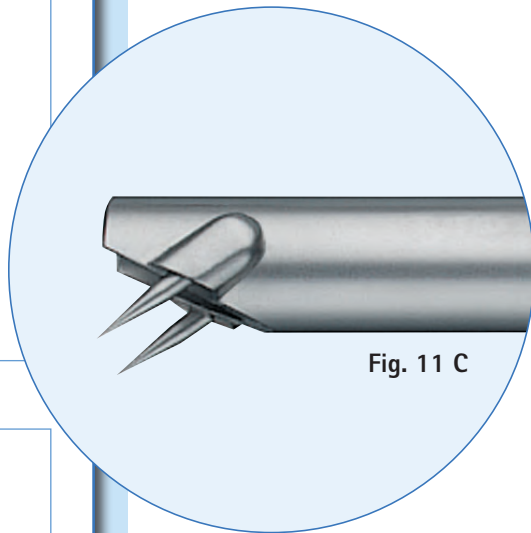
Fig. 11 C

Fig. 11 D

Fig. 11
Components of the drill guide system
**A** *Drill and inner and outer guide tubes*
B *All components mated together*
C *Close up of fixation spikes on the outer guide tube*
D *Close up of the calibration marks on the drill shaft that*
   can be used to determine the depth of penetration
   (See text on page 12 for proper interpretation)

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Protective sheath
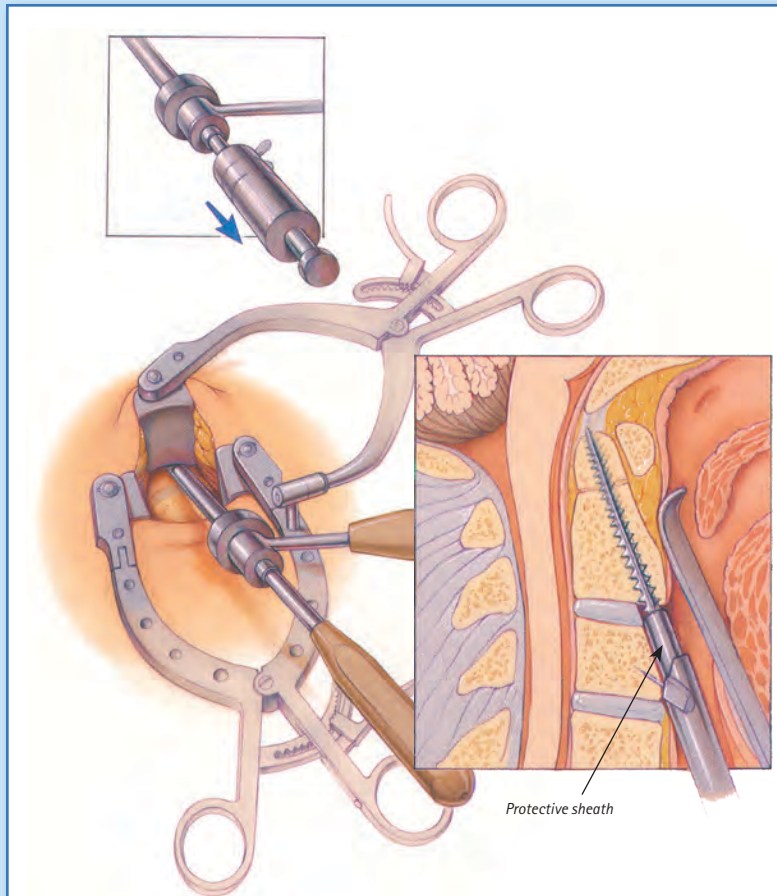
Fig. 12
Inner guide is removed and tap inserted. Tap is used to cut threads into pilot hole.

After the pilot hole is drilled and the depth noted, the drill is withdrawn and the inner guide tube removed. The tap is then inserted (Fig. 12) and rotated by hand while monitoring its progress on biplane fluoroscopy. The tap contains a protective sleeve (Fig. 12) which should be extended up to the base of C2 to protect soft tissue in this area. The tap cuts threads into the bone to accommodate the screw.

The pilot hole is usually visible fluoroscopically. As the tap is advanced to and beyond the fracture line, the alignment achieved at time of drilling is replicated by comparing the saved images taken at the final drill position. This allows precise repositioning without the need for any guide wires.

The entire length of the pilot hole, including the distal odontoid tip cortex, should be tapped for proper screw engagement and prevention of bone fracture. The tap has a calibrated depth gauge, assuming the slide sleeve contacts C2, to reconfirm the screw depth.
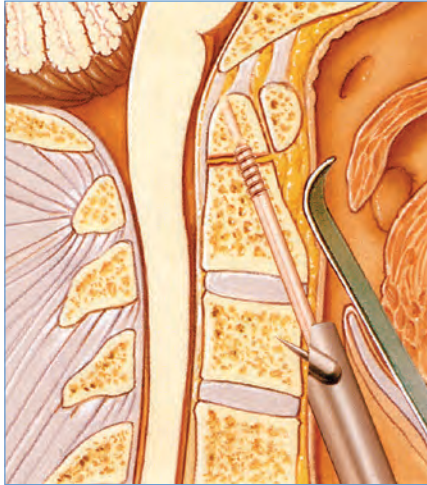
Fig. 13 A
*Screw is inserted through guide tube and advanced through the treaded pilot hole.*
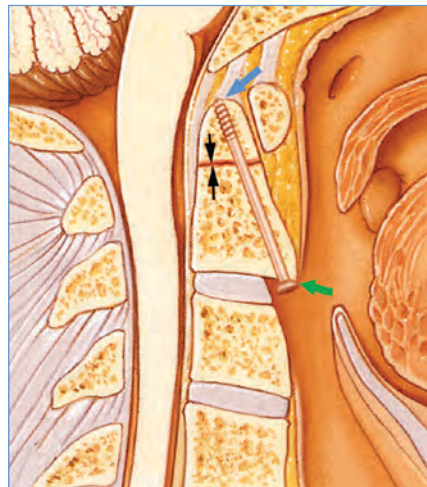
Fig. 13 B
Final screw position. Note that the screw head is up against the inferior C2 cortex (green arrow), and the screw tip has engaged the top of the apical cortex of the odontoid. (blue arrow). In recent fractures, the gap between the odontoid and body of C2 often can be reduced as indicated by the black arrows.
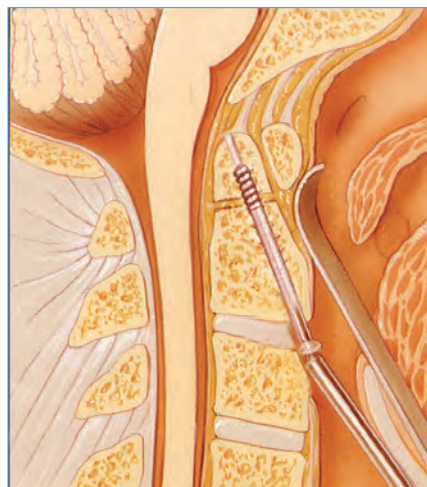
Fig. 13 C
The instrument set includes a ball driver (see fig. 14) which can be used to reengage a screw if it is necessary to replace one with a different length or adjust its final position.

Finally, a titanium screw, which is fully MRI-compatible, is inserted through the guide tube and into the tapped pilot hole. Firmly tighten the screw under biplane fluoroscopic monitoring (Fig. 13 A). The screwdriver has a holding mechanism to keep the screw engaged (Fig. 14). The screw is only threaded distally so it can engage the odontoid distal cortex and "draw back" or pull together the bone fragments if possible. The screw threads engage the distal odontoid cortex while the screw head bears against the inferior cortex of C2 (Fig. 13 B). The "lag effect" closing the fracture gap is usually seen in most acute fractures (Fig. 15 B, D, page 16).

The screw driver in this system includes a holding mechanism that engages the screw head so the screw remains affixed to the driver while being inserted or removed through the guide tube. Once the screw has been inserted into the bone and is being screwed in place, loosening this allows a more firm engagement of the screw head for the final tightening. There is also a ball end screw driver which permits screw engagement even when the driver is not completely co-axial with the screw. This is useful if it becomes necessary to remove a screw, or to change it to a more optimal length or adjust a final positioning (Fig 13C, Fig 14).
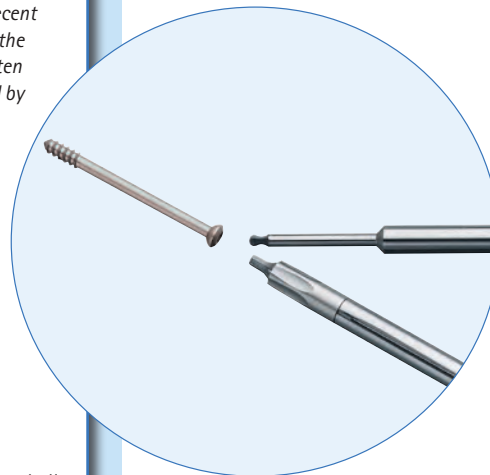
Fig. 14
The lower screwdriver has a holding mechanism to secure the screw while inserting it through the outer guide tube. The upper screwdriver has a ball end, permitting screw re-engagement while not requiring direct axial alignment.

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Fig. 15 A *Type II odontoid fracture with 4-5 mm anterolisthesis.*

Fig. 15 B *Gap between odontoid and body of C2 as seen in AP (anterior-posterior) radiograph.*
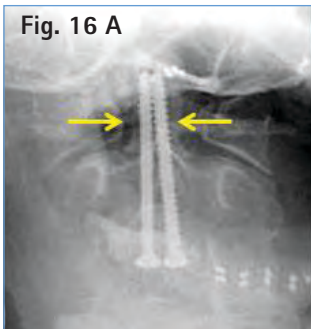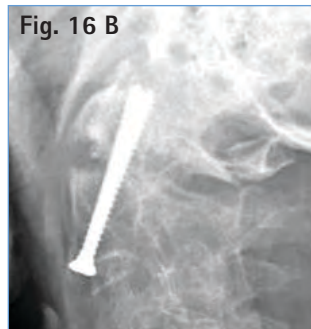
Fig. 15 C

Fig. 15 D
Good reduction and stabilization. Note closure of fracture gap (arrows Fig. 15 B) by lag effect of first screw on patient´s right. The second screw can be either a lag screw or fully threaded one as no additional lag effect is anticipated.
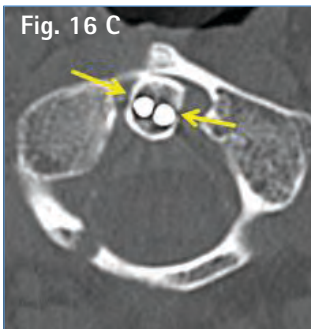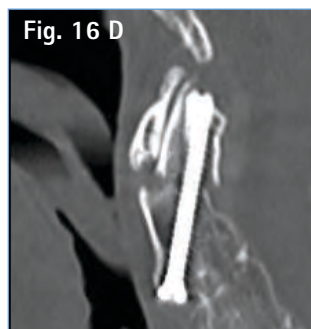
Fig. 16 A

Fig. 16 B

Fig. 16 C

Fig. 16 D

Usually, the anatomy allows[42] a second screw to be placed adjacent to the first by repeating the above steps using an entry point slightly lateral to the first screw (Fig. 15 D, Fig. 16). This provides stronger fixation prior to bone union by preventing rotation of the odontoid relative to the body of C2 and, as previously noted, greatly enhances the chance of success in older patients[43]. A fully threaded screw may be used since no further drawing together of the bone fragments will usually occur.

The wound can then be irrigated, the retractor removed, hemostasis assured and closure effected in layers. Interrupted 3-0 absorbable sutures are used in the sternocleidomastoid muscle fascia, platysma muscle and subcutaneous layer, with adhesive strips on the skin. No drains are placed.

Immediate stability can be confirmed by observing the lateral fluoroscopic image while the patient´s neck is flexed and extended.

Fig. 16
Two screws were used in this patient. By starting the initial one off the midline, converging it into the odontoid off the midline and then repeating this with the second screw, both can be placed. The side walls of the odontoid are visible on the fluoro image (yellow arrows in A), and the postoperative CT (image C) confirms good placement. Note also that both screws penetrate the apical cortex of the odontoid and are buttressed against the inferior cortex of C2.

IV. Discussion

Fig. 17 A   **Fig. 17 B**

Excellent screw position and fracture reduction in an acute odontoid fracture. Dens has reapproximated body of C2 and no fracture line is evident. Fluoroscopically, immediate stability was demonstrated on flexion and extension views.

Fig. 18 A   **Fig. 18 B**

Case of nonunion with failed posterior fusion. Note placement of two fixation screws.

This procedure provides a minimally invasive approach to stabilizing the cervical spine after a traumatic injury resulting in a fracture of the odontoid process (dens) of C2. As noted in the introduction on page 4, such injuries result in instability of the cervical spine allowing translation anteriorly and posteriorly between C1 and C2 and can result in catastrophic spinal cord injury and quadriplegia. As such, it is important to promptly and effectively restore stability in this area.

By utilizing direct screw placement from the inferior aspect of the body of C2 across the fracture into the odontoid process, stability can be immediately restored. This also optimizes the conditions needed to promote bone healing: reduction of the gap and elimination of motion between C2 and the odontoid. In addition, fixation in this manner preserves the normal rotatory motion between C1 and C2 which accounts for 50% of the normal head rotation motion.[31]

The procedure relies on biplanar fluoroscopy to provide real-time information, allowing the screw to be placed with great precision and assuring that no violation of the spinal canal occurs. Because the guide tube system is firmly docked to C3, which moves in concert with C2, the alignment between C2 and the odontoid can be optimized. Using this instrumentation, C2 and C3 can be displaced either posteriorly or anteriorly to correct for any retrolisthesis or anterolisthesis respectively of the odontoid relative to C2. The guide tube system also allows perfecting the trajectory of the screws to their optimal position and selecting a desired trajectory to allow placing two screws, which significantly increases the fusion success rate in patients over the age of 70 from 56% with one screw to 95% with two screws.[43]

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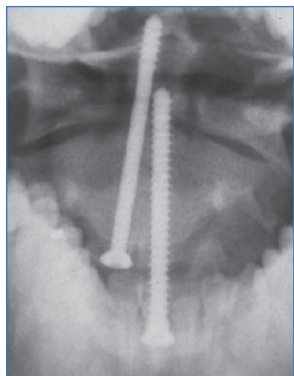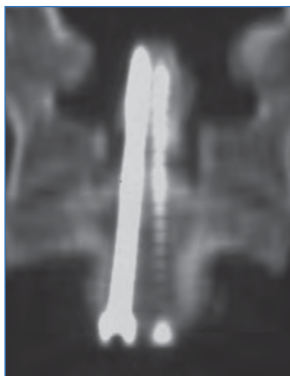
Fig. 19
Example of inadequate screw placement. The screw on the patient's left side was too short and did not properly engage the odontoid cortex. At 6 weeks it was seen to have backed out necessitating a return to the OR to replace it with a longer one.

It is important to note that this technique utilizes a K-wire only to establish an entry site for drilling and the placement of the guide tube system. The actual drilling is done with a drill, not the K-wire. This offers the advantage of precise control of the drill (and screw) path because, unlike a K-wire, the drill has excellent directional stability and will go as directed rather than being deflected off course. Using the guide tube system, there also is no concern about being able to re-access the entry hole or to follow the same pathway with the screw. The odontoid process is held in place by its ligamentous attachments and will not move away from tools and screw. By eliminating the need for a K wire to be used to drill, tap and place the screws, the very dangerous risk of neural or vascular injury due to inadvertent advancement of the K-wire when drilling over it, or placing a screw over it, is eliminated.

By tapping the screw hole, a precise fit between the screw threads and hole is achieved. This also allows removal and replacement of a screw, if needed, using the guide tube system without weakening the screw bone interface. This might need to be done to optimize screw length to achieve the desired placement with the screw head buttressed against the inferior edge of C2 and its tip fully engaging the dense apical cortex of the odontoid. Failure to engage this dense apical bone can result in failure to obtain adequate screw purchase and screw back out. (Fig. 19)

It is important to not only drill but also to tap a millimeter or two through the odontoid cortex as otherwise a screw could fracture the drilled but untapped dense apical cortex, weakening the fixation. The guide tube allows precise control of the drilling pathway. A drill or screw exiting the apex of the odontoid will not endanger any vital structures as it is well anterior to the thecal sac within the apical ligaments. It usually will not converge toward the thecal sac even if it extends for 5 mm beyond the bone. This can be evaluated on the fluoroscopic images and, if the anatomy precludes such a trajectory, then drilling should not extend beyond the odontoid toward the spinal canal.
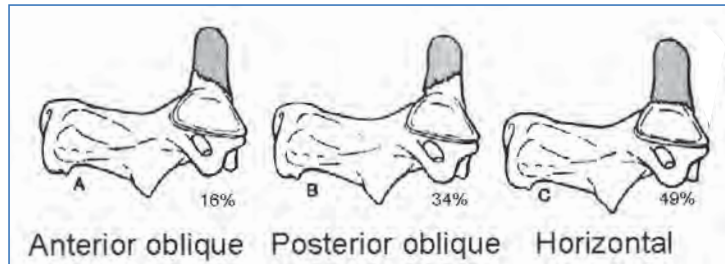
Fig. 20
Orientation of odontoid fractures
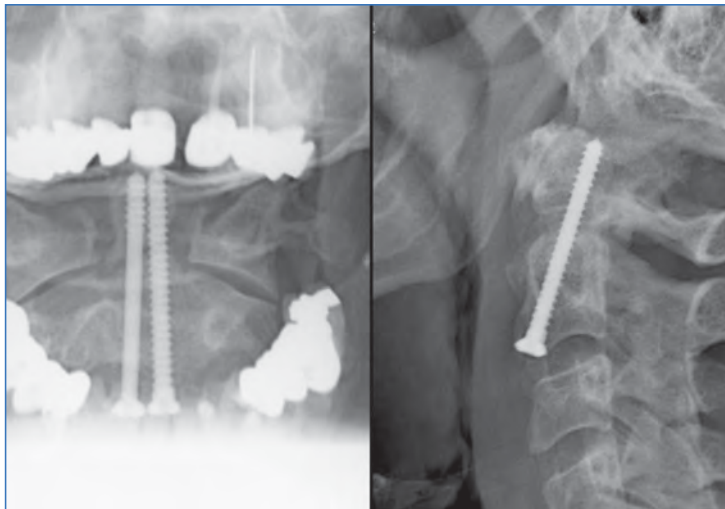
Fig. 21
This patient failed a trial of Halo-vest immobilization. Two well-placed screws resulted in immediate stability, and a solid fusion resulted.

Odontoid fractures can be horizontal or can slope from a higher position posteriorly to a lower one anteriorly (anterior oblique fracture) or vice versa (posterior oblique fracture) (Fig. 20). In our experience, the anterior oblique fracture is the least common (16%) and is the least favorable for screw fixation. With the horizontal fracture, there is little tendency for the odontoid to translate in any direction. With the posterior oblique fracture, the screw will cross the fracture line nearly perpendicular to the fracture line, and there is little tendency for the odontoid to dislocate as the screw is tightened. With an anterior oblique fracture that extends from a higher location posteriorly to a lower position anteriorly, the screw will cross the fracture line obliquely, and there is a tendency for a fixation screw to pull the odontoid forward as it is pulled down to the body of C2. Neck flexion will have the tendency to further exacerbate this prior to boney union. This was the only variation that showed any significant correlation with failure to unite. While not an absolute contraindication, in such cases we have achieved successful fusion by placing our screws with the odontoid slightly retrolisthesed and also use a rigid cervical collar for the first few weeks to reduce neck flexing movements.

In our experience [40], we achieved equally good results in acute fractures and those up to six months of age. The latter were either overlooked/ misdiagnosed or more commonly were patients who had failed treatment with rigid (usually Halo-vest) immobilization. (Fig. 21) However, chronic non-unions over 18 months of duration only achieved 25% fusion success. For this reason, we do not advocate it for such chronic non-unions, but fractures less than six months are candidates if other factors are favorable.
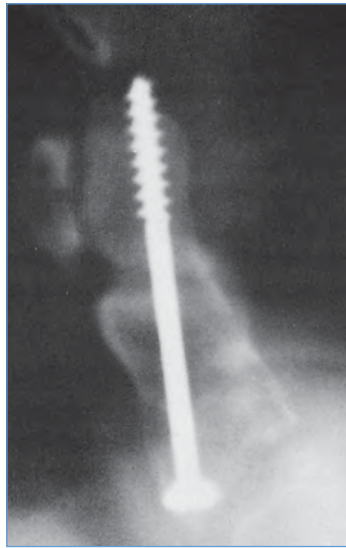
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V. Follow–Up Care

Fig. 22 A
Tomogram of odontoid fracture.

Fig. 22 B
Postoperative tomogram at four months shows early bony fusion.

Fig. 22 C
This is further solidified at six months.

There is no data to suggest that the use of cervical collar is of any value after this surgery. Therefore, we usually do not prescribe this but instead encourage our patients to do gentle daily range of motion exercises (rotation and flexion-extension). The patient is, however, cautioned to avoid strenuous, bouncing or jarring activities. The exceptions are in the case of an anterior oblique fracture as discussed on page 19 and in the case of non-compliant patients who needs to reminded to restrain from vigorous physical activity. A collar may also be used if there is any question about the quality of the screw purchase due to osteopenia. Typically, patients can be discharged in one to two days after surgery and promptly resume normal non-traumatic activities and employment.

Follow-up radiographs are taken at one day and then at 6 to 12 week intervals until bony union is achieved. Tomography or thin section CTs with sagittal reconstructions may be required to define this better (Fig. 22), as the adjacent bones are quite dense and may mask initial bony union. While no longer needed once bony union occurs, we have not found it necessary to remove the screws.

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