

Stability of two anterior fixations for three-column injury in the lower cervical spine: biomechanical evaluation of anterior pedicle screw-plate fixation

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Abstract

Objectives: This study aimed to evaluate the stability of anterior pedicle screw-plate (APSP) fixation and anterior vertebral body screw-plate (AVBSP) fixation for three-column injury in the lower cervical spine.

Methods: Six fresh-frozen human cadaveric specimens of the lower cervical spine were prepared. After measurement of the range of motion (ROM) in the intact state, the specimens were prepared as three-column injury models. The models were stabilized by AVBSP or APSP fixation. The ROM of the models in the two states was measured. The ROM in the two states was compared.

Results: The ROM of the intact state in all directions was significantly smaller than that of the AVBSP state and significantly larger than that of the APSP state. The ROM of the AVBSP state in all directions was significantly larger than that of the APSP state.

Conclusions: This study shows that APSP fixation can provide sufficient stability for three-column injury in the lower cervical spine. The primary stability of our models using APSP fixation is superior to that of AVBSP fixation. These results suggest that APSP can be used for three-column injury in the lower cervical spine.

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Keywords

Lower cervical spine, anterior pedicle screw-plate, three-column injury, stability, biomechanics, range of motion

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Introduction

Lower cervical spine injury is common among spinal cord injuries. To decrease neurological deficits and minimize residual pain, some patients with severe cervical spine injury are treated by surgery. Compression of the spinal cord in cervical spine injury mostly occurs from the front. Anterior surgery can reduce compression of the spinal cord directly, and it is less invasive than posterior surgery. Therefore, the anterior approach is routinely used for lower cervical spine injury. However, this approach is a challenge to stabilize three-column injury using anterior vertebral body screw-plate (AVBSP) fixation because of the severe degree of bony and ligamentous disruption.¹ In most conditions, a combination of anterior fixation and posterior fixation is required for three-column injury in the lower cervical spine.

An alternative lower cervical spine anterior fixation system, called anterior pedicle screw-plate (APSP) fixation, was first reported by Koller et al.² in 2008. The main advantage of APSP is that the screw is longer than that in AVBSP, and it offers three-column stability with more rigid fixation. Anatomical reports have demonstrated the feasibility of this type of screw insertion, and biomechanical studies have verified their superior pullout resistance.³ However, to the best of our knowledge, there remains a paucity of studies on lower cervical spine APSP fixation for three-column injury. The current study aimed to evaluate the stability properties of APSP and AVBSP fixation for models

of three-column instability of the lower cervical spine.

Materials and methods

Preparation of specimens

A total of six fresh-frozen human cadaveric lower cervical spines were obtained from Wenzhou Medical University. The mean (SD) age of the spine donors was 65.2 ± 2.3 years (range, 63–71 years). The mean bone mineral density of the lower cervical spine specimens was 0.51 ± 0.37 g/cm² (range, 0.314–1.358). By computed tomography examination, fractures, fusion, tumours, or deformity of the specimens were ruled out. Approval of the experiment was obtained from the Ethics Committee of Ningbo No. 2 Hospital, and written consent for the experiment was obtained from family members of the donors.

Soft tissues excluding the longus capitis muscle and longus colli muscle were removed, while preserving discs, joint capsules, and ligaments. The distal ends of the specimen (C3 and T1) were embedded in polymethylmethacrylate to pot the specimen in testing fixtures. Normal saline was used to keep the specimens moist throughout the experiment. Screws with triaxial markers were placed in the spinous process of C4 and C7, and the motion of the screws was tracked.

Surgical procedures

Corpectomy of C5 and C6, and incision of the facet capsules, ligamentum flavum, posterior longitudinal ligament, supraspinous

ligament, and interspinous ligament of C5–C6 were performed to simulate three-column injury. All disc material was removed, and placement of a titanium cage was performed in C4–C7. Each specimen was stabilized as follows. (1) For AVBSP, anterior locking plates were fixed with two vertebral body screws unicortically at C4 and C7 for avoiding spinal cord injury. The size of the screws was 4.0 mm in diameter and 14 mm in length. (2) For APSP, APSP systems were performed according to the procedure described by Koller et al.² Anterior plates were fixed with vertebral body screws in the left side and pedicle screws in the right side of C4 and C7 (Figure 1). The pedicle screws were 3.5 mm diameter and 30 mm in length, and were placed bicortically. All instrumentation was purchased from Stryker (Kalamazoo, MI, USA). In this study, the model simulated the worst clinical situation for three-column injury. In the aggressive instability model, a difference could be obviously detected.

Biomechanical testing

Specimens were tested nondestructively in the following order using a standard flexibility testing method: 1) normal intact state, 2) AVBSP fixation after three-column injury, and 3) APSP fixation after three-column injury. A 2-nm load was applied

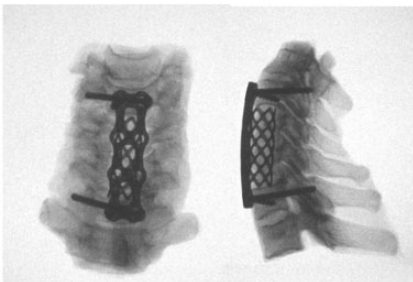


Figure 1. X-ray of three-column injury in the lower cervical spine model stabilized by APSP

at C3 for 60 seconds in multiple directions (flexion, extension, left lateral bending, right lateral bending, left axial rotation, and right axial rotation). Angular motion of C4 relative to C7 was measured from the markers after three preconditioning cycles.

Statistical analysis

The data of range of motion (ROM) of the specimens in each state are expressed as mean \pm standard deviation. Differences between groups were analysed using one-way analysis of variance followed by Tukey's multiple comparison test. $P < 0.05$ was determined to be significant. The statistical software SPSS 13.0 (Chicago, IL, USA) was used for data analysis.

Results

There was no loosening of internal fixation or fractures in the specimens after testing. The ROM data of the three states in all of the directions are shown in Table 1. The ROM of the intact state in all directions was significantly smaller than that of the AVBSP state ($P < 0.001$) and significantly larger than that of the APSP state ($P < 0.001$). The ROM of the AVBSP state in all directions was significantly larger than that of the APSP state ($P < 0.001$).

Discussion

Lower cervical spine injury is a common type of spinal cord injury. This injury is among the most challenging in trauma clinical practice because the results can be catastrophic owing to spinal cord injury.⁴ Management of lower cervical spine injury is controversial among surgeons, particularly regarding surgical decision making and choosing the surgical approach. In 2007, the Subaxial Injury Classification (SLIC) scoring system was introduced by Vaccaro et al.⁵ Since then, the SLIC

Table 1. ROM of the three states (degrees)

	Flexion-extension	Lateral bending	Axial rotation
Intact	39.77 ± 2.80	20.70 ± 2.21	26.28 ± 2.61
APSP fixation	30.63 ± 2.62	16.97 ± 1.98	21.90 ± 2.54
AVBSP fixation	47.48 ± 2.98	24.00 ± 2.09	31.65 ± 2.67
F	17.668	55.481	21.028
P	<0.001	<0.001	<0.001

Values are mean ± standard deviation. ROM, range of motion; APSP, anterior pedicle screw-plate; AVBSP, anterior vertebral body screw-plate.

system has been widely used for decisions on management and prognostication. When assessing three-column injury in the lower cervical spine by the SLIC scoring system, the anterior and middle column injury score is at least 2 for morphology, and the posterior column injury score is 2 for integrity of the discoligamentous complex. Additionally, a fragment from the disrupted middle and posterior column always intrudes into the spinal canal and leads to spinal cord or nerve root injury. Therefore, most three-column injuries have a score of more than 4 on the SLIC scale, and surgery is always required. The question remains which approach should be used in this situation.

The anterior surgical approach of the lower cervical spine was first introduced in 1952. After this time, the anterior approach was used as a routine procedure for lower cervical spine injury. Compression of the spinal cord in cervical spine injury mostly occurs at the front of the spine. Therefore, anterior surgery can reduce compression of the spinal cord directly. Additionally, anterior surgery is less invasive than posterior surgery, and it has a better biomechanical condition for fusion. However, stabilizing three-column injury using AVBSP fixation is challenging. Clinical fixation failure after AVBSP for three-column injury in the lower cervical spine was reported in 57 patients undergoing AVBSP fixation for three-column injury in the lower cervical

spine.⁶ In this previous study, hardware failure was noted in six (11%) patients and additional posterior fixation was required in four (7%) patients. A biomechanical study on AVBSP for stabilization of three-column injury has been reported.⁷ This previous study showed that reconstruction was significantly less rigid than that in the spine in the intact condition. This study also suggested that AVBSP was unsuitable for three-column injury. These results provided evidence for explanations of clinical failures. A combination of the anterior and posterior approaches for surgery is good for decompression, reduction, and reconstruction, and it is an effective surgical strategy for three-column injury. All biomechanical studies on three-column injury in the lower cervical spine showed that primary stability of the reconstructed models using a 360° construct was superior to other fixations.^{8,9} However, combination surgery has more surgical trauma with more bleeding, and it has a higher economic cost. Changing position during the operation increases the risk of neurological injury. Therefore, how to increase the stability of anterior fixation and avoid the need for additional posterior surgery needs to be investigated for management of three-column injury in the lower cervical spine.

The anchorage strength of the screw depends on the length of the path. To increase the length of the screw path, Koller et al.² developed an alternative

anterior fixation APSP in 2008. The screws of APSP travel through the vertebral body into the pedicle and out of the lateral mass. Therefore, the length of the screw path in APSP is almost twice that in AVBSP. A biochemical study showed that anchorage of screws in the APSP was 2.5-fold that of AVBSP.³ An anatomical study of APSP showed the feasibility of this type of screw insertion, and clinical application of APSP fixation for cervical facet dislocation was reported.¹⁰ A fluoroscope-assisted device was used to increase the accuracy of APSP placement.¹¹ The biomechanical characteristics of APSP for two-level corpectomy models have also been evaluated.¹² APSP offers sufficient primary stability for the lower cervical spine two-level corpectomy model.¹² Li et al.¹³ evaluated the biomechanical qualities of APSP fixation using a three-dimensional finite element model. They showed that APSP fixation offers rigid stability, and the fracture risk of the APSP system is lower than that of the AVBSP system.

All of the studies described above support the superiority of the APSP anterior and middle column injury model. However, the stability properties of APSP for the three-column injury model have not been reported yet. The main advantage of the pedicle screw is that it is longer than the screws in AVBSP fixation, and it offers three-column stability with more rigid fixation. Biomechanical studies have shown a superior stabilizing effect of the posterior pedicle screw system for three-column injury.¹⁴ The path of the screw in APSP is similar to that of a posterior pedicle screw. Additionally the screw in APSP is placed biotically, while the posterior pedicle screw is placed unicortically for avoiding injury to the oesophagus. Theoretically speaking, the APSP system should be superior to the posterior pedicle screw-plate system regarding biomechanical qualities and can also be used for three-column

injury reconstruction. In this study, we found that the ROM of the APSP state was smaller than that in the intact state, which indicated that APSP fixation could provide sufficient stability for three-column injury in the lower cervical spine. This result suggests that APSP fixation is suitable for most cases of three-column injury in the lower cervical spine.

There are limitations in this study. All of the muscles, excluding the longus capitis muscle and longus colli muscle, were removed. Muscular tissue offers certain force for stability of the cervical spine. Therefore, the results of our experiment could not completely match the situation *in vivo*. Repeated insertion of screws could destroy the bone of the specimen and affect the stability of fixation. Fatigue properties and failure mechanisms of APSP fixation for three-column injury in the lower cervical spine are unclear. Therefore, further research on these issues needs to be performed in the future.

Declaration of conflicting interest

The authors declare that there is no conflict of interest.

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