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Case Report

Laminar screw fixation of the axis in the pediatric population: a series of eight patients

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Abstract

BACKGROUND CONTEXT: Instability of the atlantoaxial spine is a recognized problem in children. Safe passage of pedicle screws at C2 poses challenges because of the proximity to the vertebral artery, size of the pedicles, and variations in the location of the foramen transversarium.
PURPOSE: The C2 translaminar technique is a useful option and its stability is comparable to that offered by C2 pedicle screws. In this follow-up from our previously published study, we wanted to verify the safety and suitability of the C2 laminar screw in the treatment of cervical instability in the pediatric population.
STUDY DESIGN/SETTING: We present a case series of eight pediatric patients who underwent laminar screw fixation of the axis as part of their operative procedure.
PATIENT SAMPLE: There were five girls and three boys, with a mean age of 7 years (range 2–17 years) who underwent this procedure. Surgical indications included atlantoaxial instability, atlanto-occipital disassociation, multilevel cervical instability, and high cervical stenosis. Seven patients had underlying dysplastic syndromes.
OUTCOME MEASURES: We studied the technical feasibility of passing laminar screws at C2 in eight consecutive patients, paying attention to screw length and diameter, vascular or neurologic complications, and stability of fixation.
METHODS: This retrospective study was funded by our institution and there was no potential conflict of interest. All patients were placed prone. The posterior aspect of the cervical spine and craniocervical junction were exposed subperiosteally. We report our modification of the Wright technique, which allowed us to safely pass 3.5-mm screws into both laminae of the second cervical vertebra.
RESULTS: A total of 15 laminar screws were passed at C2. The follow-up period ranged from 1 to 24 months (mean 8 months). There were no vascular or neurologic complications, no infection, and no instances of hardware failure either by lamina fracture or screw pullout. All patients maintained stable constructs on imaging studies at the last follow-up evaluation.
CONCLUSION: Children as young as 2 years can undergo safe and rigid fixation of the axis. The technique is especially valuable in patients with dysplastic bone and distorted anatomy where more traditional methods of C2 fixation cannot be safely used. To our knowledge, this is the largest reported series of C2 laminar screw fixation in a pediatric population.

Keywords: Atlantoaxial spine; Pedicle screws; C2 translaminar technique; C2 laminar screw; Pediatric population; Occipitocervical stabilisation

FDA device/drug status: Approved (VERTEX reconstruction system; Medtronic Sofamor Danek, Inc, Memphis, TN), Approved (MOUNTAINEER OCT Spinal System; DePuy Spine Inc, Raynham, MA 02767).

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This study was conducted at The Children's Hospital at Westmead, Sydney Children's Hospitals Network, Westmead Campus, Locked Bag 4001, Cnr Hawkesbury Rd and Hainsworth St, Westmead 2145, Sydney, NSW, Australia http://www.schn.health.nsw.gov.au/.

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Introduction

Instability of the atlantoaxial spine is a recognized problem in children, and has a wide spectrum of causes. Rigid screw fixation techniques are increasingly becoming the mainstay of surgical management [1,2]. The upper cervical spine is a critical area for internal fixation in children, especially at the second cervical vertebra. Achieving stability is difficult because of increased segmental motion in children, anatomical size constraints, and congenital malformations with less familiar anatomy [3]. Safe passage of traditional pedicle screws at C2 poses challenges because of the proximity to the vertebral artery, size of the C2 pedicles, and variations in the location of foramen transversarium. Previous studies have demonstrated a 7% to 20% incidence of anomalies that preclude safe C1–C2 transarticular screw placement in the pediatric population [4,5].

In 2004, Wright [6] described a technique for placement of C2 translaminar screws. A 4-mm polyaxial screw was successfully inserted without complications in three pediatric patients. The C2 translaminar technique has since been reported in several small studies [7,8]. Studies have shown laminar screws at C2 to have biomechanical strength comparable to that of pedicle screws [9,10]. The clinical experience in adults confirms that this procedure is associated with a significantly low morbidity rate and a high rate of fusion [3,7,8,11]. Chern et al. [7], in a morphometric analysis of computed tomography (CT) scans in the pediatric spine, found that at C2, 76.8% had a laminar height of more than 8 mm and 88.4% had laminar thickness of 4 mm or more at the isthmus.

In a previously published study [12], we reviewed digital images of axial reconstructions of cervical CT scans of 23 children (age ranging from 2 to 11 years, with a mean of 6 years.) An analysis of C1–C2 tomographic anatomy revealed that 65% of C2 laminae were suitable for 3.5-mm screw placement, and 80% for 3.0-mm screw placement, as compared with C2 pedicles (24% and 41%, respectively). Our conclusion was that C2 laminae are more likely to be suitable for screw placement than C2 pedicles in children. These demonstrated radiological parameters have been put to the test in the clinical setting, with laminar screws at C2 being used with increasing frequency at our institution. The aim of this study was to demonstrate the safety and efficacy of laminar screw placement by describing our experience in using this technique in a consecutive cohort of pediatric patients requiring C2 fixation.

Table 1
Etiology

Etiology
Morquio syndrome (2 patients)
Larsen syndrome
Spondyloepiphyseal dysplasia
Atlanto-occipital dissociation
Metatropic dysplasia
Down syndrome
Osteogenesis imperfecta (Cole-Carpenter type)+basilar invagination

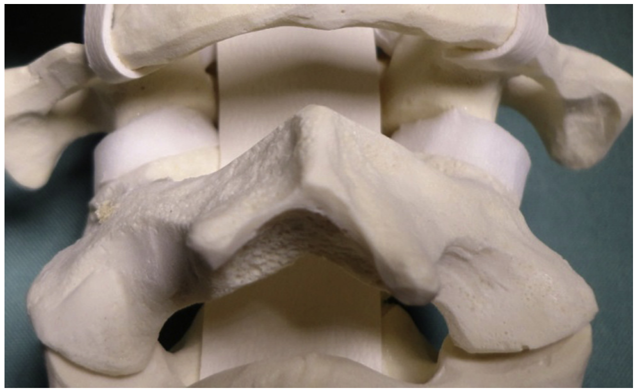

Fig. 1. The bifid portion of the tip of the spinous process is less pronounced in children.

Materials and methods

We identified eight patients who underwent translaminar screw fixation of the axis as part of their operative procedure. There were five girls and three boys, mean age 7.9 years (range 2.4–17.9 years). Preoperative workup included CT scans, the axial and sagittal reconstructions of which were then examined to plan screw trajectory. Even where anatomy was small or distorted, the C2 laminae were more likely to allow 3.5-mm screw passage than the C2 pedicles. Surgical indications included atlantoaxial instability requiring decompression (four patients), atlanto-occipital dissociation (one patient), multilevel cervical instability (one patient), and high cervical stenosis (two patients). The underlying conditions are explained in Table 1.

Surgical technique

All patients were placed prone on a Jackson table with the head and neck maintained in the neutral position.

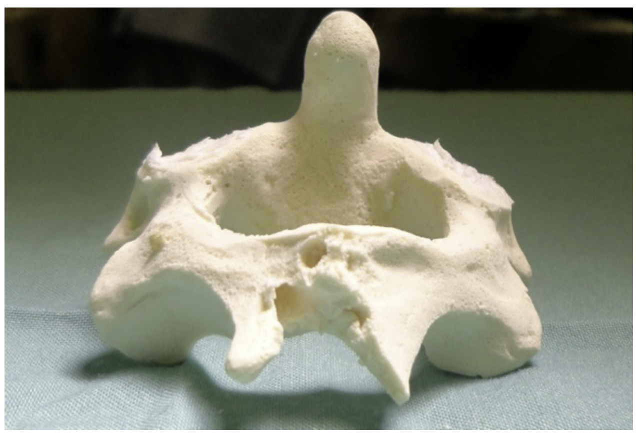

Fig. 2. Preparation of the entry points for the screws in the notch of the process does not compromise the stability of the laminar arch of C2.

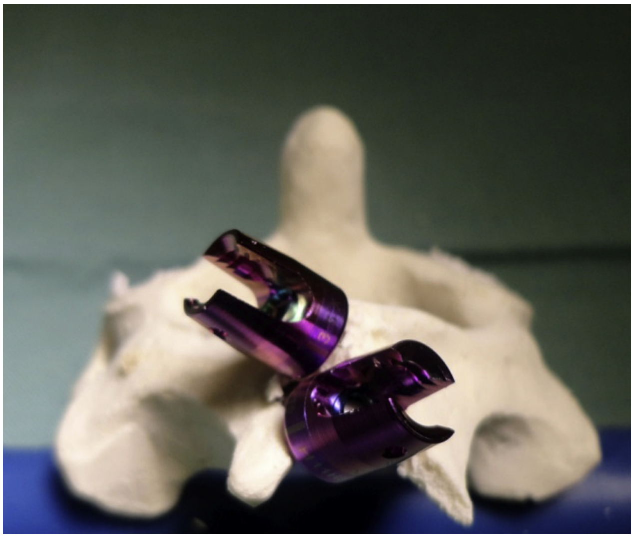

Fig. 3. Screw can then cross each other within the spinous process. Keeping the screws slightly proud allows one to position the "tulip" away from the other screw without compromising on the fixation.

Neurophysiological monitoring was performed during the entire course of the procedure. The posterior aspect of the cervical spine and craniocervical junction were exposed subperiosteally to visualize the spinous processes, laminae, and lateral masses. C2 laminar screws were inserted using the Wright technique. (VERTEX reconstruction system; Medtronic Sofamor Danek, Inc, Memphis, TN, and MOUNTAINEER OCT Spinal System; DePuy Spine Inc, Raynham, MA). All but one of our patients had underlying skeletal dysplasia with short stature, spine misalignment at other levels, and varying degrees of distortion of the spine anatomy. The vertebrae were generally smaller, more deformed, and of suboptimal bone quality. Five patients were younger than 5 years at the time of surgery. Nevertheless, 3.5-mm diameter screws, invariably longer than 18 mm, could be passed bilaterally at the level of the axis. Including two screws at C3, 17 laminar screws were passed.

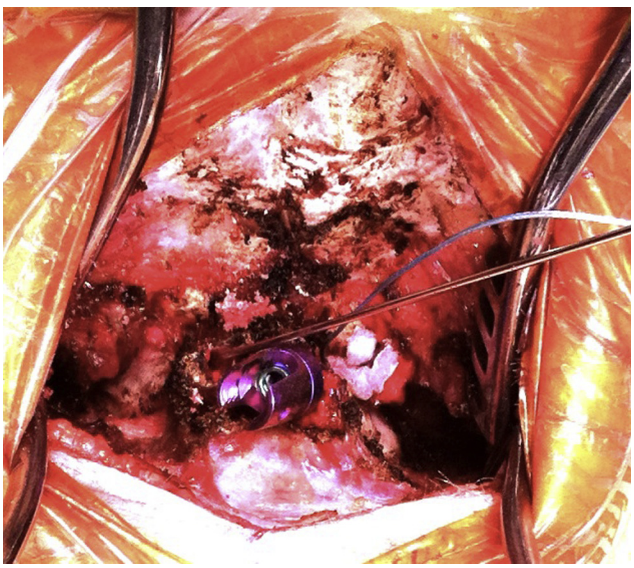

Fig. 4. Drilling and tapping of the lamina is done under direct vision, with frequent palpation with a fine blunt probe to identify any cortical breach and to measure the depth of the channel.

Fig. 5. Axial computed tomography scans in a 4-year-old child with atlanto-occipital dissociation demonstrate how 22- and 20-mm screws can be safely passed in younger laminae.

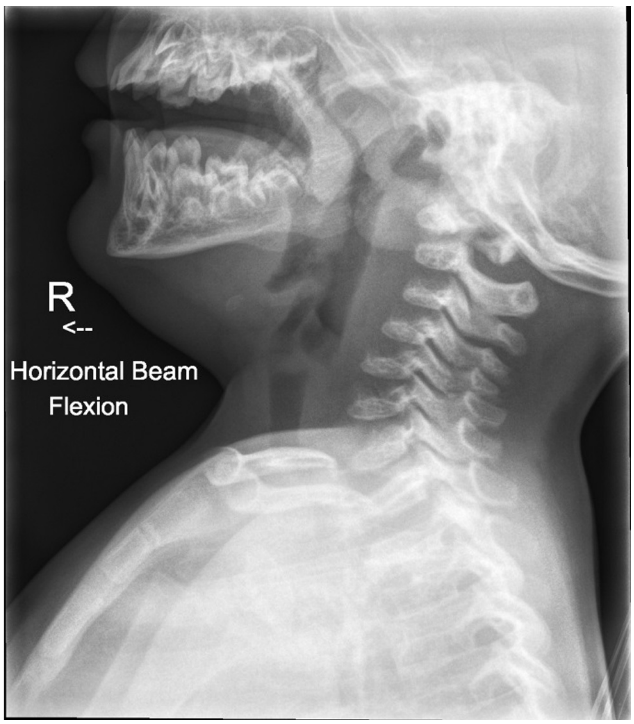

Fig. 6. Dynamic radiographs showing C1–C2 instability in a 2-year-old with Morquio syndrome.

Fig. 7. Dynamic radiographs showing C1–C2 instability in a 2-year-old with Morquio syndrome.

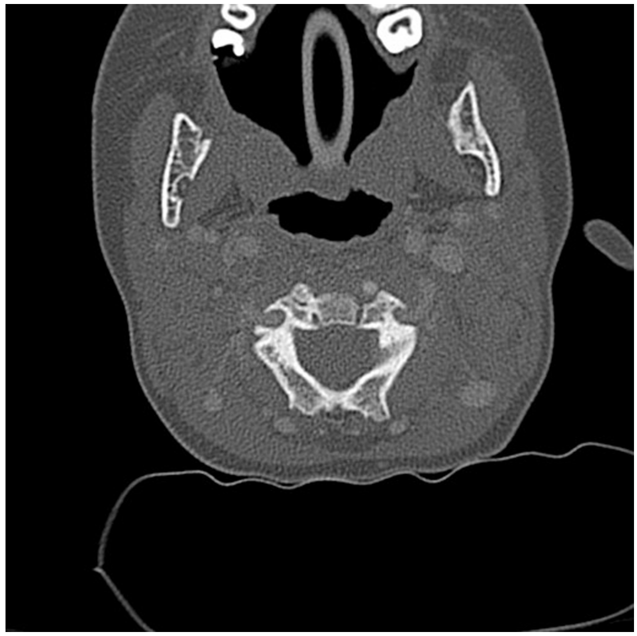

Fig. 9. Computed tomography imaging of the relationship of the vertebral artery suggests that the axis is not amenable to safe placement of pedicle or transarticular screws.

Intraoperative fluoroscopy was used only later during the procedure to confirm occipitocervical alignment. Occipital screw-plate constructs and subaxial lateral mass screws, where necessary, were placed in the standard manner. Contoured titanium rods were used with the help of lateral connectors to the polyaxial screws. Autologous rib struts harvested via a minimal dorsal approach, usually the left fourth or fifth rib, were placed from occiput to C2 or C3. Cancellous morselized allograft and bone morphogenic protein (BMP-7, OP-1; Stryker Biotech, Kalamazoo, MI), was used for fusion in six cases. Postoperatively, a custom-made occipitocervicothoracic orthosis was used for rehabilitation.

Fig. 8. Magnetic resonance imaging shows significant cervical stenosis and spinal cord signal changes.

Fig. 10. Computed tomography imaging of the relationship of the vertebral artery suggests that the axis is not amenable to safe placement of pedicle or transarticular screws.

Fig. 11. Computed tomography scan shows dysplastic features, however the C2 lamina thickness measures 4 mm at the isthmus.

Wright [6] describe their technique in adult spines, using a high-speed burr to make a cortical window at the junction of the C2 spinous process and lamina, close to the rostral margin of the C2 lamina. The lamina is carefully prepared with the drill visually aligned along the angle of the exposed contralateral laminar surface. In our experience with the small anatomy of young children, making two cortical windows on the contralateral side of the lamina was difficult. The bifid portion of the tip of the spinous process is less pronounced in the pediatric population. However, we found that the cranial-caudal extent of the base of the C2 spinous process was large enough to allow bilateral crossing 3.5-mm screws even though the laminar height itself

Fig. 12. The cephalo-caudal extent of the lamina at the entry point measures more than 8 mm.

Fig. 13. Occiput-to-axis instrumented fusion.

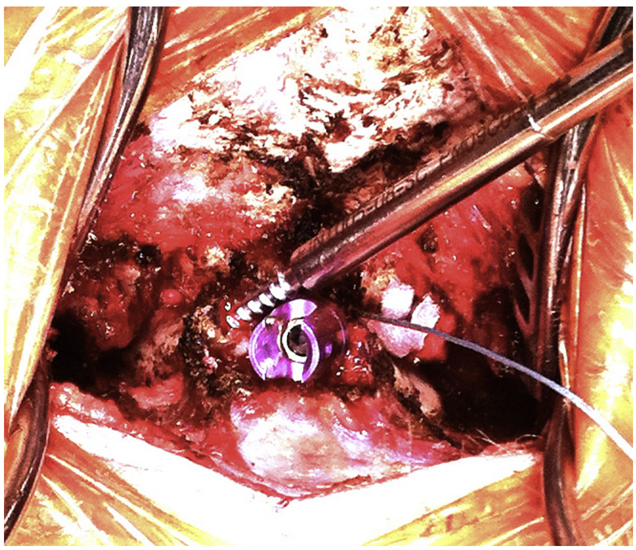

Fig. 14. Occiput-to-axis fusion. The spinous process is prepared as described, and the left C2 lamina is tapped with the tulip of the polyaxial right laminar screw tilted out of the way. The occiput is instrumented later to allow more working space.

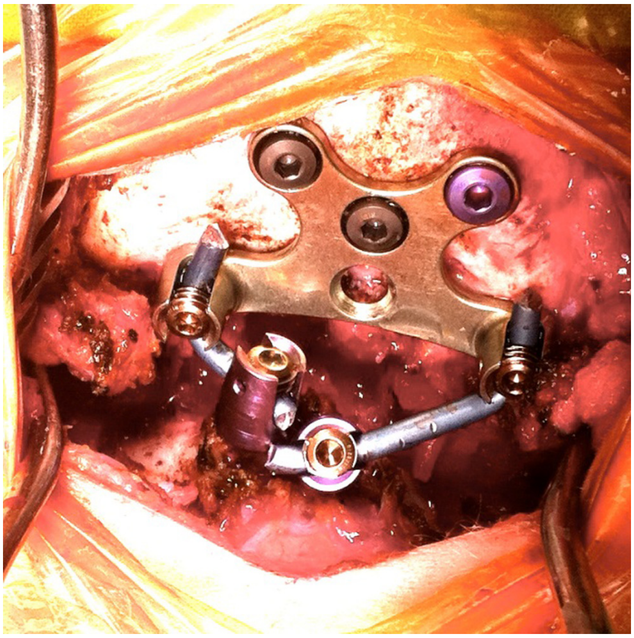

Fig. 15. Final construct with contoured 4-mm rods and occipital plate.

Fig. 17. Occiput to C3 fusion with decompression at C1; 18- and 20-mm-long screws could be passed despite the young age and platyspondyly.

was small. This was true even in children with skeletal dysplasia. Where the anatomy was small, a slight preparation of the dorsal cortex of the bifid spinous process with a high-speed burr allowed the selection of the optimum entry point without compromising the stability of the laminar arch (Figs. 1–5).

A drill was used to create a screw hole along the visualized trajectory. A small blunt probe was used repeatedly during drilling and tapping to palpate the length of the hole and rule out cortical breakthrough into the spinal canal. On one side, a deliberately longer screw was sometimes left slightly proud so that the tulips did not impinge on one another, without compromising the stability of the screw. Lateral connectors were easily applied to contoured rods to give a construct that felt strong and stable.

Fig. 16. C1–C2 instability and stenosis with signal changes in the spinal cord in a 4-year-old girl with spondyloepiphyseal dysplasia.

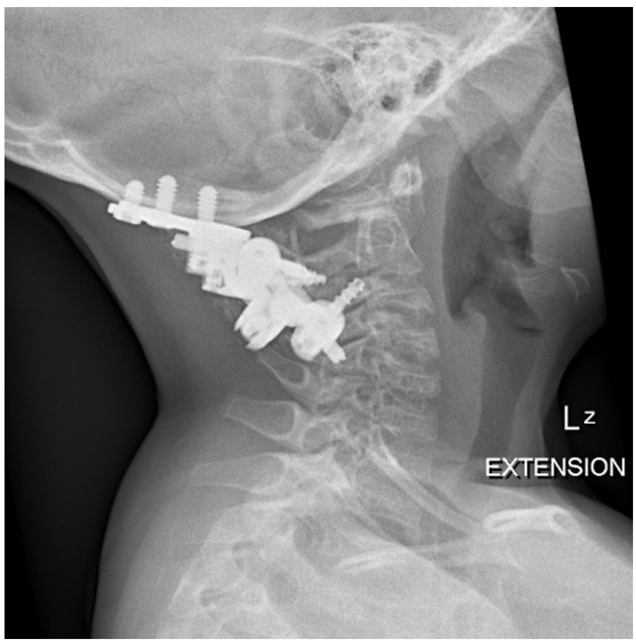

Fig. 18. Occiput to C3 fusion with decompression at C1; 18- and 20-mm-long screws could be passed despite the young age and platyspondyly.

Fig. 19. Magnetic resonance imaging showing typical findings of atlanto-occipital dissociation including apical ligament disruption and tectorial membrane injury.

Results

Eight patients with an age range of 2 to 17 years (mean 8 years) underwent fusion incorporating the second cervical vertebra during the study period (Table 2). The follow-up ranged from 1 to 24 months (mean 8 months). There were no vascular or neurologic complications or injuries, no infections, and no instances of hardware failure either by lamina fracture or screw pullout. One patient with Larsen syndrome had swelling of the neck secondary to a dural leak that had occurred during initial subperiosteal dissection. This was managed conservatively and settled within a few days. One patient with osteogenesis imperfecta had poor bone quality, and one C2 screw cut out during assembly of the rod-screw construct. Some patients had postoperative CT scans to assess craniovertebral decompression, and these showed good hardware placement. No screws required revision surgery. All patients maintained stable constructs on imaging studies at last follow-up evaluation. All five patients who were monitored for 4 months or more postoperatively achieved solid fusion. There were no

Fig. 20. Magnetic resonance imaging showing typical findings of atlanto-occipital dissociation including apical ligament disruption and tectorial membrane injury.

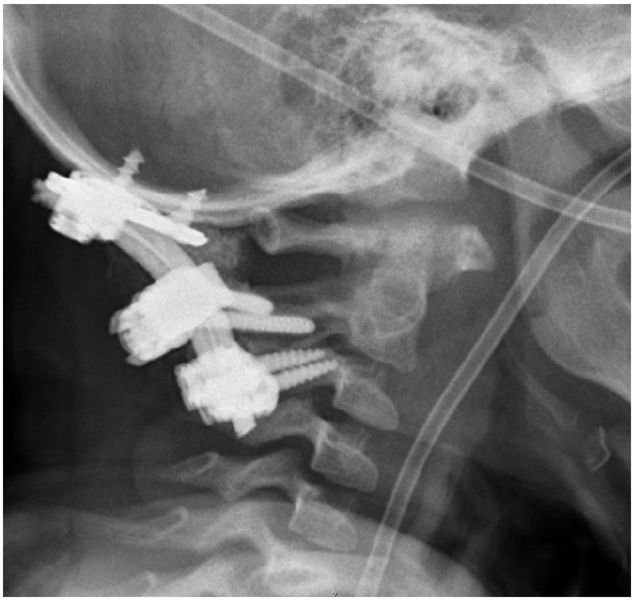

Fig. 21. Postoperative radiographs showing stabilization and fusion from occiput to C3.

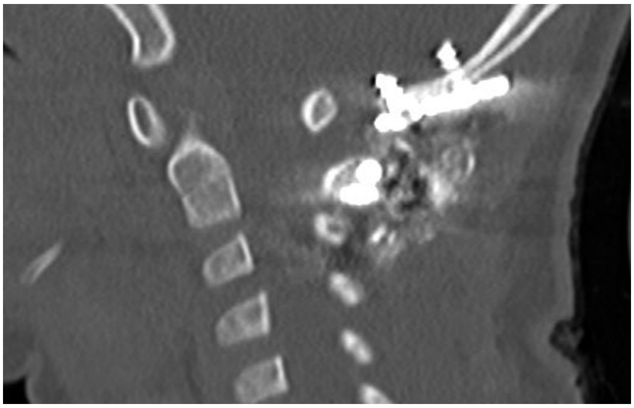

Fig. 22. Sagittal cut demonstrates the two screws crossing each other inside the lamina at the base of the spinous process.

Fig. 23. Postoperative computed tomography scans show 22- and 20-mm screws with good cortical purchase in the axis lamina, and placed at a safe distance from the vertebral artery.

complications related to the use of recombinant human bone morphogenetic protein in any of our patients.

Illustrative cases

Cases 1 and 2

A pair of identical twins aged 2 years with Morquio syndrome were referred with atlanto-occipital instability. One had had an episode of quadriplegia for which a C1 posterior decompression had been done elsewhere. Examination revealed myelopathic signs of hypertonicity and abnormal reflexes in both children. Thoracolumbar kyphosis with some subluxation at T12/L1 was being treated with bracing. Dynamic radiographs demonstrated C1–C2 instability, with significant cervical stenosis and spinal cord signal changes on MRI. CT scan showed dysplastic features. One child underwent revision of C1 laminectomy with O–C3 fusion. An occipital plate with four screws was connected with contoured 4-mm rods to bilateral laminar screws at C2, and a laminar screw and one lateral mass screw at C3. The other twin had C1 laminectomy with O–C2 fixation using an occipital plate and bilateral laminar screws in the axis. A rib strut autograft harvested from a small dorsal approach was placed on either side, supplemented by allograft and OP1 (Figs. 6–15).

Case 3

A 4-year-old girl presented with symptoms of myelopathy on a background of spondyloepiphyseal dysplasia while being treated with a brace for thoracolumbar scoliosis. Imaging revealed C1–C2 instability and stenosis, with signal changes in the spinal cord on MRI (Figs. 16–18).

The axis did not appear amenable to safe placement of pedicle or transarticular screws. She underwent O–C3 fusion with posterior decompression at C1. Despite the young age and platyspondyly, 18- and 20-mm screws could be passed. An entry point made in the notch of the bifid C2 spinous process allowed efficient use of the vertical height of the lamina.

Two 3.5-mm polyaxial laminar screws were passed bilaterally at C2 and one in the left C3 lamina. Dynamic radiographs on follow-up demonstrated stable fusion. Her myelopathy resolved completely.

Case 4

A 4-year-old girl presented with atlanto-occipital dissociation after being struck by a car. Other injuries included diffuse axonal brain injury, third cranial nerve palsy, clavicle and rib fractures, widened mediastinum, and pulmonary injury. She was stabilized with O–C3 fusion, with separate procedures for raised intracranial pressure. After a period of rehabilitation lasting several months, she recovered excellent function (Figs. 19–23).

Table 2
Master table

Patient no.	Age	Sex	Etiology	Procedure	Follow-up, mo	3.5-mm Screw length, mm	Additional subaxial screws
1	2	M	Morquio syndrome	C0–C3 fusion+revision decompression	2	20, 18	C3 LS 16 mm
2	2	M	Morquio syndrome	C0–C2 fusion and C1 decompression	2	20, 18	
3	3	F	Larsen's syndrome	C2–T3 fusion	10	20, 18	C3 LMS×2. T2 and 3 PS×4
4	4	F	Spondyloepiphyseal dysplasia	C0–C3 fusion with C1 decompression	6	20, 18	C3 LS 20 mm×1, LMS×1
5	4	F	Atlanto-occipital dissociation	C0–C3 fusion	12	22, 20	2×C3 LMS
6	12	F	Metatropic dysplasia	C0–C4 fusion following anterior transnasal decompression	24	22, 20	C3, C4 LMS×4
7	15	F	Down syndrome	C0–C3 fusion	5	24, 20	C3 LMS×2
8	17	M	Osteogenesis imperfecta basilar invagination	C0–C4 fusion with decompression	1	24, 20	C3, C4 LMS×4

LMS, lateral mass screws; LS, laminar screw; PS, pedicle screws.

Conclusions

In this follow-up from our previously published study [12], we verified the safety and suitability of the C2 laminar screw in the treatment of occipitocervical or atlantoaxial instability in the pediatric population. Children as young as 2 years can undergo safe and rigid fixation of the axis. The technique is especially valuable in patients with dysplastic bone and distorted anatomy where more traditional methods of C2 fixation cannot be safely used. We feel laminar screws are an important addition to the armamentarium of a spinal surgeon, and can be especially valuable in the pediatric population requiring stabilization of the axis. A limitation of this report is that our management has been based on evidence from adult clinical and biomechanical studies. To our knowledge, this is the largest reported series of bilateral C2 laminar screw fixation in a pediatric cohort.

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