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Original Article

# "Two-step" technique with OsiriX™ to evaluate feasibility of C2 pedicle for surgical fixation

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## Abstract

**Background:** Surgical treatment of craniovertebral junction pathology has evolved considerably in recent decades with the implementation of short atlanto-axial fixation techniques, notwhithstanding increasing neurovascular risks. Also, there is strong evidence that fixation of C2 anatomical pedicle has the best biomechanical profile of the entire cervical spine. However, it is often difficult and misleading, to evaluate anatomical bony and vascular anomalies using the three orthogonal planes (axial, coronal, and sagittal) of CT. **Objectives:** The authors describe an innovative and simple technique to evaluate the feasibility of C2 pedicle for surgical screw fixation using preoperative planning with the free DICOM (Digital Imaging and Communications in Medicine) software OsiriX™. **Materials and Methods:** The authors report the applicatin of this novel technique in 5 cases (3 traumatic, 1 Os Odontoideum, and 1 complex congenital malformation) collected from our general case series of the Department in the last 5 years. **Results:** In this "proof of concept" study, the pre-operative analysis with the "two-step" tecnique was detrimental for choosing the surgical tecnique. Detailed post-operative analysis confirmed correct position of C2 screws without cortical breach. There were no complications or mortality reported. **Conclusion:** This "two-step" technique is an easy and reliable way to determine the feasibility of C2 pedicle for surgical fixation. The detailed tridimensional radiological preoperative evaluation of craniovertebral junction anatomy is critical to the sucess and safety of this surgeries, and can avoid, to certain degree, expensive intra-operative tridimensional imaging facilities.

**Key words:** C2 pedicle, multi-planar reformatting (MPR), OsiriX™

## INTRODUCTION

In the last decades, the development of surgical techniques, such as posterior atlanto-axial short fixations,[1] have gradually replaced the occipital-cervical (subaxial) long fixations. Moreover, there is strong evidence that fixation of C2 vertebra, and particularly its anatomical pedicle, has the best biomechanical profile of the entire cervical spine, either in short (C1-C2) or longer constructions (C0-C1-C2 or C2-subaxial).[2,3] However, quite often, it is difficult, and sometimes misleading, to evaluate anatomical bony variations (i.e., C2 pars or pedicle morphology) and vascular anomalies [i.e., high riding vertebral artery (VA)] using only the conventional three orthogonal planes of CT

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(axial, coronal, and sagittal).[4] For example, in Figure 1 (a type II odontoid fracture in a 92-year-old patient [case 2]), only by changing the gantry angle of the axial plane (from the plane of the inter-vertebral disc to the possible pedicle angle) is enough to clarify the position of VA. Additionally, frequently the "true" plane is biased either because of suboptimal acquisition technique, or because of patient-related factors, such as scoliosis, rotation, or dislocation of vertebral bodies.

There is also debate related to the best intraoperative imaging facility, ranging from free-hand technique to three-dimensional (3D) fluoroscopy or intraoperative computed tomography (CT).[5-7]

## MATERIALS AND METHODS

The authors propose a new and easy technique to rapidly evaluate the feasibility to surgical screwing of C2 pedicle using the multi-planar reformatting (MPR) function of OsiriX™, a free-source DICOM ("Digital Imaging and Communications in Medicine") software. We use this function of OsiriX™ (version 5.5.2, Pixmeo, Geneva, Switzerland) to determine the anatomical variations (i.e., C2 pedicle/VA route) of this region in only two simple steps and additionally to calculate the position, length and angle of screws, as others have described.[4]

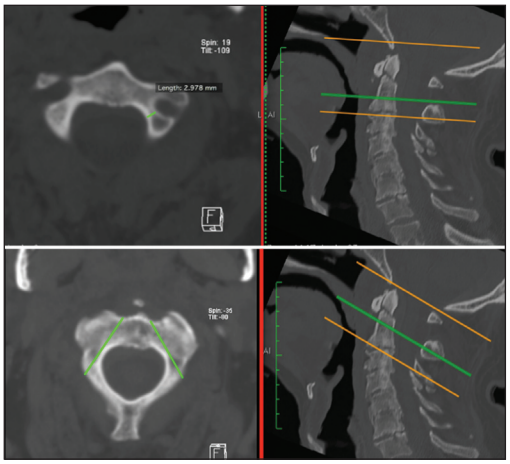

**Figure 1: Effect of variation of gantry angle on perception of high-riding vertebral artery: upper pictures depicts axial plane parallel to vertebral disc with bilateral high-riding vertebral artery; below, just by tilting to the interpolation angle (parallel to pedicle axis) it is clear the change in perception on anomalous vertebral artery**

All patient had a thin cut cervical spine CT (1.25mm) either noncontrast or CT angiography (CTA), that was loaded in the DICOM software. Using the MPR tool, we perform the first step of reconstruction to the true axial and sagittal plane of C2 vertebrae, aiming to correct possible deformity or inaccurate acquisition technique. In a second step of reconstruction, we try to find the true anatomical pedicle of C2, with the "parasagittal" (yellow in figures) and "paraaxial" (purple in figures) planes showing the longitudinal axis of the "true" pedicle and the "paracoronal" (blue in figures) plane showing the cross-section of the pedicle. The narrowest point of this plane is the most important value to judge if the pedicle is feasible for screwing.

Usually, we prefer to have a margin, of at least 1 mm in each side, which means that for a 3.5 or 4.0 mm screw we ought to have a minimum of 5.5 or 6.0 mm pedicle, respectively.

Additionally it is possible to calculate the lateral-to-medial and caudal-cranial angles, as well as the entry point from the midline and the possible length of the screw, as adapted from others [Figure 2].[8]

The authors exemplify this technique in five cases out of the general series of craniovertebral junction (CVJ) pathology operated in the last 5 years in our department. All patients in our series were operated with 2D fluoroscopy.

### Case 1

A 86-year-old female with a C2 body fracture (coronal split) sustained after ground-level fall. The initial CT without reconstruction (first column to the left in the picture) reveals a probable *high-riding* left VA with narrow pedicle. However, it is possible to see that there is a huge bias because of the incorrect position of the axes of gantry planes. After the first step of

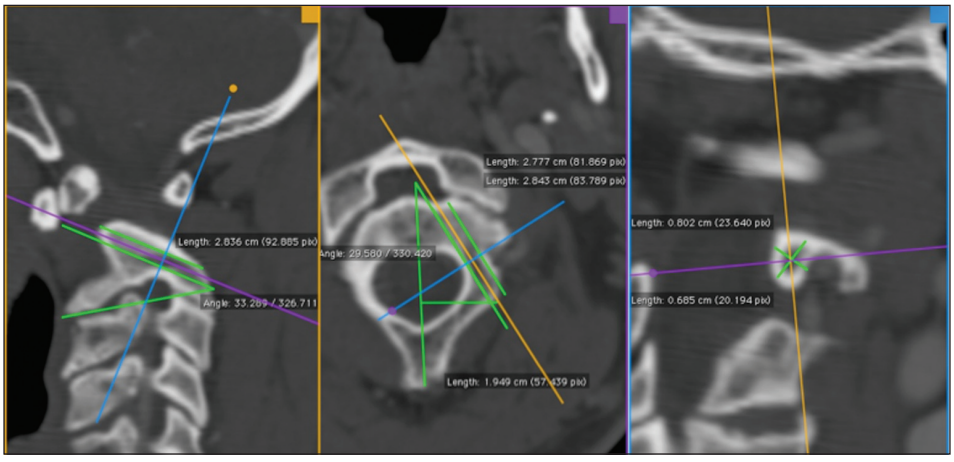


**Figure 2: Exemplification of measurements possible after the "two-step" reconstruction technique: Screw length, entry point, lateral-to-medial angle and caudal-cranial angle**

reconstruction [to the true axial (purple in Figure 3) and sagittal planes (yellow)] the pedicle seems favorable. After the second step of MPR (correction for the true pedicle axis), we found the pedicle to be reasonable (7.1 × 8.6 mm) for a pedicle screw (blue). The patient was treated with C1-C2 posterior fixation (Goel's technique);[9,10] the last column shows the postoperative scan with adequate position of the screws [Figure 3].

## Case 2

A 92-year-old male with a type II odontoid fracture from low-energy trauma (hyperextension mechanism). The patient had no neurologic deficits and the dynamic x-ray and CT showed atlantoaxial instability. In first column to the left, the CT without any reconstruction depicting a probable *high-riding* left VA with narrow pedicle. However, after two steps of MPR we found the pedicle to be reasonable (7.9 × 6.4 mm) for a pedicle screw. This patient was treated with C1-C2 posterior fixation (Goel's technique); the last column shows the postoperative scan. The postoperative period was uneventful, without any morbidity [Figure 4].

## Case 3

A 41-year-old male with a late diagnosis of an *Os Odontoideum* with severe atlanto-axial instability, due to persistent mechanical axial cervical pain without neurologic deficit, but with Lhermitte's sign and constant episode of cervical "blockage." In the first column to the left, the CT without any reconstruction depicting a probable *high-riding* left VA (even with a reasonable "orthogonal" gantry plane); after two steps of MPR we found the pedicle to be favorable (7.6 × 8.6 mm) for a pedicle screw, although with a mild *high-riding* vertebral on left; This patient was treated with C1-C2 (pedicle bilaterally) posterior fixation (Goel's technique), but on the left, purposely, it was done a more convergent (lateral-to-medial) and superior (caudal-cranial) trajectory. The last column on the right shows the postoperative scan with a very good result, namely the left pedicle screw without cortical breach very close to the prominent VA (arrow on the picture) [Figure 5].

## Case 4

A 63-year-old male presented with a diagnosis of an acute shallow type III odontoid fracture with dislocation, due to high-

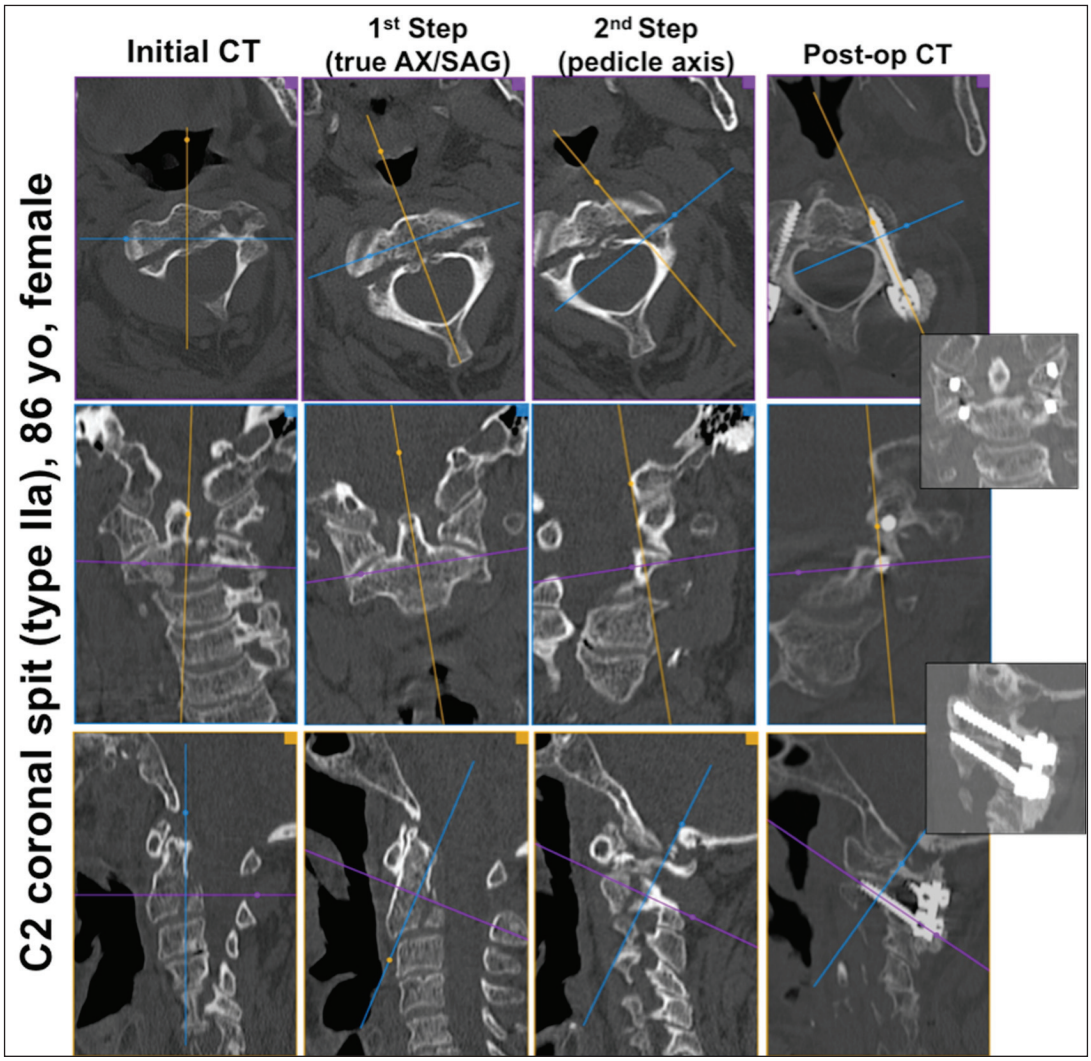


**Figure 3: Case 1, C2 coronal split of C2: Effect of 3D reconstruction (see text for details)**

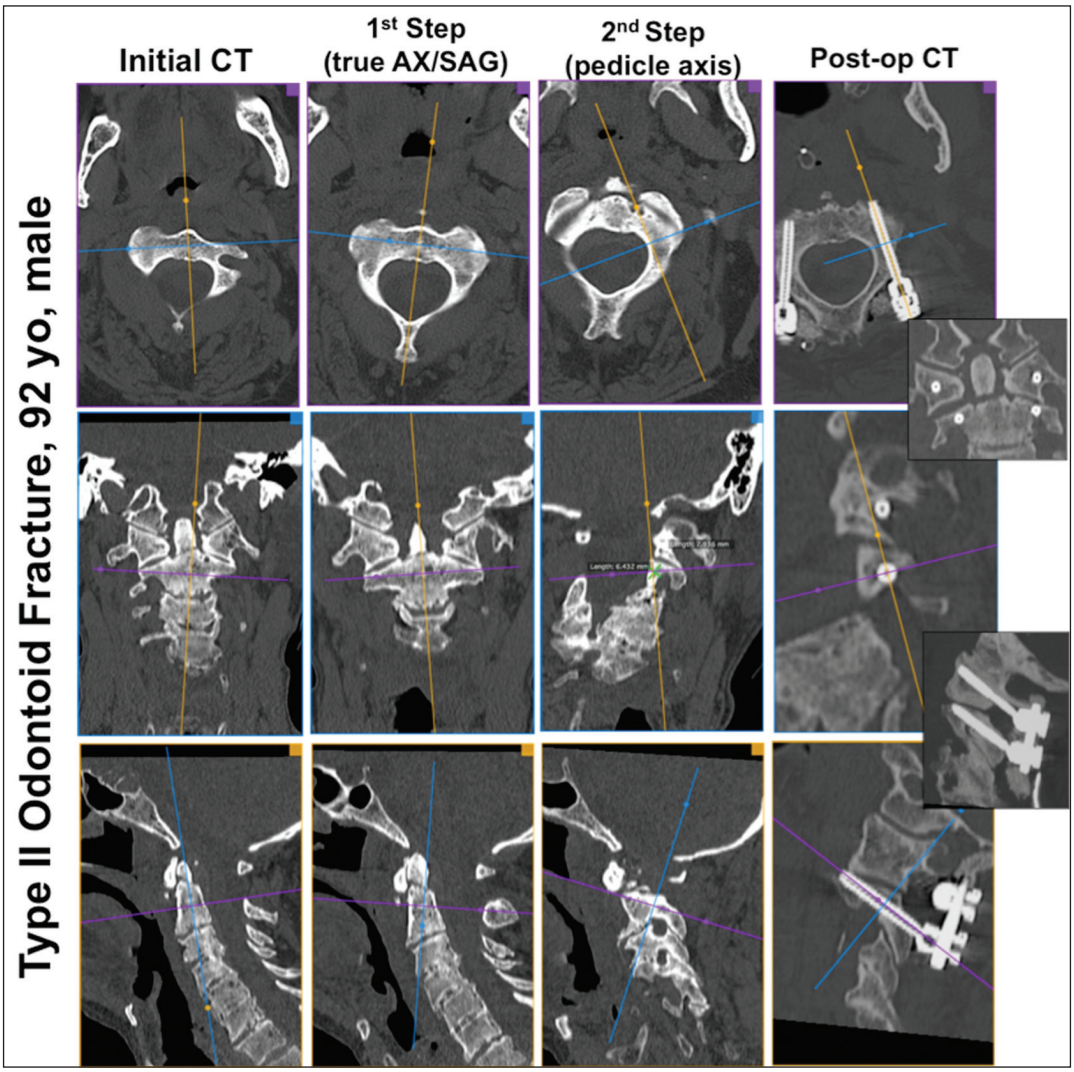


**Figure 4: Case 2, type II odontoid fracture: Effect of 3-D reconstruction in evaluation of vertebral artery anatomy (see text for details)**

energy trauma (fall from height). The first CT revealed probable bilateral high-riding vertebral arteries. However the two steps 3D reconstruction confirms adequate pedicle for screwing (8.2 × 6.2 mm on the left and 7.9 × 6.5 mm on the right). The patient was treated with a C1-C2 posterior fixation (pedicle bilaterally), with excellent result, with normal alignment of the fracture and correct position of the screws. Clinically, the patient had no neurological deficit and no complications [Figure 6].

### Case 5

In the last case, we report a 62-year-old female with a late diagnosis of a very rare CVJ malformation with atlantoaxial instability due to bipartite atlas (fusion defect of C1 anterior and posterior arches[11,12]) and an odontoid hypoplasia.[13] The patient had a long-term mild tetraparesis that began to deteriorate one and a half years prior to referral to our department. Again, the first CT depicts a probable *high-riding* left VA, but after the first step of reconstruction it seemed to be favorable for screwing. However, after the second step the pedicle was found to be in the borderline zone (5.3 × 5 mm) for a pedicle screw and it was decided to perform crossed translaminar technique in C2[14,15] associated with a standard lateral mass screw in C1 (last column the postoperative scan). The patient reported an impressive neurologic recovery, without postoperative morbidity [Figure 7].

## RESULTS

The authors present this "proof of concept" study based on their general case series of CVJ pathology treated in the department in the last 5 years. In all 5 cases presented in this paper, the first pre-operative analysis showed anatomical variations precluding safe pedicle screwing (high-riding vertebral artery, for example). However the 3-D multiplanar reconstruction was able to correctly determine the exact measurements of the true anatomical pedicle of C2 vertebra, that was within the safe limits for surgical fixation in 4 cases. Only in one case, due to borderline dimensions of the pedicle (5,3x5mm), it was considered safer to perform an alternative technique (translaminar crossed screwing). Therefore, using the pre-operative analysis with the "two-step" reconstruction was

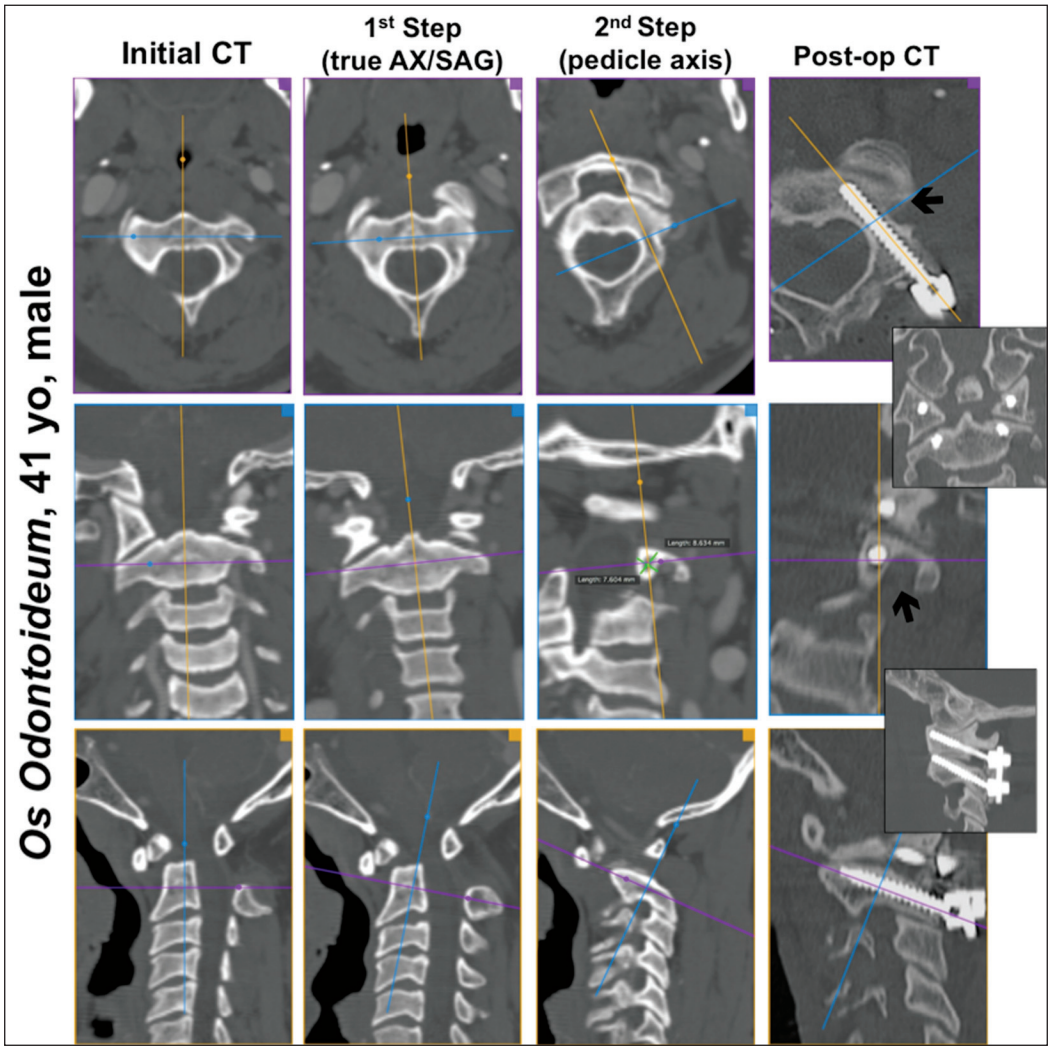


**Figure 5: Case 3, Os Odontoideum: "Two-step" 3-D reconstruction (see text for details)**

detrimental for choosing the surgical technique for posterior C2 screwing in every case. Detailed post-operative analysis with "thin-cut" CT confirmed correct position of C2 screws without cortical breach or vascular complications. There was no other complications or mortality reported.

## DISCUSSION

The short posterior cervical fixation techniques (such as Goel's technique) presents potential increased risks of neurovascular complications, but shows high effectiveness in the consolidation of fusion, maintaining great part of cervical range of motion (theoretically reducing around 50% of cervical rotation, but maintaining flexion and lateral bending). There is also some evidence that fixation of C2 vertebra and particularly its anatomical pedicle is biomechanically the strongest screwing modality in C2 vertebra. The incorrect acquisition of the CT scan or the proper deformity of each patient renders very difficult and misleading to judge feasibility of this surgical technique only by the original orthogonal three planes.

One critical step is to obtain a preoperative thin-cut CT, as "thicker" CT scans may hinder the reconstruction image quality and therefore impar correct reading of measurements. There is also some debate whether to perform CTA in every patient to study the anatomy of this region. As shown by Tomasino *et al.*,[16] there is enormous variation in VA occupancy in transverse foramen throughout entire cervical spine. At the same time, O'Donnell *et al.*[17] evaluated 975 patients and found only 0.42% with extraosseous VA anomalies. Therefore, we agree with the opinion that there is no recommendation for routine preoperative CTA in upper cervical spine surgery. Either because of relatively rare extraosseous VA anomalies or because the C2 pedicle screw technique in purely intraosseous, meaning that, avoiding cortical breach at any mean, will prevent VA injury, independent of the real intraosseous trajectory. In our department, in general, we order a CTA only in certain cases such as C2 body fracture reaching transverse foramen, (with potential VA stenosis or dissection) or in some congenital CVJ malformations in syndromic patients (i.e., Down's syndrome),[18] or inflammatory conditions, both with evidence of increased number of VA anomalies.

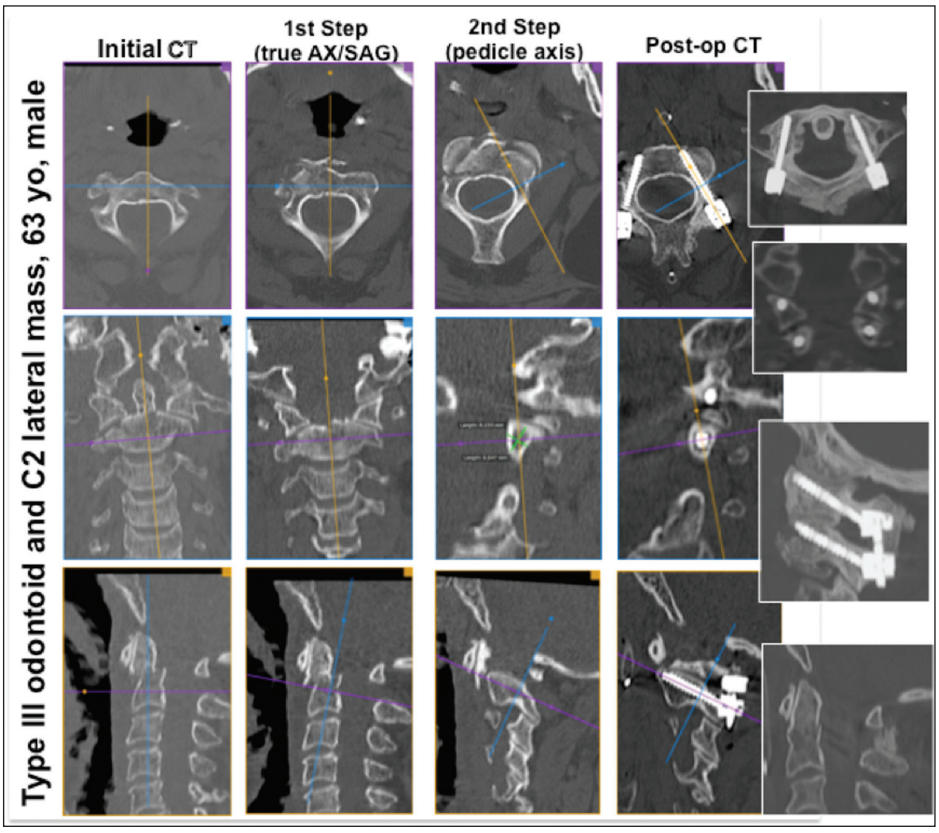


**Figure 6: Case 4, shallow type III fracture: Effect of 3-D reconstruction (see text for details)**

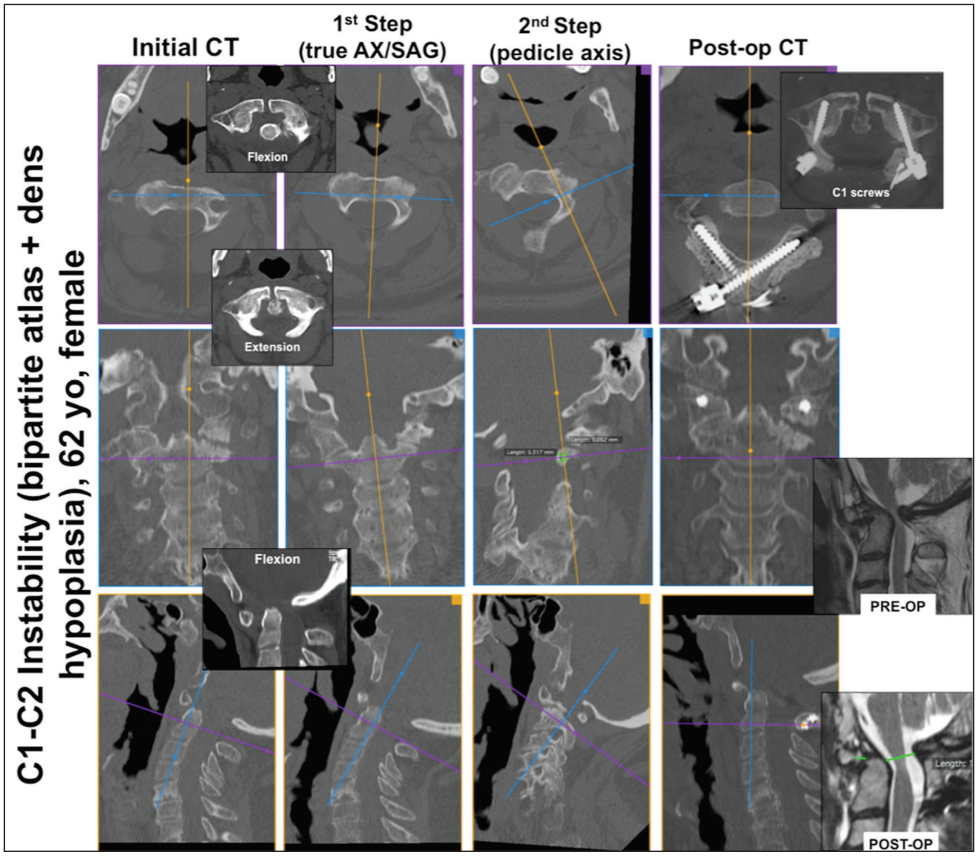


**Figure 7: Case 5, rare CVJ malformation (bifid atlas and odontoid hypoplasia): Effect of 3D reconstruction (see text for details)**

This simple and practical "two-step" reconstruction technique described by the authors, allows for a rapid determination of the narrowest point of pedicle of C2. This is, in our experience, the main factor to determine the feasibility for preforming C2 pedicle screwing with safety and effectiveness. Furthermore, after obtaining the "true" anatomical pedicle, it is possible to quickly measure the correct angle and entry point for each screw, as this may vary from patient to patient. Also, there is no consensus in the cutoff size that enables safe C2 pedicle screwing. Burke *et al.*[19] report an analysis on 47 patients (94 samples) in which they measure the length and width of each C2 pedicle with OsiriX™. They found an overall average width of C2 pedicle of 8.272 +/-1.364 mm and, with the same criteria of 1 mm free for each side, they calculate that 98% of pedicles tolerate a 3.5 mm screw and 97% a 4.0 mm screw.

## CONCLUSION

The authors propose a simple and effective "two-step" technique to access the feasibility of C2 pedicle for surgical screwing. The preoperative detailed study with OsiriX™ is, in our experience, crucial to study the vascular and osseous variations of CVJ and especially to study the feasibility to screw the true anatomical pedicle of C2 and, therefore, can change the approach or surgical technique. Additionally it provides valuable information concerning the angles and trajectories (lateral to medial and caudal to cranial, as well as proper length and correct entry point).

This technique is, in author's opinion, an invaluable tool to improve safety and effectiveness in complex CVJ surgery. It also proves that, with detailed tridimensional radiological evaluation of this complex anatomical region, this type of surgeries can be performed even without advanced intraoperative technology, such as 3-D neuronavigation, only available in a limited number of departments.

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### Conflicts of interest
There are no conflicts of interest.

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