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Anatomic and Biomechanical Study of Posterior Cervical Spine Plate Arthrodesis: An Evaluation of Two Different Techniques of Screw Placement

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Summary: This study compares two techniques of screw placement for posterior plate arthrodesis of the cervical spine: one in which the screw is placed in a parasagittal plane, and the other in which the screw is directed anteriorly, laterally, and cranially. **Key Words:** Internal fixation devices—Posterior plate arthrodesis.

The last decade has seen a proliferation of internal fixation devices for treatment of trauma or degenerative diseases in the cervical spine. Specifically, the use of plate screw fixation devices has been advocated recently (1–7). These devices can be used when the lamina or spinous processes are missing or incompetent. Alternatively, they can be used when the anterior column is incapable of sufficient load bearing, e.g., in burst fractures or multilevel injuries.

The purpose of this study was to compare two techniques of screw placement for posterior plate arthrodesis of the cervical spine: one (technique I, Roy-Camille) in which the screw is placed in a parasagittal plane (Fig. 1), and the other (technique II, Magerl) in which the screw is directed anteriorly, laterally, and cranially (Fig. 2).

METHOD

Six cadaver spine specimens were harvested and frozen at 20°C until ready for testing. The specimens consisted of C2–C7. The specimens were thawed overnight and stripped of all superficial muscles. All posterior ligaments were cut, including facet capsule ligamentum flavum posterior and anterior longitudinal ligaments. Additionally, the body of C5 was removed to create an unstable triple column injury (Fig. 3).

One of the two surgical techniques was used to stabilize the C4–C5 and C5–C6 motion segments. Tech-

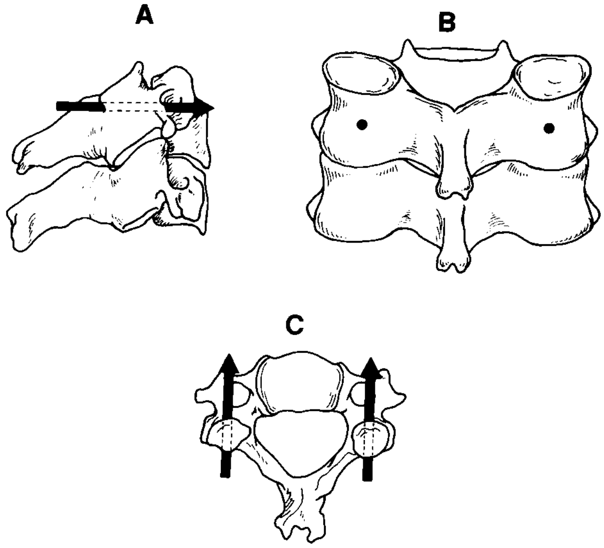

FIG. 1. Technique I, in which the screw is placed in a (**A**) sagittal direction. **B:** The point of screw penetration lies halfway between two adjacent articular projections and 5 mm medial to the lateral margin of the articular pillar. **C:** The screw length must not extend beyond the depth of the posterior column, i.e., a mean distance of 14 mm.

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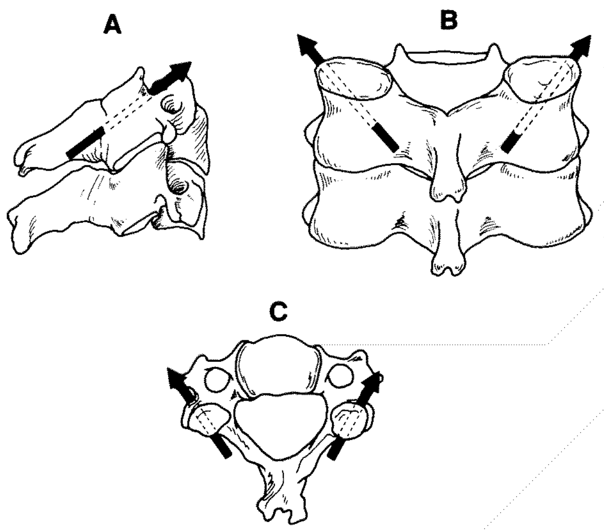

FIG. 2. Technique II (Magerl), in which the screw is directed anteriorly (**A**), laterally (**B, C**), and superiorly (**A**). The axis of the screws diverge by 30–45° and run parallel to the surface of the intervertebral joints. In the clinical situation, the inclination of the articular joints may be determined by inserting a blind dissector into them.

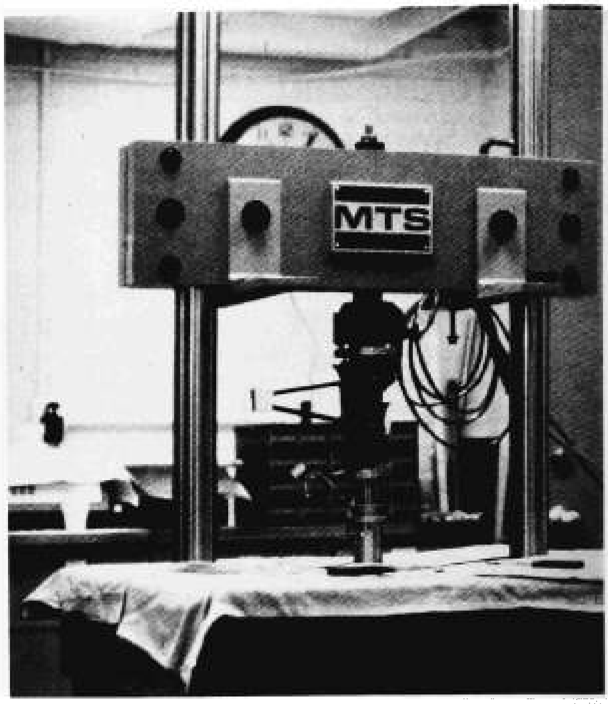

FIG. 4. Specimens were tested in axial compression on an MTS mechanical testing machine.

FIG. 3. An example of a cadaver specimen in which plates have been applied using technique II. Note that a vertebrectomy at C5 has been performed.

nique I used 3.5-mm cancellous screws placed in the articular pillar and directed anteriorly, parallel to the vertebral endplates and slightly lateral, whereas technique II used 3.5-mm cancellous bone screws directed up through the lateral mass, both anteriorly, laterally, and cephalad. Both methods used the AO stainless steel reconstruction plate and AO 3.5-mm cancellous screws. Screw lengths were noted. Once plating was completed, radiographs were made of the specimens to document that correct screw placement and com-

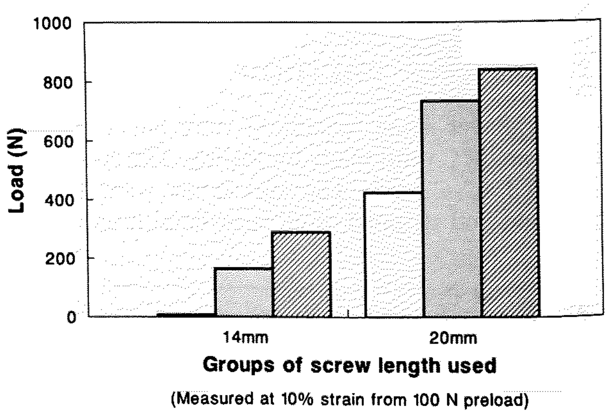

FIG. 5. Technique II, which used 20-mm screws, produced a higher load to failure than technique I did. Failure load was measured at 10% strain.

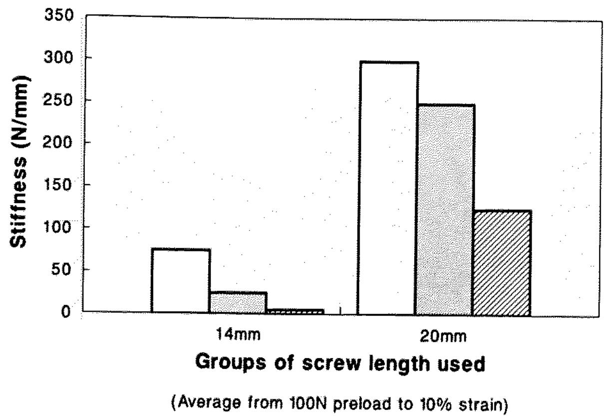

FIG. 6. Technique II, which used 20-mm screws, produced a significantly stiffer construct than technique I did.

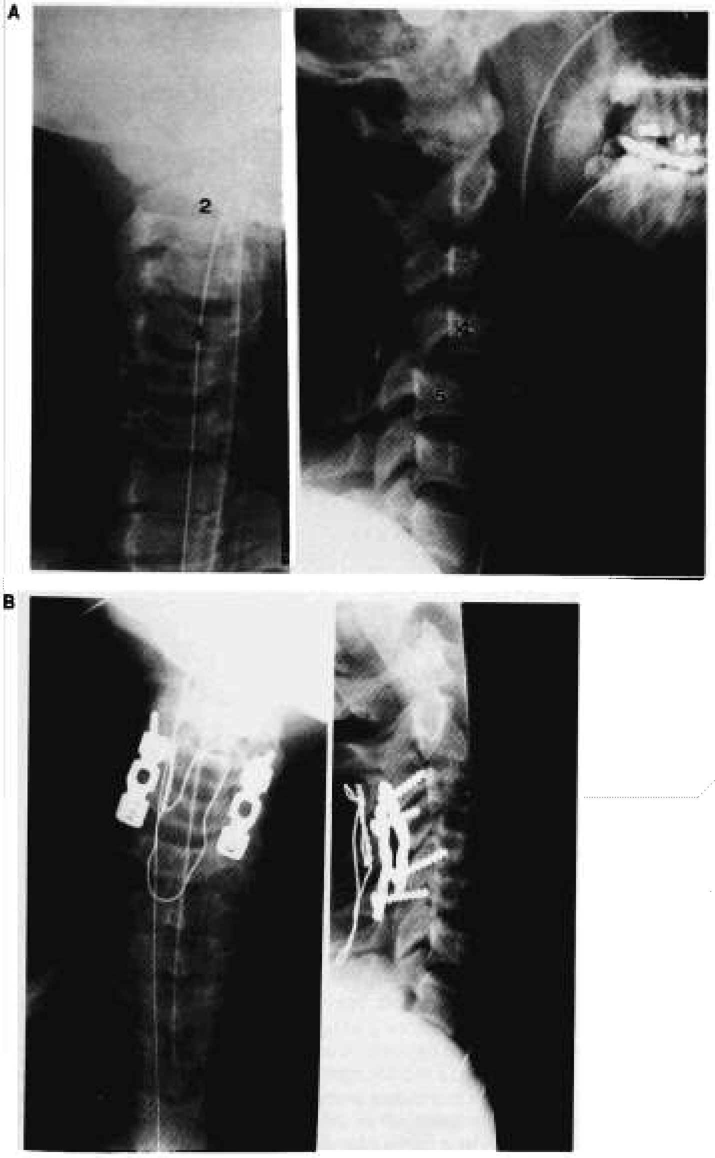

FIG. 7. Preoperative (**A**) and postoperative (**B**) radiographs of a 16-year-old girl who sustained a C4–C5 fracture dislocation, as a result of a motor vehicle accident. Neurologically she was a Frankel A. Because of a severe posterior lamina fracture, a spinous process wiring would not have been able to reconstruct the sagittal plane alignment. It was, therefore, elected to form a posterior plate arthrodesis using technique II. The patient was able to be mobilized bed to chair without a halo postoperatively.

A

B

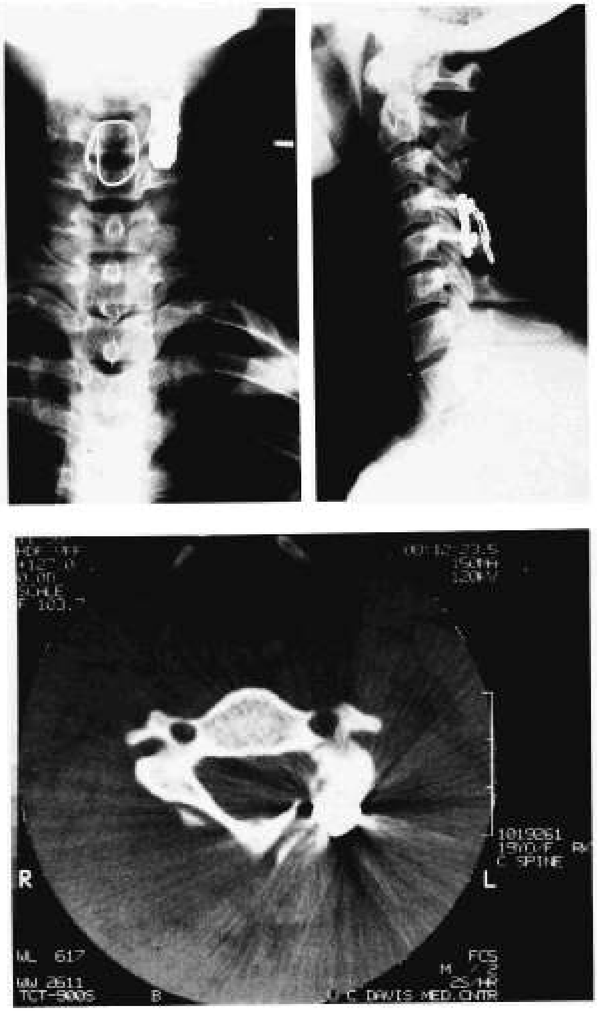

FIG. 8. This 17-year-old girl was involved in a motor vehicle accident and sustained a unilateral facet dislocation at C4–C5. Neurologically she was a Frankel E. The patient was taken to the operating room for a posterior open reduction internal fixation. Intraoperatively, it was discovered that the patient had a lamina fracture. Therefore, a spinous process wiring would not have been able to control rotation. **A:** The patient's internal fixation was supplemented with a unilateral posterior plate arthrodesis, again using technique II. A computed tomography scan is also shown (**B**) to illustrate the cross-sectional screw position. Note the screw position relative to the neurovascular structures.

plete vertebrectomy had been achieved. Furthermore, specimens were closely observed to determine how close the screws came to the neurovascular structures. Three specimens were tested with each technique of fixation.

Specimens were tested in axial compression on an MTS mechanical testing machine (Fig. 4). All spine segments were attached caudally to the fixed compression plate of the testing machine using two to three screws placed through the compression plate and into the body of C7 typically. An additional screw was inserted through the plate into the spinous process of C7. The specimen was attached to the load cell and preloaded to 20 N. Attempts to allow for flexion on loading were made by placing the specimens in slight flexion while the preload was applied. A strain gauge was attached to the specimens using rubber bands to assure contact with the knife edges at the C4 and C6 vertebral bodies anteriorly. The specimens were loaded at a constant deformation rate of 0.2 mm/s.

The instrumented specimens were loaded first to a nondestructive load of 100 N, and second to failure of the construct.

FIG. 9. Postmortem cryosections from a 72-year-old man who had been operated on with multilevel carpectomies because of spinal stenosis and myelopathy. After insufficient anterior stabilization with fibula grafting and Orozco plates, the fixation was enhanced with posterior plating using AO's small fragment DC plates and 3.5-mm cancellous screws. Posterior stabilization was performed using a modification of technique I. Note the screw position relative to the neurovascular structures. The upper arrow demonstrates indentation of the vertebral artery. The lower arrow calls attention to a nerve root compromise.

RESULTS

The mean screw length for technique I was 14 mm and for technique II it was 20 mm. Failure load was determined as the load at 10% strain, based on the work of Nagel and Perren. They have shown that the fusion rate decreases when 10% strain is exceeded. The mean failure load of technique II was 585 versus 152 N for technique I ($p < 0.05$) (Fig. 5). Technique II was stiffer: 223 versus 34 N/mm ($p < 0.05$) (Fig. 6). The failure mechanism for the two techniques was different: technique II failed by plate bending whereas technique I failed by caudal screw pullout.

DISCUSSION

Posterior plate fixation of the cervical spine provides an alternative to wire constructs. It is particularly useful when the posterior elements are missing or incompetent. Furthermore, it allows the ability to apply a distractive force to the cervical spine, as would be necessary in the treatment of burst fractures. Last, it is capable of obtaining a more anatomic reduction, especially in the more severe cervical spine fractures in which longer, more complicated wire constructs would be necessary.

The ideal magnitude of strength and rigidity for a cervical spine construct is unknown.

Based on clinical experience of Cooper and Roy-Camille, both techniques have proven to be sufficient (2,6). Biomechanically, however, technique I had a mean load to failure of 152 N, which is quite a considerable force.

Nonetheless, technique II is clearly stronger and a more rigid construct. This fact may only be important in the more severe multilevel instability patterns.

According to anatomical studies, there are other technical advantages of technique II. First, it avoids entering unfused motion segments. In technique II, the screw is located entirely within the lateral mass exiting away from the joint. In technique I, the more caudal motion segment is frequently entered. The long-term consequences of this are unknown. Second, in technique II the neurovascular structures are protected because the screw is directed in a lateral and superior direction. In technique I, the screw is aimed closer to the neurovascular structures.

Third, technique II required a longer screw, which means it is capable of sustaining higher loads before screw–bone interface failure.

CONCLUSION

Technique II stayed away from neurovascular structures and intact motion segments. It used longer screws, was stiffer, and had a higher load to failure.

We believe this study indicates that technique II provides, as does technique I, an alternative to be used when the lamina and spinous processes are missing or incompetent. Technique II is to be recommended in severe instability, especially with vertebral body insufficiency (Figs. 7–9).

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