C1-C2 Pedicle Screw Fixation for Treatment of Old Odontoid Fractures

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abstract

Nonunion and C1-C2 instability of odontoid fractures usually result from delayed diagnosis and inappropriate treatment. However, the available treatment options for odontoid fractures remain controversial. The authors evaluated the effectiveness of internal screw fixation via the C1 and C2 pedicle in cases of old odontoid fractures. This retrospective study included 21 patients with old odontoid fractures (13 men and 8 women; mean age, 46.5 years; range, 24-69 years). Internal screw fixation via the C1 and C2 pedicle was performed in all patients. Fracture reduction and C1-C2 fusion were assessed with imaging. The neck pain visual analog scale score and cervical spinal cord functional Japanese Orthopaedic Association score (for those who had cervical spinal cord injury) were used to evaluate the effectiveness of treatment. Postoperative complications were recorded. Postoperative imaging showed that the C1-C2 dislocation was satisfactorily repositioned in all patients. Bone fusion was observed 1 year after surgery in all patients. No loosening or breaking of internal fixation occurred. The preoperative neck pain visual analog scale score was 5.9±1.5 and improved significantly to 1.8±0.8 after surgery ($P<.001$). The Japanese Orthopaedic Association score in patients with cervical spinal injury (n=14) was 9.2±1.9 and also significantly improved to 13.8±1.9 at the last follow-up examination ($P<.001$), with an average improvement rate of 61.0%. No iatrogenic vertebral artery injury or severe spinal cord injury occurred. Screw fixation via the C1 and C2 pedicle was found to be an effective and safe surgical approach for the treatment of old odontoid fractures with C1-C2 dislocation or instability. [Orthopedics. 2015; 38(2):94-100.]
Fracture of the odontoid (also known as dens fracture) is a common type of cervical spine fracture (approximately 10% to 20% of all cervical spine fractures).\textsuperscript{1,3} Most odontoid fractures are unstable, especially the most common Anderson and D’Alonzo type II\textsuperscript{4} fracture that could lead to necrosis and nonunion because of instability and the poor blood supply of the odontoid process.\textsuperscript{2,5} Primary clinical symptoms and manifestations of odontoid fractures are not always typical. Furthermore, patients might be unconscious or might have other, more severe trauma. As a result, odontoid fractures can easily be overlooked at first and may therefore evolve into old fractures. Delayed or improper treatment of odontoid fractures may result in nonunion or malunion, and subsequent C1-C2 instability or dislocation can lead to cervical spinal cord injury, causing upper- and lower-limb symptoms, breathing difficulty, and other life-threatening symptoms.\textsuperscript{6-9}

Several surgical strategies for odontoid fractures and C1-C2 instability are available, including external fixation, anterior screw fixation, and posterior C1-C2 fusion. However, the effectiveness of these strategies is controversial.\textsuperscript{10-13} External fixation of the cervical vertebrae with a halo vest for type II dens fracture was reported to produce no more than a 68% union rate.\textsuperscript{14,15} On the other hand, anterior screw fixation can increase surgical success rate up to 100%.\textsuperscript{16-18} but it may not be applicable in patients with old fractures, poor repositioning, unfavorable fracture line direction, dislocation, osteoporosis, and comminuted fractures.\textsuperscript{17,19,21} The high success rate of posterior C1-C2 fusion makes it applicable in patients with odontoid fractures with difficult healing and those associated with C1-C2 instability, but this technique limits motion of the cervical spine, especially rotation. Indications for posterior C1-C2 fusion have been extended by the Harms technique.\textsuperscript{22} In recent years, the approach using screw fixation in C1 via the posterior arch and lateral mass has been developed to overcome the disadvantages of the Harms technique, including damage to the paravertebral venous plexus and the nerves and blood vessels anterior to the lateral mass.\textsuperscript{23-26}

Anterior odontoid screw fixation for the treatment of odontoid fractures is widely used in clinical practice and offers a unique advantage: direct fixation without bone graft or external fixation, which facilitates fracture healing. In addition, odontoid screw fixation enables preservation of maximal C1 motion.\textsuperscript{16-18,27} However, the effectiveness of odontoid screw fixation for old fractures is still controversial.\textsuperscript{19,28} Anterior odontoid screw fixation was previously used for the treatment of old odontoid fractures by Apfelbaum et al.,\textsuperscript{19} and they reported that 31% patients had to undergo a secondary posterior surgery because of nonunion.

In the current study, patients had a relatively long disease course, with a maximum of 6 years. It is generally believed that a longer disease course is associated with a higher possibility of nonunion with screw fixation only. In addition, C1 repositioning was unsuccessful in 11 patients before surgery and 6 patients had posterior dislocation of C1. Therefore, posterior fixation surgery was selected for all patients in the current study. The goal of this study was to investigate the feasibility, therapeutic effect, and complications of internal screw fixation via the C1 and C2 pedicle in old odontoid fractures.

**Materials and Methods**

**Patients**

Twenty-one patients (13 men and 8 women; mean age, 46.5 years; range, 24-69 years) with old odontoid fractures underwent screw fixation via the C1 and C2 pedicle between October 2006 and November 2010 in the Spine Surgery Department of Qilu Hospital of Shandong University, Jinan, China. Causes of odontoid process injuries included traffic accident (n=10), falling injury (n=5), crush injury (n=4), and low-energy damage (n=2). Inclusion criteria were: (1) nonunion of an odontoid fracture with C1-C2 instability; (2) more than 6 weeks between fracture and surgery; and (3) follow-up for more than 1 year. Exclusion criteria were: (1) severe lower cervical spinal stenosis; (2) cervical infection or tumor; and (3) congenital malformation.

Four patients had injury to the brain/cranium or to other vital organs, and the diagnosis and treatment of odontoid fractures was delayed in their local hospitals. Seven patients underwent conservative therapy, such as external fixation, which resulted in nonunion of odontoid fractures and late C1-C2 instability. Anterior screw fixation failed in 4 patients, and the remaining 6 patients had mild initial symptoms that gradually developed into cervical spine injury or occurred after a secondary trauma. The disease course from trauma to the current surgery ranged from 1.5 months to 6 years.

Seven patients had neck pain as their single symptom on admission. Fourteen patients had symptoms of cervical spinal injury, such as sensorimotor dysfunction in the extremities. Two of these patients had obvious respiratory dysfunction.

The Japanese Orthopaedic Association score was used to evaluate spinal cord function,\textsuperscript{29} and the visual analog scale was used to evaluate neck pain.

**Imaging**

Preoperatively, all patients underwent radiographic cervical anteroposterior examination with open mouth, lateral, and hyperextension views. Patients were classified as either type II (n=16) or type III (n=5), according to the Anderson and D’Alonzo classification.\textsuperscript{4} C1-C2 dislocation was anterior in 13 patients and posterior in 6 patients. Two patients had no
obvious dislocation. However, for the 2 patients without obvious dislocation, the fractured bone did not heal after odontoid screw fixation and there was obvious bone resorption around the odontoid screws.

All patients also underwent cervical computed tomography (CT) scan with sagittal reconstruction to clarify the type of odontoid fracture and the features of the anatomic structure.

Cervical spine magnetic resonance imaging scan showed no obvious compression at C1 and C2 in 7 patients and obvious compression in 14 patients. Furthermore, 8 of 14 patients showed high signals in the spinal cord on T2-weighted images at the compressed level, indicating severe spinal cord damage. No lower cervical spinal stenoses or lower cervical spinal cord injuries were noted.

Treatment

The 2 patients who had no obvious C1-C2 dislocation (fractured bone did not heal after odontoid screw fixation and bone resorption occurred around the screws) directly underwent posterior surgery. In another 2 patients who had failure of odontoid screw fixation, I had a light shift of the screws after fixation and was treated with direct posterior fusion and the other had obvious loosening and shift of the screws and underwent posterior fusion after the loosened screws were removed via the original fixation approach. The remaining patients who had C1-C2 dislocation (n=17) underwent preoperative skull traction for 2 weeks, starting with 3 kg and reaching a maximum of 10 kg. After traction, 12 patients achieved complete (n=6) or nearly complete (n=6) diaplasis and underwent posterior surgery; 5 patients with irreducible C1-C2 dislocation underwent antero-posterior surgery.

Surgical Approach

For the anterior approach, oral cavity disinfection was performed for 3 days before surgery, an indwelling nasogastric tube was placed, and general anesthesia was performed with orotracheal intubation.

The posterior pharyngeal wall was cut open to expose the odontoid bone line. Hyperplastic tissues and callus around the fracture lines were removed, and adhesive tissues were further separated from the joints. Using skull traction, C1 and C2 were repositioned with the assistance of a curette. However, repositioning was not stable with anterior surgery in 3 patients and satisfactory repositioning was finally achieved after posterior surgery.

The posterior arch of C1 and the axial lamina were accessed with the posterior approach, and the posterior arch of C1 was exposed from the middle line of the spinous process to both sides (approximately 1.5 cm wide). The surgeon continued to strip along the posterior and inferior margins of the posterior arch of C1 to both sides until the nerve dissector detected the inner margin of the C1 pedicle. The inner and superior margins of the C2 pedicle were identified with a nerve dissector. After determination of the screw entry points in the C1 and C2 pedicle, screw implantation in the C1 and C2 pedicle was completed. The position and length of the screws and C1 repositioning were monitored intraoperatively with C-arm radiography. Nine patients underwent posterior surgery without complete C1 repositioning. They underwent adjustment of the screw and plate/rod position to reach satisfactory C1 repositioning. The surfaces of the posterior arch of C1 and the lamina of C2 were appropriately ground for bone graft bed preparation, and an autogenous iliac bone graft was implanted after being shattered. The incision was closed after the indwelling drainage tube was placed.

Postoperative Treatment and Follow-up

The drainage tube was removed 48 hours after surgery. Bed rest was not necessary for all patients; off-bed activity was suggested according to the patient’s condition. Acupuncture, electrical stimulation, and neurotrophic drug treatment were routinely advised for patients who had symptoms of spinal cord injury to facilitate recovery of neurologic function.

Radiographic examination was performed at 3, 6, and 12 months after operation. Sagittal CT reconstruction was performed 6 and 12 months after surgery to monitor fracture repositioning and C1-C2 fusion. Bone fusion was defined as trabecular continuity through the posterior arch of C1, with visibility of the lamina of C2 on CT reconstruction. Japanese Orthopaedic Association scores were recorded at the last follow-up examination to evaluate cervical spinal cord function. Japanese Orthopaedic Association score improvement rate=(postoperative score−preoperative score)/(17−preoperative score)×100%.

Neck pain was also evaluated at the last follow-up examination by visual analog scale score.

Statistical Analysis

Changes in Japanese Orthopaedic Association and visual analog scale scores are presented as mean±SD and were analyzed with paired t tests. P<.05 was considered statistically significant. Data were analyzed with SPSS version 17.0 software (SPSS Inc, Chicago, Illinois).

RESULTS

Baseline characteristics of the 21 patients are shown in Table 1. Postoperative imaging showed that the C1-C2 dislocation was satisfactorily repositioned in all patients. Trabecular continuity through the posterior arch of C1 and the lamina of C2 was shown by radiograph and CT reconstruction 1 year after surgery, and the bone fusion rate was 100%. The position of the screw did not change. No loosening or breaking of internal fixation occurred, and no C1 redislocation occurred during follow-up.

The visual analog scale score for neck pain was significantly improved at the last
follow-up examination ($P<.001$). No new onset of spinal cord injury occurred after surgery. Symptoms of spinal cord injury were improved in 14 patients who had cervical spinal damage before surgery. At the last follow-up examination, Japanese Orthopaedic Association scores were significantly improved, with an average improvement rate of 61.0% ($P<.001$) (Table 2).

No severe surgical complications were observed, such as iatrogenic vertebral artery or spinal cord injury. Although postoperative CT scan showed a C2 pedicle screw penetrating the wall of the vertebral artery foramen in 7 cases, penetration was less than 1 mm and no symptoms of vertebral artery injury were observed. No infection occurred in the pharyngeal posterior wall or the posterior cervical incision. Three patients (14.3%) had upper cervical and occipital pain, numbness, or hypersensitivity. These symptoms were relieved after 3 months of symptomatic treatment, without the need for medication. Neck stiffness and limited neck rotation occurred after operation. In the current study, 7 patients had limited neck rotation and gradually adapted their work and daily activities to accommodate this limitation. Typical cases are shown in Figure 1 and Figure 2.

**Discussion**

The odontoid process is an important anatomic structure for maintaining the stability of the C1-C2 joint, and odontoid fractures that do not receive timely and appropriate treatment lead to nonunion or to old odontoid fractures, resulting in cervical spinal cord compression. Nonsurgical treatments are usually considered first for type I or III odontoid fractures, and surgery is considered for patients with C1-C2 instability. However, conservative treatment of type II fractures might lead to nonunion, even with halo brace fixation, and the fracture healing rate is reported to be low.$^{4,30}$ Therefore, most orthopedic surgeons prefer surgery for the treatment of type II odontoid fractures. The timing of surgery for odontoid fractures is believed to be critical, and a retrospective study reported that delay of treatment by more than 4 days could result in nonunion.$^{31}$ However, delayed or inappropriate treatment of odontoid fractures is not uncommon.
and treatment is usually initiated at the onset or progression of late neurologic symptoms; subsequently, the nonunion rate for delayed treatment of odontoid fractures was found to be higher than that for early treatment.\textsuperscript{10} In the current study, 7 patients underwent conservative treatment that resulted in nonunion of odontoid fractures (33.3%). Six patients had mild symptoms after trauma, and timely and effective therapy was not carried out until an old odontoid fracture was diagnosed when neurologic symptoms occurred after a secondary trauma or simply after progression of C1-C2 instability.

The biomechanical strength of C1 and C2 pedicle screw fixation is similar to the strength of Magerl screws,\textsuperscript{32} providing reliable biomechanical stability of C1 and C2. The binding wire at the posterior edge of C1 is not needed; therefore, C1 and C2 pedicle screw fixation is suitable for patients who have a defect on the posterior arch of C1 or those who need extra pressure from the posterior arch of C1. Compared with Magerl screws, C2 pedicle screws are inserted with an interior angle of 20° to 25°, which effectively avoids injury to the vertebral artery, even if the vertebral artery foramen is enlarged. In addition, C2 pedicle screws enable better direct vision during surgery, making C2 pedicle screw fixation safer than the use of Magerl screws.\textsuperscript{12,33,34} Although it was reported that C2 pedicle screws penetrated into the vertebral arterial foramen in 5.4% of patients because of the limited experience of the surgeon, no obvious clinical symptoms occurred.\textsuperscript{12} In addition, 4 of 160 patients had hemorrhage during C2 pedicle screw placement;\textsuperscript{35} however, no abnormality was shown by postoperative angiography and no relevant symptoms occurred. In the current study, C2 pedicle screws penetrated into the interior wall of the vertebral arterial foramen by less than 1 mm in 7 patients. No uncontrollable hemorrhage occurred, and no symptoms were observed during follow-up. Therefore, penetration of the screw by less than 1 mm should not injure the vertebral artery. Because preoperative complete repositioning of C1 was not a prerequisite for posterior surgery, the screws, titanium plate, or rod used for internal fixation could help in repositioning, which is an apparent advantage over other posterior instruments. In the current study, incomplete repositioning of C1 dislocation before posterior surgery was observed in 9 patients and these patients required further fixation with posterior surgery.
The C1 and C2 pedicle screw placement should be individualized; screw position, length, and insertion direction should be planned with detailed preoperative imaging. In addition, CT reconstruction can help to determine the thickness of the C1 posterior arch and the possibility of performing pedicle screw placement and to estimate the possible influence of the location and size of the vertebral artery foramen. Screw placement is finally determined with the use of a nerve dissector to intraoperatively detect the interior edge of the C1 pedicle, the posterior edge of the C1 lateral mass, and the interior and upper edges of the C2 pedicle. Some patients had a narrowed posterior arch of C1, and 3.5-mm screws should penetrate through the pedicle, without the need for special treatment. In the current study, 9 of 42 screws penetrated the pedicle. No effect on the stability of internal fixation was observed, and stability was still better than that achieved with C1 lateral mass screws. The nerve root and venous plexus between the C1 and C2 vertebral laminae do not need deliberate exposure, but sometimes there is unavoidable hemorrhage of the venous plexus that can be stopped with electrocoagulation. Sponge compression hemostasis is usually used for massive hemorrhage.

In the current study, neck pain and symptoms of cervical spinal cord injury were significantly improved as a result of satisfactory repositioning and timely C1 and C2 pedicle screw fixation. Few postoperative complications occurred. No vertebral artery or spinal cord injury occurred, although 3 patients had occipital pain that might be associated with C2 nerve root irritation. This irritation might also be caused by sponge compression hemostasis for vein bleeding between the C1 and C2 vertebral laminae, by bone particle stimulation during bone graft, or by penetration of the C1 pedicle screw through the posterior arch. These complications could be effectively avoided by careful manipulation during operation. Patients recovered promptly with postoperative symptomatic treatment. Limitations of the current study included the small sample size, the short follow-up period, and the lack of a control group.

**Conclusion**

The findings showed that C1 and C2 pedicle screw fixation can be directly used for repositioning of C1-C2 dislocation with firm fixation and a high rate of bone graft fusion. Few complications such as vertebral artery and spinal cord injury occurred in this study, and C1 and C2 pedicle screw fixation could be a safe and effective surgical treatment for old odontoid fractures associated with C1-C2 dislocation or instability.

**References**

2. Hadley MN, Dickman CA, Browner CM,


