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IDEAS AND TECHNICAL INNOVATIONS

Transuncovertebral joint screw placement: technical note

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Abstract
Purpose Although a C2 pedicle screw and a C1–2 transarticular screw are the most rigid anchors, these screws cannot be used in cases with bilateral high-riding vertebral arteries. The authors describe their recent experience using a novel method of C2–3 transuncovertebral joint screw placement for occipitocervical fixation.
Methods A 67-year-old patient suffered myelopathy due to instability at C1–2. The patient had bilateral high-riding vertebral arteries that precluded the use of a C2 pedicle screw or a C1–2 transarticular screw.
Results A C2–3 transuncovertebral joint screw was applied bilaterally under 3D navigation guidance. The patient's postoperative course was uneventful, and his neurological status improved after the surgery. Bony fusion was achieved after the surgery.
Conclusions This is the first report to describe the technique of transuncovertebral joint screw. Using a C2–3 transuncovertebral joint screw, a long screw could be used, and it provided an anchor at C3 and C2 from a posterior approach.

Keywords Cervical spine · Uncovertebral joint · Transarticular screw · Cervical pedicle screw · Navigation surgery

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Introduction

A C2 pedicle screw and a C1–2 transarticular screw are the most rigid anchors to C2 [1]. However, these screws cannot be used in cases with bilateral high-riding vertebral arteries because of the high risk of vertebral injury. Alternative methods of anchoring to C2, such as a C2 laminar screw [2] and hook [3], are biomechanically inferior to a C2 pedicle screw and a C1–2 transarticular screw [1, 4]. When a C2 pedicle screw or C1–2 transarticular screw is not applicable for occipitocervical fusion, extending the fusion segment to C3 or even lower is selected. Because the cervical fusion end needs to sustain the heavy head, a rigid anchor is required. In the present case report, a novel screw placement method, a C2–3 transuncovertebral screw, where a long screw is applied through the cervical pedicle and the uncovertebral joint from a posterior approach, is introduced.

Case presentation

A 67-year-old man with dwarfism (126 cm in height and 31 kg in weight) complained of a 3-year history of neck pain and numbness in the extremities. Although he received conservative treatment, his symptoms gradually worsened. He became unable to walk after he fell down 3 months ago. X-ray and computed tomography (CT) examinations showed instability at C1–2 with os odontoideum (Fig. 1a–d). Magnetic resonance imaging (MRI) showed severe compression of the spinal cord at C1–2 and a fluid signal at the os odontoideum (Fig. 1e). Incomplete quadriplegia seemed to be caused not only by instability but also structural stenosis at C1/2. Surgical decompression and fusion at C1–2 were scheduled. However, contrast-enhanced CT showed bilateral high-riding vertebral

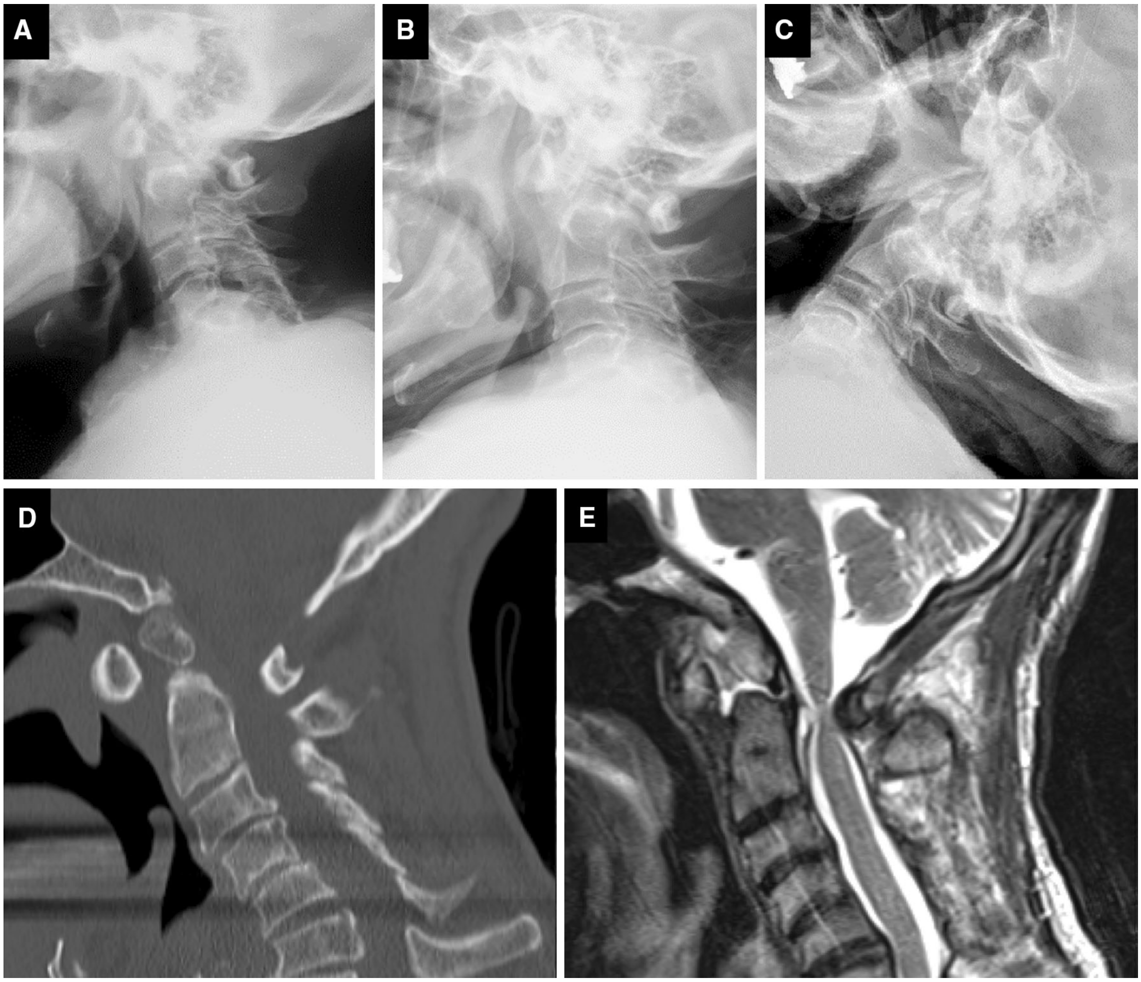

Fig. 1 Preoperative lateral radiographs in neutral (**a**), flexion (**b**), and extension positions (**c**). Sagittal CT shows os odontoideum (**d**). MRI shows severe spinal cord compression at C1–2 (**e**)

arteries and a thin dorsal arch of C1 (Fig. 2a–d). Bilateral high-riding vertebral arteries abandoned application of screw placement at C2. Furthermore, application of C1 lateral mass screw seemed impossible because bilateral C1 posterior arcs were very thin, tilted caudally, and covered by vertebral arteries at the level of C1 lateral mass. The fusion area was extended from the occiput to C3, although C1–2 fusion was less invasive and more advantageous for bony union. In order to insert a long screw and to achieve strong stability for the long lever arm, a C2–3 transuncovertebral joint screw was applied for the subaxial anchor. During the surgery, a reference frame for navigation was fixed to the spinous process of C3, and an intraoperative CT scan was acquired with an O-arm system (Medtronic Inc., Minneapolis, MN). Bilateral C2–3 transuncovertebral screws were inserted (4.5 mm × 32 mm on the left, 4.5 mm × 28 mm on the right) under navigation system guidance (StealthStation S7, Medtronic Inc., Minneapolis, MN, USA). After placement of the occipital screws, the cervical spinal cord was decompressed by resecting the dorsal arch of C1. The occipital screws and the C2–3 transuncovertebral screw were connected with bilateral rods and reinforced by bilateral C2 sublaminar polyethylene tapes. C0–2 lordosis angle fixed in slightly increased position because decrease of C0–2 lordosis angle and reduction of atlantoaxial subluxation have been reported to cause dyspnea and/or dysphagia after occipitocervical fusion [5, 6]. The patient's postoperative course was uneventful, and his neurological status improved after the surgery (Fig. 3). Bony fusion was found in CT 6 months after the surgery.

Discussion

The uncovertebral joint exists bilaterally between the uncinate process and the vertebra above, which is called Luschka's joint. This joint restricts posterior translation and lateral bending motions [7]. The articular surface of the upper vertebra has been reported to be 44 mm^2 and

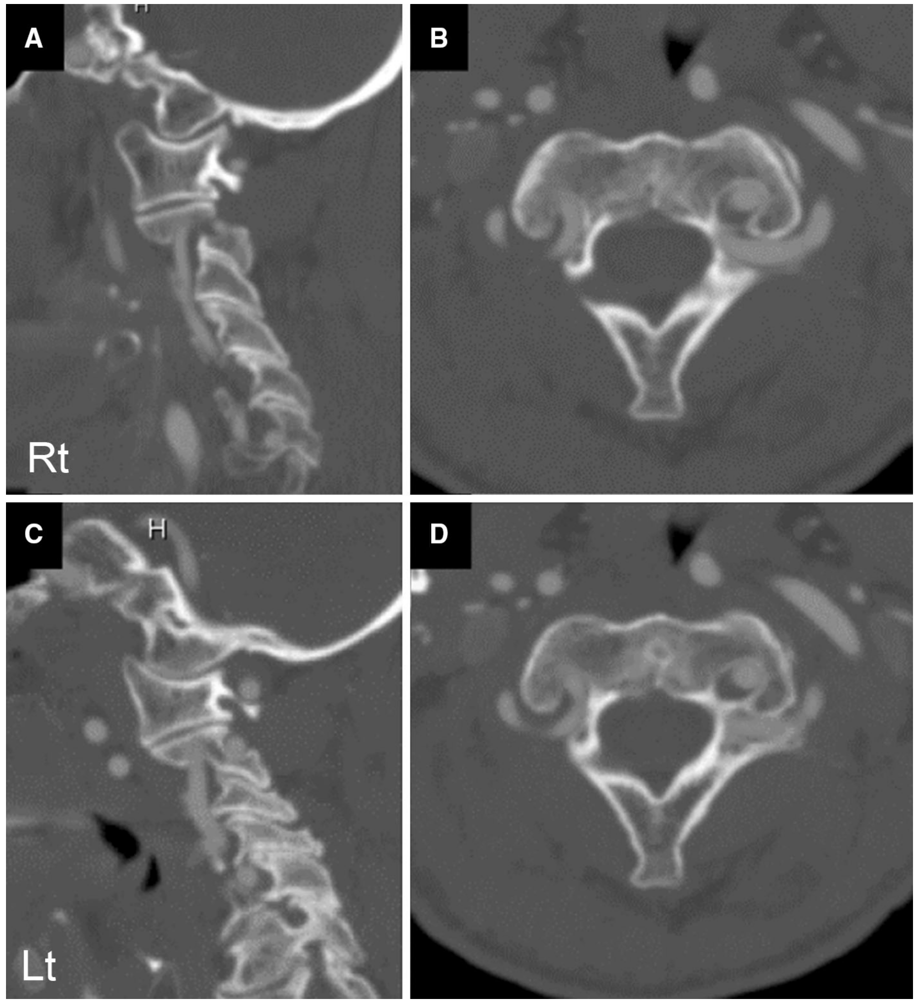

Fig. 2 Contrast-enhanced CT shows bilateral high-riding vertebral arteries. *Rt* and *Lt* represent right and left sides, respectively

approximately twice that of the lower uncinate process, with no significant difference by cervical level [8].

The entry point of the uncovertebral joint screw is approximately 2–3 mm medial from the lateral notch of the lateral mass and approximately 2–3 mm cephalad to the lower facet joint (Fig. 4). The medial to lateral relationship is similar to that of the subaxial cervical pedicle screw entry point, and the cephalad to caudal relationship is similar to that of the C1–2 transarticular screw entry point.

The cervical pedicle screw trajectory has been reported to range from 25° to 45° in the axial plane. In the sagittal plane, it is slightly cephalad at C2–4 and parallel to the upper end plate at C5–7 [9]. The cervical pedicle height is greater than its width, with a ratio ranging from 1.1 to 1.4 (1.3 at C3) [8]. This means that the cervical pedicle insertion trajectory has a larger acceptable range in the sagittal plane than in the axial plane. The angle of the cervical pedicle axes in the sagittal plane increases from 8° in the cephalad direction at C3 to 11° in the caudal direction at C7 against the posterior wall of the vertebral body. In other words, the C3 pedicle has the most cephalad-directed angle in the sagittal plane. We believe that the trajectory of the transuncovertebral joint screw in the axial plane is similar to that of the cervical pedicle screw, from 25° to 45° medially. In the sagittal plane, however, it directs more cephalad and is nearly parallel to the facet joint (Fig. 5). The facet joint inclination gradually increases from 45° at C3 to 65° at C7 [10]. Because the C3 pedicle axis directs the most cephalad in the sagittal plane, and the C2–3 facet joint inclination is the smallest, uncovertebral joint screw placement at C2–3 requires the least inclination in the sagittal plane and would be the most feasible among the subaxial regions.

There are several advantages of uncovertebral joint screw placement compared with conventional cervical pedicle screw. A longer screw can be placed, which is expected to provide higher biomechanical strength. Anchoring can be acquired in the index and upper vertebrae from a posterior approach, although the portion of the screw inserted to the upper vertebral body is short. Theoretically, steep and cephalad-directed screws can stay longer in the cervical pedicle. Furthermore, penetration of

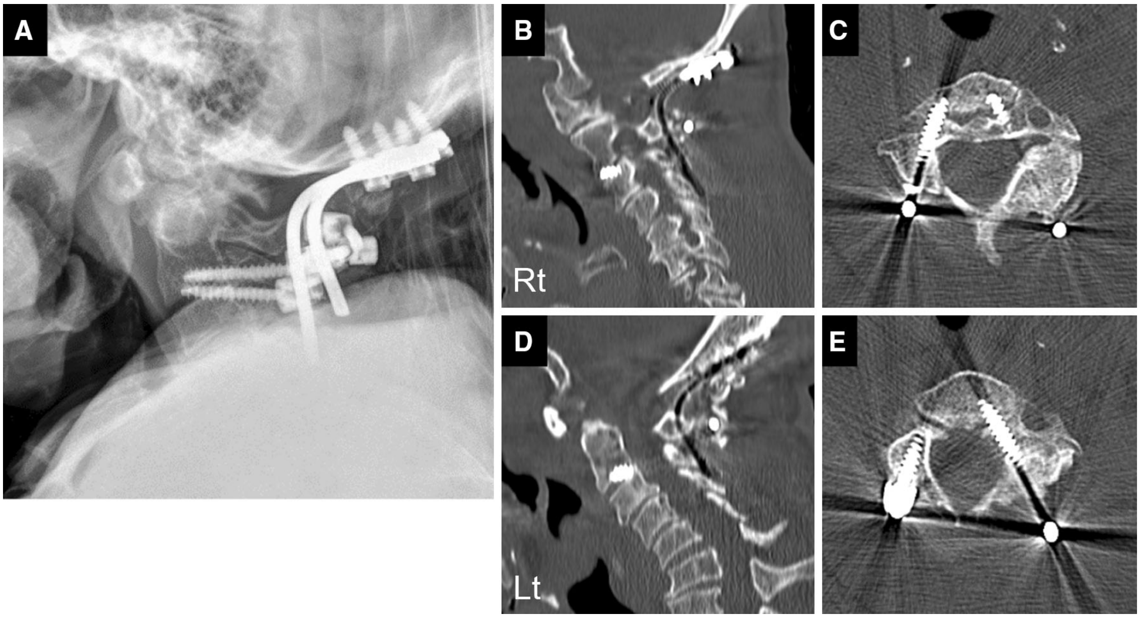

Fig. 3 Postoperative lateral radiograph (**a**) and CT (**b**–**e**). Bilateral C2–3 transuncovertebral screws were inserted through the pedicle and the uncovertebral joint. *Rt* and *Lt* represent right and left sides, respectively

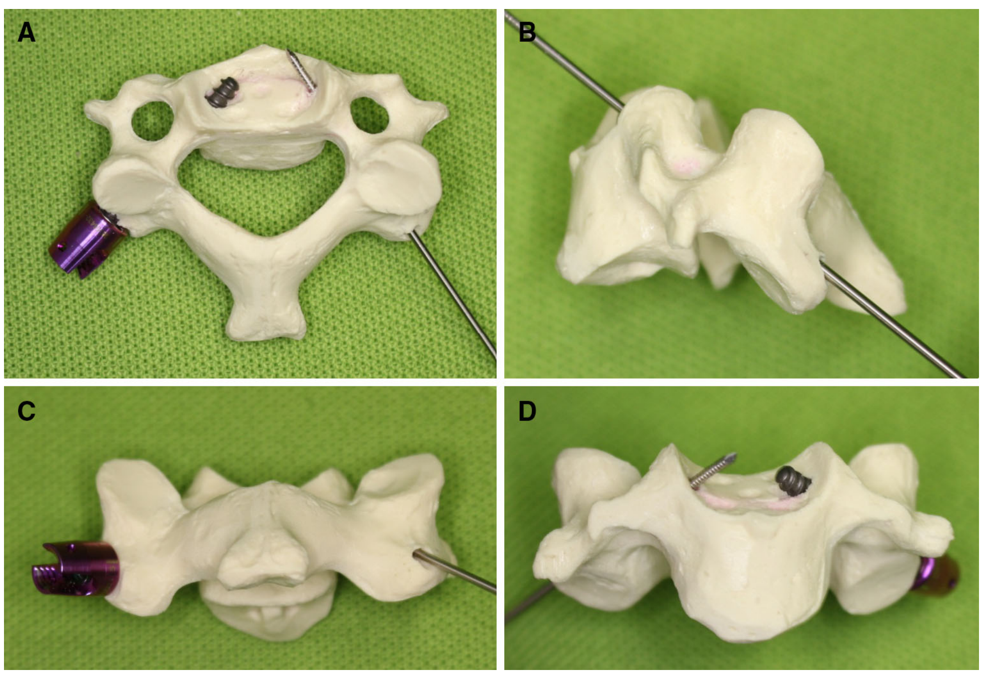

Fig. 4 Transuncovertebral joint screw placement in top view (**a**), lateral view (**b**), posterior–anterior view (**c**), and anterior–posterior view (**d**). A 4.0 mm × 30 mm screw is inserted on the left side, and a 1.4 mm wire is inserted on the right side in the model bone of C3

the articular joint occurs in a tri-cortical fashion and would also contribute to immediate rigid stabilization and acceleration of bony fusion. On the other hand, uncovertebral screw placement is technically more difficult and has several risks. Lateral or medial penetration of the pedicle may result in vertebral artery injury or spinal cord injury, respectively. Careful pre-operative planning is important. In the presented case, asymmetry of the vertebral arteries was found with the left side dominant. Because injury of the dominant left vertebral artery may cause fatal complications, we aimed at the medial edge in order not to violate the dominant vertebral artery, which resulted in grade 2

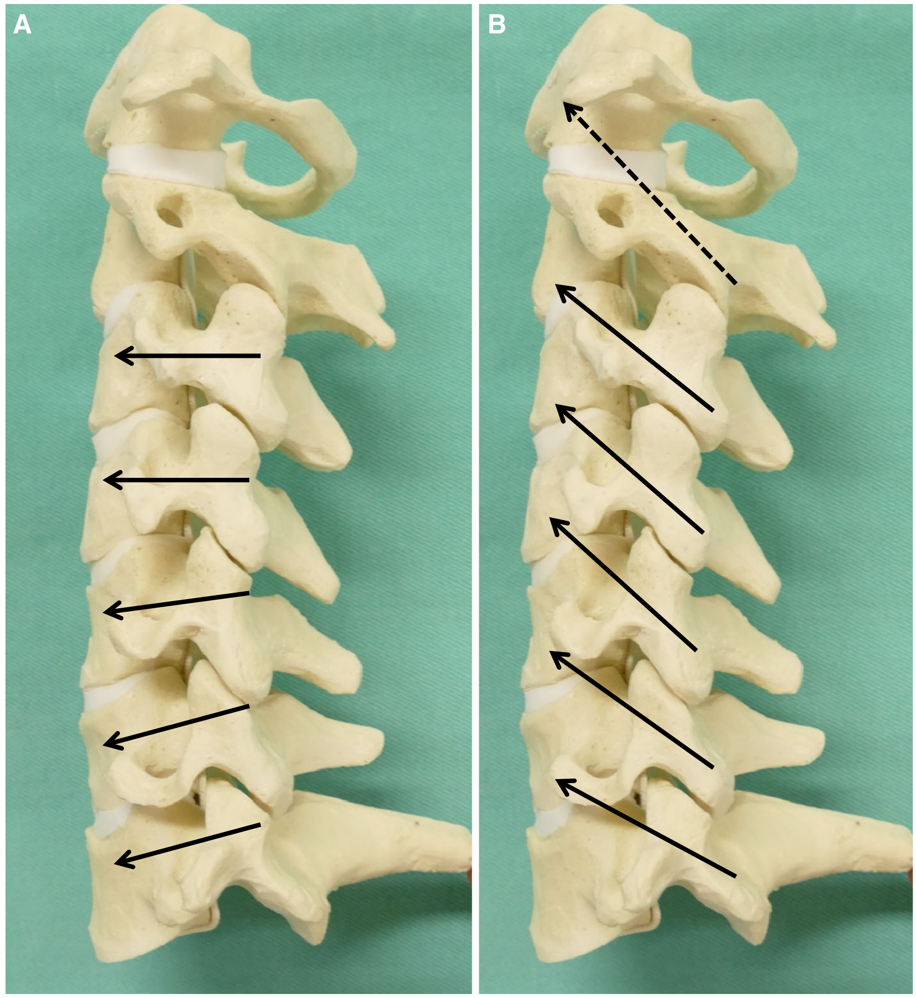

Fig. 5 Comparison of screw trajectory in the sagittal plane. The cervical pedicle screw trajectory is slightly cephalad or parallel to the upper end plate (**a**). The transuncovertebral screw trajectory is parallel to the facet joint (*black arrow* in **b**), which is similar to the C1–2 transarticular screw trajectory (*dotted arrow* in **b**)

medical penetration (less than 2 mm) with no clinical symptoms. Although the medial–lateral trajectory of the uncovertebral joint screw is the same to the cervical pedicle screw, a longer screw may increase the chance of lateral or medial screw breach. Because the trajectory of the uncovertebral joint screw in the sagittal plane is more cephalad, the risk of nerve root injury by the uncovertebral joint screw may be increased by superior penetration of the pedicle compared with the conventional cervical pedicle screw. When penetrating the uncovertebral joint, an anterior superior force may be applied to the upper vertebra. In order to avoid unexpected motion of the upper vertebra, holding the spinous process of the upper vertebra is encouraged.

Careful preoperative planning and thorough understanding of the anatomy are mandatory for the transuncovertebral joint screw placement. Furthermore, an intraoperative navigation system is required to avoid serious complications. A systematic review revealed that the accuracy of cervical pedicle placement is 69.4 % with conventional fluoroscopy, 73.3 % with 2D fluoroscopic navigation, and 90.3 % with 3D fluoroscopic navigation [11]. The review also compared two 3D fluoroscopic navigation techniques and showed that O-arm fluoroscopy was more accurate than Iso-C 3D fluoroscopy. Because the optimal pathway for uncovertebral joint screw is limited, navigational guidance, such as with an 0-arm, is necessary.

This study is only for the introduction of the novel method. In addition to clinical accumulation of experiences, anatomical studies (i.e., screw trajectory studies, and screw feasibility studies) and biomechanical studies such as pullout test and cyclic loading test should be performed until the use of this technique spreads.

Conclusion

Although we introduced transuncovertebral screw placement at C2–3 for occipitocervical fixation, this technique can also be used at lower cervical levels. This technique may also be applicable to cases with significant osteoporosis or previously failed fusion as a reinforcement or salvage technique. Obviously, further biomechanical and anatomical studies are required. However, we believe that transuncovertebral joint screw placement can be a useful treatment option when a rigid anchor is required.

Compliance with ethical standards

Conflict of interest The authors declare that they have no conflicts of interest.

References

1. Du JY, Aichmair A, Kueper J, Wright T, Lebl DR (2015) Biomechanical analysis of screw constructs for atlantoaxial fixation in cadavers: a systemic review and meta-analysis. J Neurosurg Spine 22:151–161
2. Wright NM (2004) Posterior C2 fixation using bilateral, crossing C2 laminar screws: case series and technical note. J Spinal Disord Tech 17:158–162
3. Daentzer D (2009) Operative management for atlantoaxial instability in case of bilateral high riding vertebral artery. Arch Orthop Trauma Surg 129:177–182
4. Hong JT, Takigawa T, Udayakunmar R, Shin HK, Simon P, Orías AAE et al (2011) Biomechanical effect of the C2 laminar decortication on the stability of C2 intralaminar screw construct and biomechanical comparison of C2 intralaminar screw and C2 pars screw. Neurosurgery 69:ons1–ons6
5. Izeki M, Neo M, Ito H, Nagai K, Ishizaki T, Okamoto T et al (2013) Reduction of atlantoaxial subluxation causes airway stenosis. Spine (Phila Pa) 38:E513–E520
6. Izeki M, Neo M, Takemoto M, Fujibayashi S, Ito H, Nagai K, Matsuda S (2014) The O-C2 angle established at occipito-cervical fusion dictates the patient's density in terms of postoperative dyspnea and/or dysphagia. Eur Spine J 23:328–336
7. White AA, Panjabi MM (1978) Kinematics of the spine. In: White AA, Panjabi MM (eds) Clinical biomechanics of the spine. JB Lippincott, Philadelphia, pp 61–90
8. Panjabi MM, Duranceau J, Goel V, Oxland T, Takata K (1991) Cervical human vertebrae. Quantitative three-dimensional anatomy of the middle and lower regions. Spine (Phila Pa) 16:861–869
9. Abumi K, Ito M, Sudo H (2012) Reconstruction of the subaxial cervical spine using pedicle screw instrumentation. Spine (Phila Pa) 37:E349–E356
10. Pal GP, Routal RV, Saggu SK (2001) The orientation of the articular facets of the zygapophyseal joints at the cervical and upper thoracic region. J Anat 198:431–441
11. Mason A, Paulsen R, Babuska JM, Rajpal S, Burneikiene S, Nelson EL et al (2014) The accuracy of pedicle screw placement using intraoperative image guidance systems. A systemic review. J Neurosurgery Spine 20:196–203