Cervical pedicle subtraction osteotomy was initially described by Simmons in 1972 for fixed cervical flexion deformity in ankylosing spondylitis. In his original description, the osteotomy was indicated in patients with a fixed cervical kyphotic deformity and a chin-on-chest deformity. This affected the patient’s frontal horizontal gaze and impaired functional activities, such as walking, driving, and swallowing.

Simmons performed the osteotomy under a local anesthetic with continuous neuromonitoring. A laminectomy was performed from C6-T1, and wide facetectomies were performed to unroof the C8 nerve roots bilaterally. The patient’s head was then manually extended, creating a fracture through the anterior and medial columns of the spine, functionally lengthening the anterior column while shortening the posterior column around the C7 pedicle axis. A bone graft was then packed at the decorticated site, and the patient was placed in halo immobilization until fusion occurred. This was a technically challenging procedure and had a 4% mortality rate.2

Mehdian et al3 recognized the need for a controlled extension moment after the osteotomy to limit the possibility of catastrophic sagittal translation of the osteotomized segment into the spinal canal. He reported the use of a temporary fixation rod that would prevent sudden translation of the vertebral bodies during gradual correction, limiting the chance of a devastating complication. During manual closure of the osteotomy, the translational rod would slide through the posterior screws, allowing a contralateral titanium rod to be placed, locking the degree of extension. The translational rod would then be replaced by its titanium counterpart.

Mummaneni et al4 reported on their front–back–front technique with anterior and posterior instrumentation for the correction of this deformity. An anterior release was initially performed with discectomy, cervical osteotomy, and unilateral pediculectomy. This was followed by a posterior laminectomy, foraminotomy, and contralateral pediculectomy. Posterior closure of the osteotomy was performed by placing the neck in extension and compressing across the osteotomy site via the posterior instrumentation. Finally, anterior fusion was performed with an interbody graft and a hybrid anterior cervical plate.4

The current authors have performed this procedure at their institution, and this article describes a technical modification during the osteotomy that ensures careful identification and protection of the exiting nerve roots, allows maximal resection of bone and thus correction, and provides a fulcrum onto which the extension osteotomy occurs in a controlled manner. The authors obtained the patient’s informed, written consent for print and electronic publication of the case report.

Materials and Methods

A 61-year-old man with ankylosing spondylitis sustained a C6 compression fracture that

Abstract: Flexion deformities of the cervical spine are multiplanar surgical challenges. This article describes a technical modification during the osteotomy that protects the cervical cord and exiting nerve roots while removing the maximal amount of bone for the osteotomy in the safest fashion.
was treated conservatively in a rigid cervical collar 6 months before presentation. The fracture healed uneventfully, but a progressive kyphotic deformity developed at that level. The patient developed significant problems with forward gaze and posture (Figure 1). Then, he began having trouble opening his jaw for deglutition and was having trouble swallowing. He was able to drive but used a hand mirror to assist him while driving due to the inability to maintain forward gaze. He reported no neck pain and had no neurologic deficits in his upper or lower extremities on examination.

Preoperative radiographs revealed a healed C6 vertebral body fracture with complete ankylosis of the cervical spine in a fixed flexion posture (Figure 2). The preoperative chin-brow vertical angle was 45°. A preoperative computed tomography (CT) scan was performed to assess the healed C6 fracture site, as well as the status of the C6-T1 neural foramina. This is an important aspect of the evaluation because any preexisting neural foraminal narrowing could worsen with closure of the osteotomy and should be addressed prior to decompression. In addition, the CT scan is helpful in determining the size of the thoracic pedicles and the location of the foramen transversarium in relation to the lateral masses for screw orientation and angulation.

The authors chose to perform the cervical pedicle subtraction osteotomy at C7 to avoid the vertebral artery as it enters the foramen transversarium at C6 because the canal diameter at C7-T1 is larger than the diameter of the midcervical spine, decreasing the chance of a spinal cord injury, and because upper extremity function would be relatively preserved if a spinal cord injury were to occur as opposed to a more proximal cervical level.

On the day of surgery, the patient was anesthetized using awake nasotracheal intubation with an ear, nose, and throat specialist present in the event that an emergent tracheostomy was needed. Running supine somatosensory-evoked potentials and motor-evoked potentials were recorded as a baseline prior to positioning. Following positioning and a recheck to ensure that the patient’s forehead and brow were not impinging on the Mayfield head holder, another round of baseline somatosensory-evoked potentials and motor-evoked potentials were recorded. Standard posterior cervical exposure was then performed (Figure 4).

Due to the nature of the ankylosis, autofusion of the posterior facet joints rendered the normal anatomic landmarks indistinguishable. Intraoperative fluoroscopy was used to identify the pedicles of T1-T3. Using standard intraoperative bony anatomy, pedicle screws were inserted in the bilateral pedicles of T1-T3. Optimal position was verified using biplanar fluoroscopy. Lateral mass screws were then inserted in the lateral masses of C3-C5 according to the technique popularized by An et al.5

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**Figure 1:** Preoperative anteroposterior (A) and lateral (B) photographs of the patient with a fixed kyphotic flexion deformity. The chin–brow vertical angle is 45°.

**Figure 2:** Preoperative midsagittal computed tomography scan (A) and lateral radiograph (B) showing bony ankylosis typical of ankylosing spondylitis. Note prior evidence of a healed C6 vertebral compression fracture on the computed tomography scan.

**Figure 3:** Photograph of the severe fixed flexion deformity after intubation and Mayfield head holder placement.
After all of the instrumentation was inserted, the osteotomy began. A generous laminectomy of C7 was performed, and the spinous process of C6 was removed. A high-speed, diamond-tipped burr was used to remove the inferior third and the superior third of the laminae of C6 and T1, respectively, in a chevron-type fashion. This allows for excellent closure of the osteotomy with good bony apposition. In addition, a wide proximal and distal laminectomy prevents pinching of the dura, as well as incarceration of the C7 and C8 nerve root as the osteotomy is closed and the deformity is corrected (Figure 5).

In the authors’ experience, a key technical point has been the preparation of the pedicles and exposure of the exiting nerve roots. Meticulous laminoforaminotomies were performed to trace the exiting C7 and C8 nerve roots bilaterally. The extent of the laminoforaminotomies were from pedicle to pedicle such that in a C7 cervical pedicle subtraction osteotomy, the pedicles of C6, C7, and T1 were palpated with a beaded probe from within the laminectomy defect. An internal pediculectomy of the C7 pedicle was then begun from within the spinal canal with a #3 Kerrison rongeur (Integra Life Sciences, Plainsboro, New Jersey). The C7 pedicles were then skeletonized so that the exiting C7 and C8 nerve roots were clearly visualized at their takeoff from the cervical spinal cord.

A high-speed, diamond tipped burr was then used to burr within the C7 pedicle bilaterally (Figure 6). This was done in such a way that a Woodson elevator was passed within the hollow pedicles bilaterally into the anterior body of C7. This elevator was then used to push spongy cancellous bone to the front of the...
C7 vertebral body. Using the burr tip within the pedicles allows for protection of the medial cervical cord and nerve roots with a dural/nerve root retractor.

In a modification of the original technique, the axis of the pedicle was burred down until it was flush with the exiting nerve roots above and below. Once the nerve roots were identified and protected, the burring of the axis of the pedicle was resumed until the vertebral body was approached. Once the pedicle was completely decancellated, it was subtracted using rongeurs, curettes, and elevators from inside-out rather than outside-in, thus protecting the spinal cord and nerve roots at all times.

At this point, the ventral C7 body and the attached posterior longitudinal ligament remained completely intact. A dural retractor was then used to protect the spinal cord, and the burr was used to gently widen the pediculectomy in a medial direction. Once a thin bridge of bone remained between the hollowed-out and widened C7 pedicles, a curved microcurette was used to push the posterior cortex in a dorsal direction. This allowed cancellous bone to be indirectly packed against the front of the body of C7, forming an anterior pivot point onto which the osteotomy site could close over posteriorly. Enough room was left available for the exiting C7 and C8 nerve roots bilaterally; at this point in the procedure, 1 large foramen with 2 nerve roots (C7 and C8) should remain because the intervening C7 pedicle has been subtracted.

Once the bilateral pediculectomy was completed, a transition rod was contoured in place and fixed loosely with set screws on the left side (Figure 7). The assistant surgeon then cautiously detached the Mayfield arm from the head holder and grasped the Mayfield head holder with both hands. In a controlled and gentle manner, he then extended the head so that the patient’s eyes were perpendicular to the floor. Care was taken not to hyperextend the head. At each step, the surgeon monitored the osteotomy closure and the status of the C7 and C8 nerve roots.

Once the optimal chin–brow vertical angle was achieved and the bony osteotomy surfaces were well opposed, the Mayfield arm was attached to the head holder and the transition rod was locked into place. The status of dural buckling and the exiting C7/C8 nerve roots were again carefully reviewed (Figure 8). Once these were deemed satisfactory, a final rod was contoured, using the transition rod as a template for size, length, and diameter, and locked into place with set screws on the contralateral right side. The transition rod was removed, and a final rod was placed on the left side. The wound was irrigated, and the osteotomy site and exiting nerve roots were inspected a final time.

Local laminectomy bone was packed into the osteotomy site, a subfascial drain was placed, and the skin was closed in layers.

Postoperatively, the patient remained intubated and was observed in the Intensive Care Unit. Once the airway was deemed suitable for extubation,
the patient was awakened, extubated, and transferred to the orthopedic floor. A soft collar was placed for comfort for 4 to 6 weeks. The patient did well and was happy with the return of his horizontal gaze and physiologic chin–brow vertical angle (Figures 9-11).

**Conclusion**

Fixed flexion deformities of the cervical spine are multiplanar surgical challenges. This article described a technical modification during the osteotomy that protects the cervical cord and exiting nerve roots while removing the maximal amount of bone for the osteotomy in the safest fashion.

**References**