

# Assessment of Cervical Screw Trajectory Using 3-Dimensional Software Planning

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## Abstract

**Objective:** It is important and helpful for surgeons to understand the correlation between spinal anatomy and screw trajectory before surgery. We aimed to assess a simple technique using 3D imaging software available on the hospital intranet for visual and quantitative feedback to prepare surgeons for an appropriate entry point and safe trajectory when placing cervical screws. **Methods:** A total of 59 cervical screws were inserted from C1 to T1 in 12 consecutive patients using this technique. First, a single CT optimal slice was selected from 3D CT images of the cervical spine to determine the intervals of bilateral entry points and lateral angle. Next, this 3D image was rotated to the lateral angle. Finally, bone was cut out on the entry point using subtractive manipulation, which removed the core of the pedicle or lateral mass. Screw trajectory was indicated, and surgeons could assess the correlation between surface landmarks, spinal anatomy, and screw trajectory. Posterior cervical fusion was performed using fluoroscopy. Postoperative outcomes and incidence of complications were retrospectively assessed. **Results:** One perforation (1.4%) was identified on postoperative CT images. No vascular injuries occurred. Differences in the intended entry point location and lateral angle of the screw from actual postoperative values were  $1.49 \pm 1.23$  mm and  $5.46^\circ \pm 4.46^\circ$ , respectively. **Conclusions:** A novel 3D CT imaging assessment underwent in cervical screw fixation. This technique is easily accessible on the hospital intranet and provides training in cervical screw placement for fellows. Surgeons can simulate screw placement and share surgical strategy.

## Keywords

Cervical Screw, Trajectory, 3D CT Planning, Simulation, Training

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## 1. Introduction

Cervical spine anatomy varies greatly. Successful placement of a cervical screw requires sufficient three-dimensional (3D) understanding of cervical structures to allow accurate identification of an ideal screw trajectory [1]-[3]. Cervical screw instrumentation has advantages of rigid and effective fixation of the cervical spine [4]-[6]. However, cervical screw misplacement can injure the vertebral artery (VA) and nerves [7]-[9].

To place cervical screws accurately and safely, the following surgical techniques have been proposed: 1) pre-operative assessment, 2) identification of surface landmarks, 3) laminoforaminotomies, and 4) use of computer-assisted surgical guidance systems [10]-[15]. Surgeons integrate these techniques before placing screws. Therefore, it is important and helpful for surgeons to understand, preoperatively, the correlation between surface landmarks, spinal anatomy, and screw trajectory.

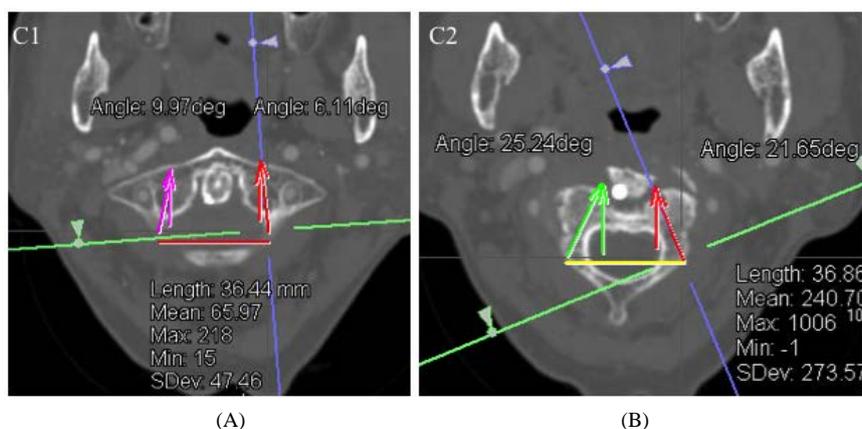
Recently, a number of software programs have been used to reconstruct three-dimensional (3D) images [16]. Simulators for screw insertion have been developed to minimize the misplacement of pedicle screws [12] [13] [15]. A computer-assisted surgical guidance system and CT-based navigation reduce the risk of VA and nerve injury. However, these systems are neither simple to use for preoperative assessment, nor commonly implemented in a hospital intranet system. In this report, we propose a simple technique using 3D software to allow for an appropriate entry point and safe trajectory on the hospital intranet monitor. Surgeons can simulate, and then share the information and surgical strategy. This technique can provide training in cervical screw placement for surgical residents and fellows.

## 2. Materials and Methods

In this study, a 3D CT scan of the cervical spine of the patient is first obtained using 1-mm slice thickness (Aquilion 16, Toshiba Medical Systems Corp.). The Aquarius workstation was used to reconstruct 3D images (Aquarius NET, TeraRecon, Inc.).

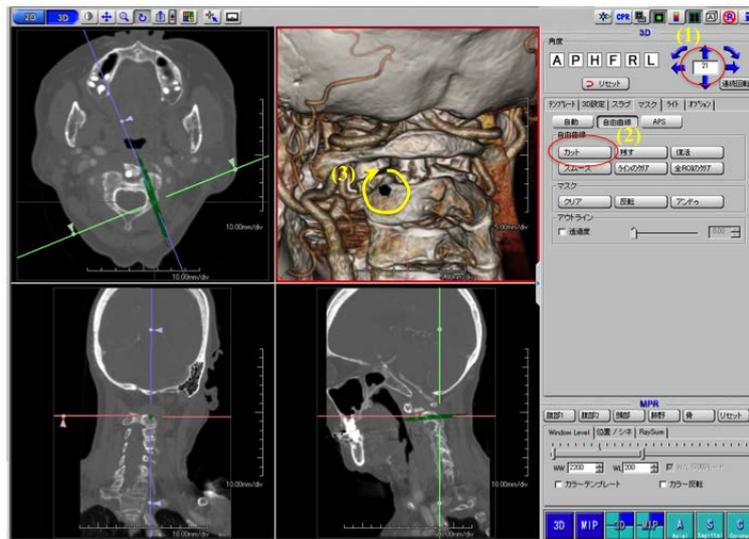
Three multiplanar reformation planes (sagittal, coronal, and axial) are shown for the indicated location. Surgeons can access this workstation via the hospital intranet.

As described below, surgeons simulate and manipulate the virtual position of the cervical screw. For the first step, a single best axial image is chosen for each vertebral level on which the pedicle, lamina, and transverse foramen are all included for the pedicle screw to be placed (Figure 1). Bilateral lines passing through the centers of the isthmus of the pedicles are drawn directly on the CT image. The entry point is the point of intersection between the line and lateral mass. The intervals of bilateral entry points and left and right lateral angles are obtained. For lateral mass screw placement, a modified Magerl screw placement technique is used. The targeted entry point is 1 - 2 mm medial and 1 - 2 mm inferior to the lateral mass center, and the screw trajectory is parallel to the facet joint under fluoroscopy.

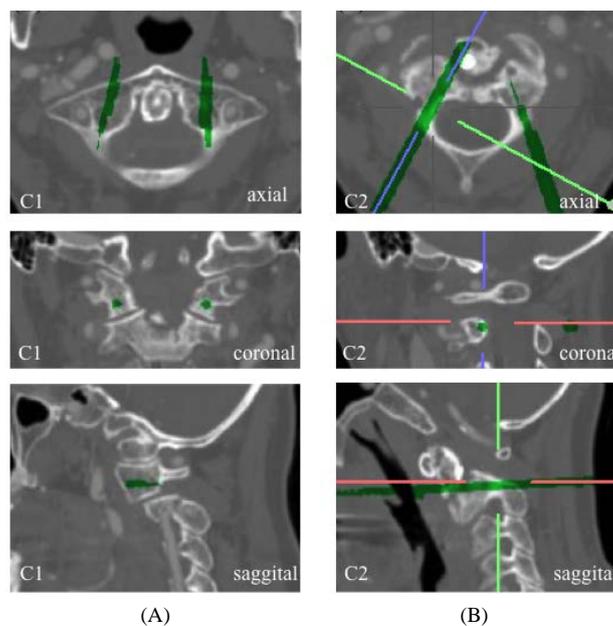


**Figure 1.** Multi-planar images showing a single best CT image captured from reconstructed 3D CT images of the cervical spine in case of dens fracture. On this image, we determined the intervals of bilateral entry points, and the lateral angle. In case of dens fracture, (A) C1: right lateral angles, 9.97 degrees; left lateral angles, 6.11 degrees; the intervals of bilateral entry points, 36.44 mm; (B) C2: right lateral angles, 25.24 degrees; left lateral angles, 21.65 degrees; the intervals of bilateral entry points, 36.86 mm.

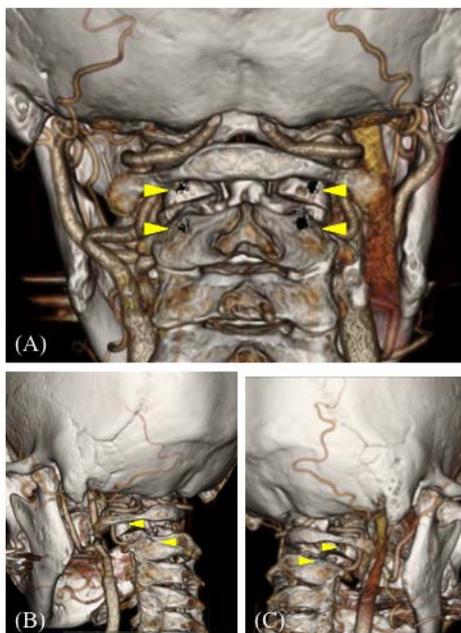
Then, the locations of left and right entry points are marked on reconstructed 3D CT images. The intervals of entry points indicate the location of the left and right entry points. Next, this 3D image is rotated to the selected lateral angle (**Figure 2**). Bone is subtracted from the marking using removing manipulation, which removes the core of the pedicle and lateral mass. Moving the cursor to make small circle will cut out the shape directly (**Figure 2**). Screw trajectory is indicated by a green line, and viewed in the axial, coronal, and sagittal planes (**Figure 3**). The correlation between surface landmarks, anatomy, and screw trajectory is assessed on reconstructed 3D images (**Figure 4**). If the virtual screw trajectory deviates from the pedicle and lateral mass, rotation and entry points can be readjusted.



**Figure 2.** Screw trajectories are assessed on reconstructed 3D images. The following three steps are performed: (1) enter the lateral angle, and then, this 3D image automatically rotates to the lateral angle; (2) select removing manipulation; and (3) move cursor to make a small circle on either entry point (yellow arrow). You can see the proper insertion point and insertion trajectory of screws. Screw trajectory is indicated by green line.



**Figure 3.** Bilateral screw trajectories are indicated by green line, and shown in the axial, coronal, and sagittal views. (A) C1 lateral mass screws; (B) C2 pedicle screws in case of dens fracture.



**Figure 4.** Correlation between surface landmarks, anatomy, and entry points (yellow arrow heads) in case of dens fracture. (A) Posterior view; (B) (C) Posterolateral views.

Twelve consecutive patients (6 men and 6 women) undergoing posterior cervical fusion underwent placement of cervical screws using fluoroscopy, but not using a CT image-guided system, since 2010 at Osaka University Hospital. The average patient age was 70 years. There were 6 schwannomas, 2 atlanto-axial dislocation, 1 retroodontoid pseudo tumors, 1 dens fracture, 1 basilar impression, and 1 multiple myeloma. Forty-four lateral mass screws (C1: 8, C3-C6: 36) and 15 pedicle screws (C2: 7, C7-T1: 8) were placed. The fluoroscopic image intensifier was positioned so that the cervical vertebra of interest was centered in the anterior, posterior, and lateral planes. Screws with polyaxial heads were used in all cases. The entry points were determined from preoperatively measured distances for bilateral entry points using a ruler and surface landmarks, and then decorticated using a high-speed drill under microscopy. A protractor was used for indicating preoperatively measured right and left lateral angles. The rostral-caudal angle of screw trajectory was determined under fluoroscopy. Tapping was performed along the protractor under fluoroscopy. After the holes were probed with a small ball-probe to verify that there was no bony breach, screws were placed. To evaluate screw position, postoperative radiographs and CT scans were obtained (Figure 5).

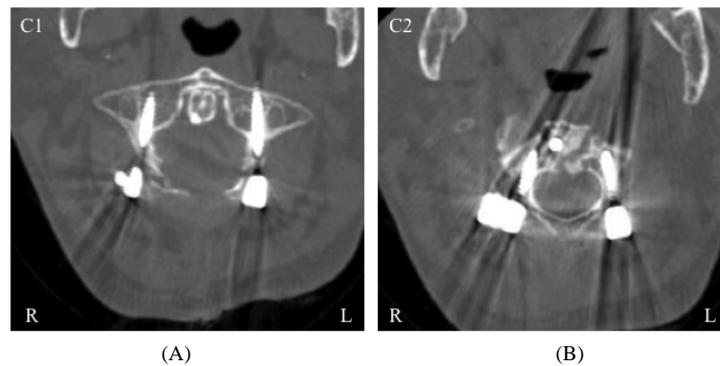
### 3. Results

Differences in the intended entry point and lateral angle of the screw from actual postoperative values were  $1.49 \pm 1.23$  mm and  $5.46^\circ \pm 4.46^\circ$ , respectively. No vascular injury was encountered. One perforation (1.4%) was identified on postoperative CT images in which a C7 pedicle screw diameter was completely exposed. We could not detect the C7 vertebra on intraoperative fluoroscopy because the patient's shoulder obscured it.

### 4. Discussion

We propose a simple preoperative assessment for determining an ideal trajectory for cervical screw placement. This method is reproducible, and provides informative training for surgical residents and fellows. This method can present information on the correlation between surface landmarks and screw trajectory. Surgeons can manipulate planning images on the intranet system and then share this information and surgical strategy. However, it is not possible to conclude that this method facilitates cervical screw fixation with decreased risk of VA and nerve injury because of the small sample size.

Various educational software programs are available for pedicle screw insertion [12] [17] [18]. Practice on a simulator is very helpful in teaching residents and fellows about patient-specific spine anatomy. It is important



**Figure 5.** Postoperative axial CT images demonstrate proper insertion of the screws in case of dens fracture. (A) C1 lateral mass screws; (B) C2 pedicle screws.

for trainees to have access to these educational tools. These systems are of benefit to surgical trainees in improving the trajectory of pedicle insertion. As our technique is performed on the hospital intranet monitor, surgeons are not relatively constrained to use a particular workstation.

A computer-assisted surgical guidance system has been reported to reduce the risk of nerve and VA injury. In our technique, there were deviations between planned and postoperative lateral angles in screw placement. These findings indicated that intraoperative correction was needed despite preoperative planning. Although a computer-assisted surgical guidance system is not simple to use, it can prepare surgeons for an appropriate entry point and plan a safe trajectory by providing accurate and dependable information for intraoperative correction.

## 5. Conclusion

We propose a simple technique using 3D software to plan appropriate entry points and safe trajectories for cervical screw placement. This technique can be accessed easily on the hospital intranet and also provide training in cervical screw placement for residents and fellows. This procedure can help determine correlations between surface landmarks and screw trajectory. Surgeons can simulate appropriate screw placement. However, there are limitations of this study because of the small sample size. The intraoperative correction was needed to more precisely place screws.

## Acknowledgements

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## Disclosure

The authors report no conflicts of interest concerning the materials or methods used in this study or the findings specified in this paper.

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