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Technical Note

Anterior single-screw fixation in 24 patients with Type II odontoid fractures

Kuo-Feng Fan*, Jen-Chung Liao, Chi-Chien Niu, Lih-Huei Chen, Wen-Jer Chen, Mel S. Lee

Department of Orthopedic Surgery, Chang-Gung Memorial Hospital, 5 Fu-Hsing Street, Kueishan, Taoyuan 333, Taiwan, ROC

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A B S T R A C T

Background: Fractures of the odontoid process make up 9–15% of adult cervical fractures; Type II odontoid fractures are the most common type. Most patients with these fractures recover after early treatment utilizing the proper surgical approach.
Purpose/Aims: A retrospective study was performed to evaluate the bone union rate and to identify factors that might contribute to non-union in patients undergoing anterior single-screw fixation for Type II odontoid cervical fractures.
Methods: From November 2000 to December 2008, 24 patients (16 males, 8 females) underwent anterior single-screw fixation for Type II odontoid cervical fractures. Prior to surgery, all patients had cervical spine radiographs and computed tomographic (CT) scans. Surgery to correct the fractures used the technique of Abfelbaum et al, and fluoroscopy was used to confirm spinal stability. At follow-up, bone fusion was considered successful if trabeculation across the fracture site was seen on lateral radiographic studies. Non-union was confirmed when the fracture line was visible on follow-up lateral radiographic studies. After surgery, all patients were followed at approximately 2 weeks, 4 weeks, 6 weeks, 3 months, 6 months, 9 months, and annually thereafter.
Results: All 24 patients had odontoid fractures confirmed by radiographic films and CT scans. Twenty-three patients had Type II odontoid fractures that were posterior-oblique or horizontal, and one had an anterior oblique fracture. Twenty patients achieved successful fusion. The presence of a lag effect was significantly different between patients who had successful fusion and the four patients with fusion failure. All patients achieved immediate spinal stabilization after surgery and none experienced major neurologic sequelae.
Conclusions: Anterior single-screw fixation is an effective and safe surgical approach for patients with Type II odontoid fractures. A satisfactory long-term outcome depends upon careful selection of patients for fracture orientation and attention to the technical aspects of surgery.

1. Introduction

Fractures of the odontoid process, usually caused by motor vehicle accidents or other trauma, make up 9–15% of adult cervical fractures. Odontoid fractures are commonly categorized into one of three types: Type I, an oblique fracture through the upper part of the odontoid process; Type II, fracture at the junction of the odontoid process with the body of the cervical vertebra; and Type III, fracture extending down into the cancellous portion of the vertebral body.[1] Most odontoid fractures occur at the junction of the odontoid process and the C2 body (Type II fracture) or at the body of C2 (Type III fracture). Type I and Type III fractures are relatively stable and are usually treated with nonsurgical immobilization.[2] For Type II fractures, which are less stable, surgery is generally considered the best treatment approach.

Various treatment approaches are available. External immobilization with a cervical collar and/or vest can produce successful healing rates from 37% to 75%.[3] However, mortality rates from 26% to 47% have been reported with this approach, perhaps due to respiratory-related complications resulting from prolonged external immobilization.[4] Traditional posterior C1–C2 arthrodesis has resulted in union rates from 92.8% to 100%.[4] The downside to this approach is reduced cervical motion, an important consideration because movement at the C1–C2 junction accounts for more than 50% of cervical rotation. Arthrodesis can also reduce cervical spine flexion–extension by up to 10%.[2]

Since direct anterior screw fixation was introduced independently by Nakanishi in 1980[5] and Bohler in 1982,[6] it has become the

* Corresponding author. Department of Orthopedic Surgery, Chang-Gung Memorial Hospital, 5 Fu-Hsing Street, Kueishan, Taoyuan 333, Taiwan, ROC. Tel.: +886 3 3282820x2423; fax: +886 3 3289582.
E-mail address: fan0429@adm.cgmh.org.tw (K.-F. Fan).

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most widely-used surgical method for stabilizing Type II odontoid fractures. It has been shown to be an effective treatment for all adult patients, including the elderly.[7]

We designed a retrospective study to evaluate the bone union rate and to identify factors that might contribute to non-union in patients undergoing anterior single-screw fixation for Type II odontoid cervical fractures at our institution.

2. Methods

2.1. Patients

A search for all patients who underwent anterior screw fixation for Type II odontoid fractures from November 2000 to December 2008 at Chang-Gung Memorial Hospital revealed that 24 patients had undergone this procedure. This group included 16 males and 8 females, and the average age was 45 years (range, 18 to 65 years). Data for each patient were obtained from hospital medical records of clinical examination, operative findings and imaging studies. These data were then used to analyze surgery-related results. All subjects had fractures from trauma and underwent radiographic examination via cervical spine radiography and computed tomography (CT) prior to surgery. All fractures were assessed preoperatively by evaluating the initial lateral and open-mouth anteroposterior radiographs and CT scans of the odontoid. One surgeon (Dr Fan) performed all surgical procedures.

2.2. Surgical technique

All patients were treated with the standard surgical technique first described by Apfelbaum et al.[3] The patient was placed supine on the operating table, with his or her head fixed in a hyperextension position with mandibular traction designed by the surgeon. The traction device also immobilized the jaw and facilitated wound exposure. The pins of the mandibular traction were inserted transversely through the mandible. Pin insertion through the mental foramina was avoided to prevent injury to the mental nerve (Fig. 1A and B).

A transverse incision was made and a right-sided Robinson approach was carefully used to prevent injury to the recurrent laryngeal nerve. A posterior cruciate ligament (PCL) retractor was used to retract. A biplane C-arm imaging system, developed at the University of Utah, was used to monitor the progress of surgery. A single 3.5-mm partly threaded cancellous screw was used for fixation. A Miami J Cervical Collar was used postoperatively for immobilization.

2.3. Postsurgical clinical evaluation and follow-up

All patients underwent preoperative and serial postoperative clinical examinations at approximately 2 weeks, 4 weeks, 6 weeks, 3 months, 6 months, and 9 months, and annually thereafter. The presence of occipital neuralgia, or other neck pain, and range of motion were evaluated at each visit.

All fractures were reassessed postoperatively with serial lateral and open-mouth anteroposterior radiographs of the cervical spine at each follow-up visit, to evaluate screw position, fracture alignment, and fusion status. Lateral flexion–extension radiographs were obtained to determine fusion status in cases of suspected fusion failure. Bone fusion was considered successful if solid bony fusion, seen as trabeculation across the fracture site, was present on lateral radiographic studies (Fig. 2A–E). Unsuccessful fusion (non-union or fibrous union) was determined when the fracture line was visible on lateral X-ray studies.

2.4. Statistical analysis

Because of the small sample size, the two groups were compared with the Mann–Whitney *U* test for continuous variables and the Fisher's exact test for categorical variables. Data are presented as median interquartile range (IQR) for continuous data and numbers (percentages) for categorical data. All statistical assessments were two-sided and evaluated at the 0.05 level of significant difference. Statistical analyses were performed using SPSS 15.0 statistics software (SPSS Inc, Chicago, IL, USA).

3. Results

Table 1 shows the demographic and clinical characteristics of the 24 patients who underwent anterior odontoid screw fixation between November 2000 and December 2008. All 24 patients had odontoid fractures confirmed by radiographs and CT scans. Twenty-three patients had Type II odontoid fractures that were posterior-oblique or horizontal, and one patient had an anterior oblique fracture. The average operation time was 3.5 hours and no

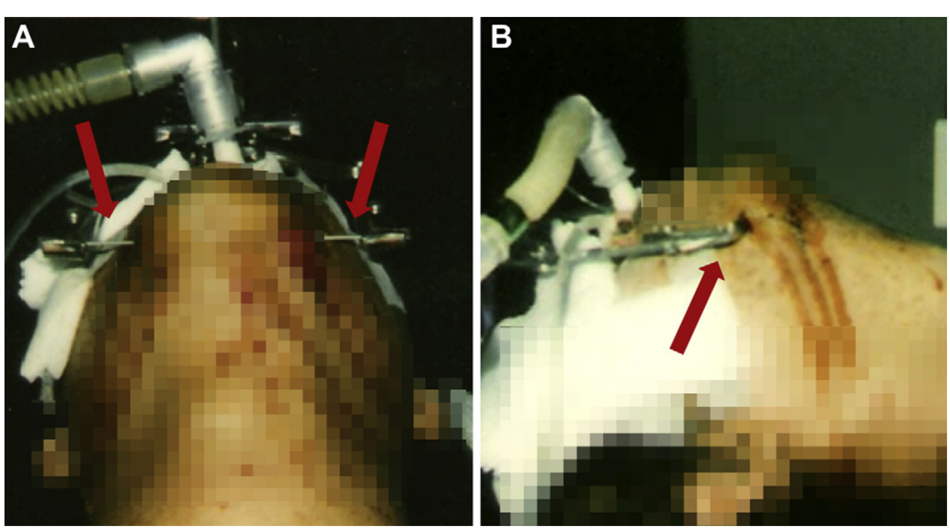

Fig. 1. Mandibular traction. A 1.8-mm pin was inserted transversely through the mandible (arrows). Pin insertion through the mental foramina was avoided to prevent injury to the mental nerve. (A) Caudal view; (B) lateral view.

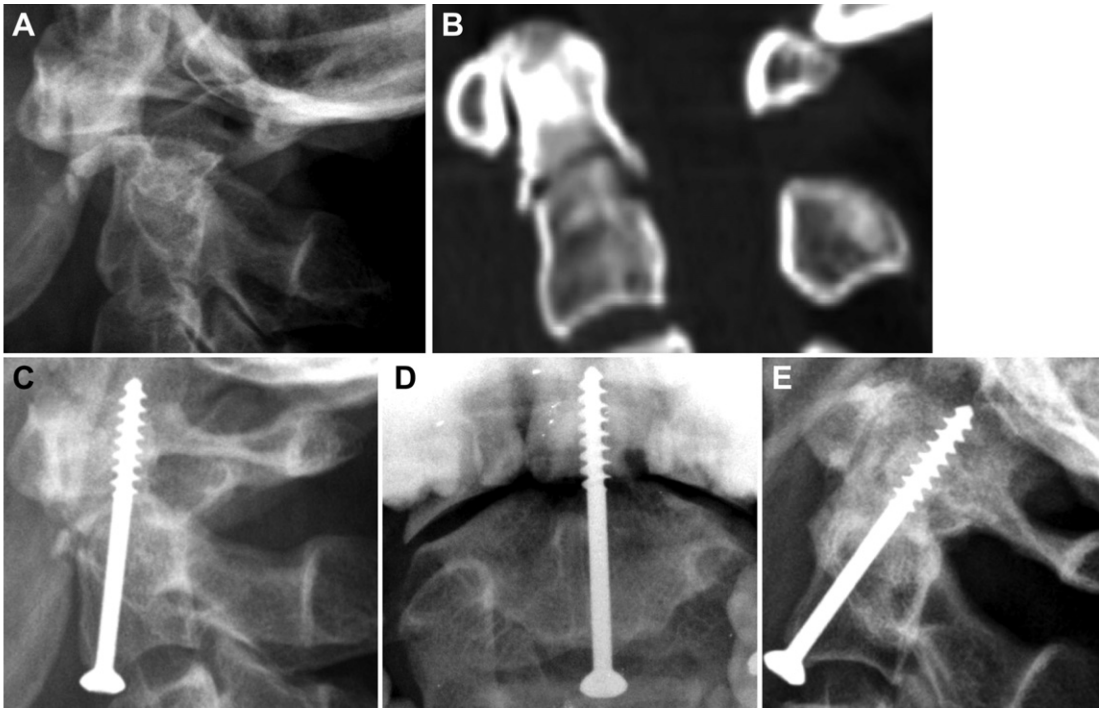

Fig. 2. Successful union of a Type II odontoid fracture in a 56-year-old female patient. (A) The initial X-ray film shows anterior displacement of the distal fragment. (B) This computed tomographic (CT) scan shows ideal fragment reduction after closed reduction by Gardner–Wells traction. (C, D) Insertion angle of the single-screw; (E) solid bony fusion 2 months postoperatively.

intraoperative complications were reported. Patients had minimal blood loss and experienced no complications such as bleeding, hoarseness, infection, or vascular or neural structure injuries. No mental nerve injuries were sustained due to the use of mandibular traction. All patients achieved immediate spinal stabilization after surgery and none experienced major neurologic sequelae.

Median follow-up was 24 months (range 6–120 months). No patients were lost to follow-up and no deaths occurred. Four patients experienced non-union with C1–C2 instability (Fig. 3A–F).

As shown in Table 1, the median age was 45 years (range 32–52 years). Of the 24 patients, 20 (83.3%) had fractures sustained in motor vehicle accidents and four (16.7%) had fractures resulting from falls. The median time interval from injury to operation was 6 days (IQR = 4–8 days) and the median fracture displacement and gap were 5 mm and 2 mm, respectively.

Patient age, gender, cause of fracture, time interval from injury to operation, fracture displacement, and fracture gap were not statistically significant between the four patients who had fusion failure after anterior screw fixation and the 20 patients who had successful fusion. However, fusion failure was found to be significantly associated with presence of proper lag effect ($p < 0.05$; Table 1). In addition, implant failure occurred in all four patients who had unsuccessful fusion.

Table 1
Patient demographics and clinical characteristics between those with successful fusion and those with fusion failure after anterior odontoid screw placement ($n = 24$).

	Patients ($n = 24$)	Successful fusion ($n = 20$)	Fusion failure ($n = 4$)	p
Age, years, mean (IQR)[a]	45 (32–52)	45 (31–56)	41 (34–49)	1.000
Gender, n (%)[b]				
Male	16 (66.7)	14 (70.0)	2 (50.0)	0.578
Female	8 (33.3)	6 (30.0)	2 (50.0)	
Causes of fractures, n (%)[b]				
Traffic accident	20 (83.3)	16 (80.0)	4 (100.0)	1.000
Falls	4 (16.7)	4 (20.0)	0 (0.0)	
Interval, mean, from injury to operation (days)[a]	6 (4, 8)	6 (4.5, 8.0)	6 (4, 8)	0.523
Fracture displacement (mm)[a]	5 (3.5, 5)	5 (4, 5)	4 (3, 5)	0.328
Fracture gap (mm)[a]	2 (2, 3)	2 (2, 3)	2.5 (2, 3)	0.867
Lag effect, n (%)[b]				
Yes	20 (83.3)	20 (100.0)	0 (0.0)	<0.001*
No	4 (16.7)	0 (0.0)	4 (100.0)	

All numbers are median (interquartile range, IQR) unless otherwise specified.
*Significant difference between successful fusion and fusion failure.
[a] All p values are based on Mann–Whitney U test and
[b] Fisher's exact test.

4. Discussion

For optimal treatment of Type II fractures, patient selection, timing of surgery, and proper surgical technique are essential because the unstable nature of these fractures places patients at significant risk for immediate or delayed catastrophic spinal cord compromise. Treatment can be challenging because of the complex anatomy of this area. The fracture, which occurs through the base of the odontoid process, is usually caused by hyperflexion or hyperextension forces, and the blood supply to the area may be compromised. Patient age can also be a factor, contributing to non-union in 30–50% of older patients, especially when the displacement is greater than 5 mm. The risk of non-union is also greater when significant displacement, angulation greater than 10 degrees or translation greater than 5 mm, is present.[3]

Numerous studies have pointed out the efficacy and high fusion rate possible with anterior screw fixation to stabilize Type II

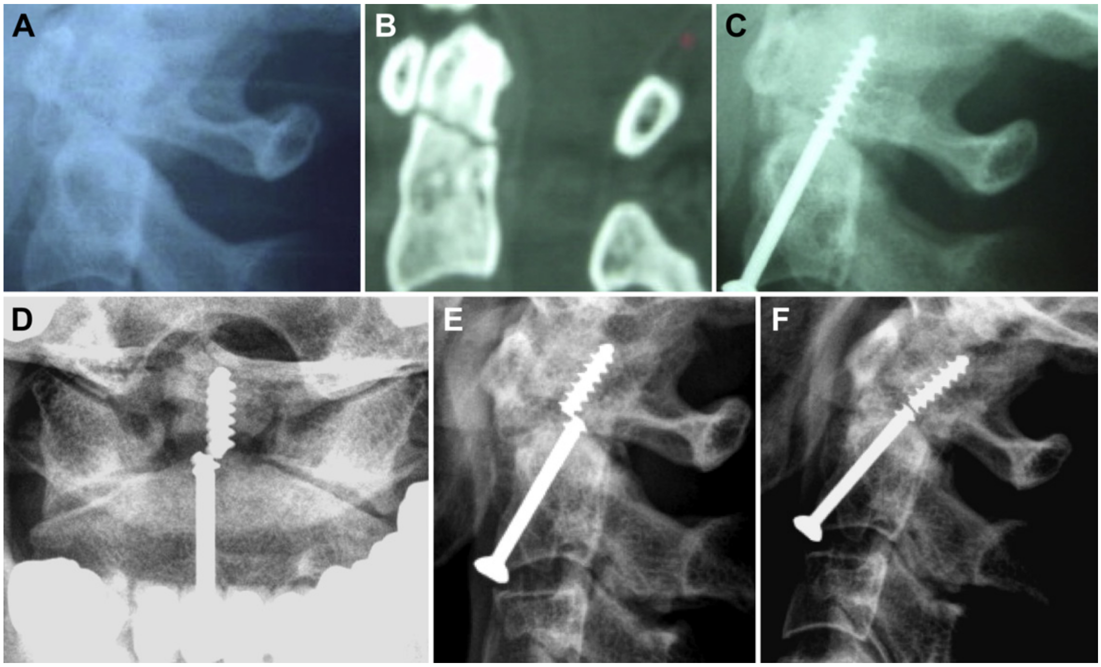

Fig. 3. Non-union of a Type II odontoid fracture in a 39-year-old female patient. (A) The initial X-ray film shows anterior displacement of the distal fragment. (B) This computed tomographic (CT) scan shows ideal fragment reduction after closed reduction by Gardner–Wells traction. (C) Insertion of a single screw. The threaded portion of the screw impinged upon the fracture line, and failed to produce a proper lag effect. (D, E, F) These three views, taken 22 months after surgery, show non-union of the fracture and implant failure with C1–C2 instability.

odontoid fractures.[8–10] Hou et al[8] reported that anterior odontoid screw fixation is an effective approach for direct fracture fixation without autologous bone graft. These researchers cited a number of advantages over posterior C1 arthrodesis, including immediate stabilization, less postoperative pain, no requirement for bone graft, and preservation of the normal atlantoaxial rotational movement. This was true despite the fact that their patients had a mean age of 80 years.

In a large study by Li et al, it was found that anterior screw fixation can be performed safely in elderly patients with Type II odontoid fracture. High fusion rates, low postoperative complications, and maintenance of cervical motion were achieved. The authors concluded that anterior screw fixation can be a reliable and reasonable treatment for Type II odontoid fractures in elderly patients. [11]

The success of this treatment depends on patient selection, attention to technical operative details, and adequate follow-up. Internal screw fixation gives immediate direct fixation of the fracture, offers a high rate of fusion without requiring prolonged halo/vest immobilization, reduces occurrence of the cervical pain, and preserves the normal mobility of C1–C2.[12]

In acute axis fractures, early surgical intervention within 3–5 days of injury is recommended for patients exhibiting acute fracture instability despite external immobilization, transverse ligament disruption, Type II odontoid fractures with dens displacement of at least 6 mm on admission, or severe Francis grade or Effendi-type hangman's fractures.[13]

In our study, the union rate of 83% is comparable to other reports, in which the success rate has ranged from 73% to 100%.[4] Fractures that pass from anteroinferior to posterosuperior (anterior oblique orientation, Fig. 4A–D) are significantly more likely to result in non-anatomical union, non-union, or fibrous union than are posterior oblique and horizontally oriented fractures.[3] Aebi and colleagues concluded that an oblique fracture oriented from anteroinferior to posterosuperior provides only a small part of the C2 body for anchorage of the screw, which may result in anterior displacement of the fragment under compression.[9] Anterior oblique orientation is considered a contraindication to the anterior screw fixation technique, and hence proper fracture identification and selection are key to success.[9,14] One patient in this study had a fracture with an anterior oblique orientation. For this patient, closed reduction of the fracture was achieved preoperatively using Gardner–Wells traction, and fortunately, this patient experienced successful fusion. These factors stress the importance of careful evaluation of the orientation of a fracture when selecting patients for anterior screw fixation.

Radiologic imaging of the four patients who developed non-unions revealed that in all four, the threaded portion of the screw impinged upon the fracture line, failing to produce a proper lag effect. The lag effect is the action of pulling two fractured bony elements together with a partly threaded lag screw that is anchored in the proximal fragment with the threaded portion of the screw in the distal fragment. As the screw tightens, the distal fragment is pulled toward the proximal fragment.[15] As Johnson and Wang explained, the lag screw is seldom used to repair lumbar spine fractures but is well designed for odontoid fracture repair. The lag screw is designed with a threaded distal portion, a smooth proximal portion, and a wide head to simultaneously re-approximate the proximal and distal fragments during the final phase of screw tightening and to achieve fixation.[15] The threaded portion must be engaged only in the distal fragment. If the threaded portion enters the fracture line, compression across the fracture line will not be possible.[16] Failure of union in our four patients may have resulted from improper screw placement; this underscores the importance of proper surgical technique.

The issue of instrumentation failure due to metal fatigue is still unresolved because evidence from long-term follow-up studies is lacking. Aebi and Fountas each reported a single case of screw failure due to metal fatigue.[9,17] Their experience supports the general opinion that mechanical instrumentation failure most

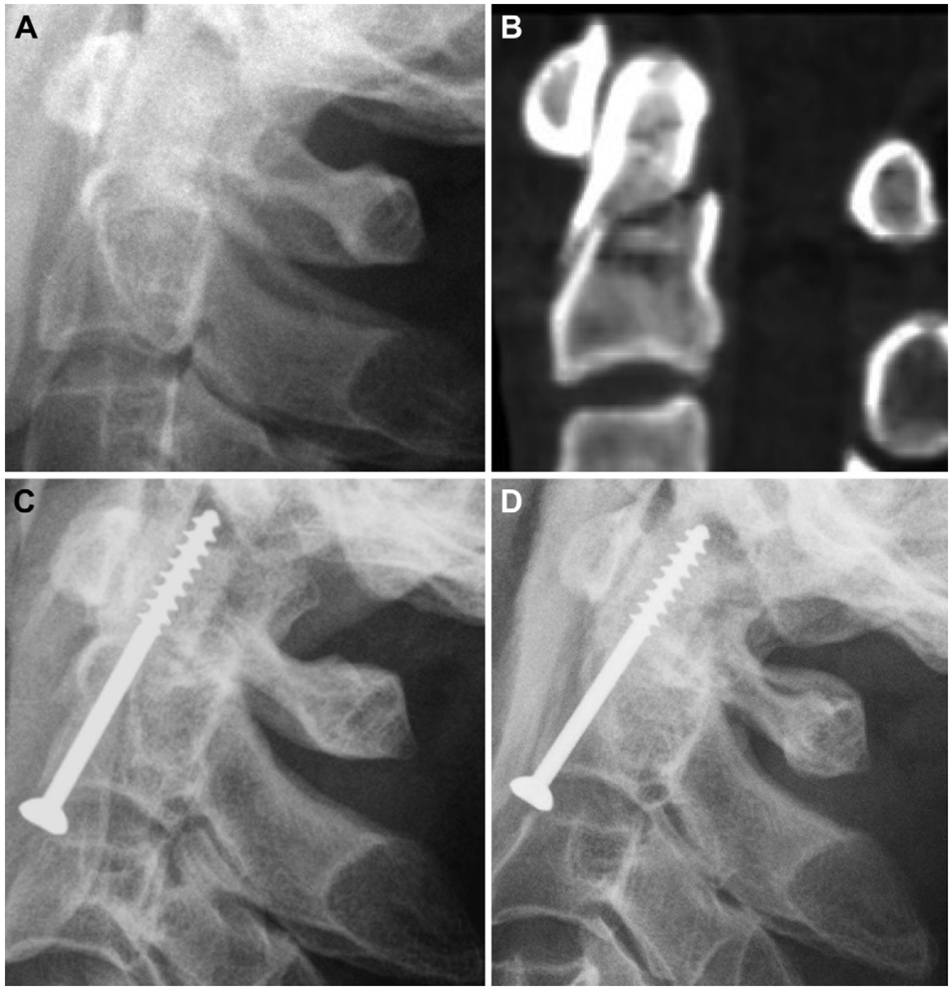

Fig. 4. Successful union of an anterior oblique Type II odontoid fracture in a 45-year-old male patient. (A) X-ray film and (B) computed tomographic (CT) scan show anteroinferior to posterosuperior fracture orientation; (C) insertion of a single screw; and (D) solid bony fusion 2 months postoperatively.

probably does not constitute a potential long-term problem in patients undergoing anterior screw fixation. However, in our study, imaging revealed screw failure in all four patients who had fusion failure (Fig. 3D–F). The screw breakage was discovered between the 8-month and 2-year follow-up visits, and these patients subsequently received conservative immobilization treatment. The four patients with broken instrumentation did not undergo further surgery because C1–C2 arthrodesis would have decreased their neck rotation by 50%, which the surgeon and patients viewed as unacceptable. All four patients received physical therapy and rehabilitation to increase their neck strength. Oral analgesics were prescribed for pain recurrences, and when pain recurred, a Miami J Cervical Collar was used for immobilization. None of the patients requested further surgical intervention, for they found the pain to be tolerable. None of the fractures healed.

Implant failure in our series occurred at a much greater frequency than in the previous reports. A possible explanation for this high rate of implant failure may be improper screw insertion (where the threaded portion of the screw impinges upon the fracture line).

4.1. Limitations

Limitations of this study include the small number of patients and its single-institution, retrospective nature. In addition, three patients were not followed-up with for a full year.

5. Conclusion

Anterior single-screw fixation is an effective and safe surgical approach for patients with Type II odontoid factures. Factors that improve the success rate and increase the likelihood of a satisfactory long-term outcome include careful selection of patients for fracture orientation and careful attention to the technical aspects of the procedure.

References

1. L.D. Anderson, R.T. D'Alonzo. Fractures of the odontoid process of the axis. J Bone Joint Surg Am 56 (1974) 1663–1674.
2. T.G. Maak, J.N. Grauer. The contemporary treatment of odontoid injuries. Spine 31 (2006) S53–S61.
3. V. Denaro, R. Papalia, A. DiMartino, N. Maffuli. The best surgical treatment for Type II fractures of the dens is still controversial. Clin Orthop Relat Res 469 (2011) 742–750.
4. R.L. Apfelbaum, R.R. Lonsser, R. Veres, A. Casey. Direct anterior screw fixation for recent and remote odontoid fractures. J Neurosurg 93 (2000) 227–236.
5. T. Nakanishi. Internal fixation of the odontoid fracture. Cent Jpn J Orthop Trauma Surg 23 (1980) 399–406.
6. J. Bohler. Anterior stabilization for acute fractures and non-unions of the dens. J Bone Joint Surg Am 64 (1982) 18–27.
7. W. Borm, E. Kast, H.P. Richter, K. Mohr. Anterior screw fixation in type II odontoid fractures: is there a difference in outcome between age groups? Neurosurgery 52 (2003) 1089–1092.
8. Y. Hou, W. Yuan, X. Wang. Clinical evaluation of anterior screw fixation for elderly patients with Type II odontoid fractures. J Spinal Disord Tech 24 (2011) E75–E81.

9. M. Aebi, C. Etter, M. Coscia. Fractures of the odontoid process. Treatment with anterior screw fixation. Spine 14 (1989) 1065–1070.
10. K. Chiba, Y. Fujimura, Y. Toyama, T. Takahata, T. Nakanishi, K. Hirabayashi. Anterior screw fixation for odontoid fracture: clinical results in 45 cases. Eur Spine J 2 (1993) 76–81.
11. C. Li, H. Chen, Y.-Hy. Lu, D.Y. Wu. Percutaneous anterior cannulated screw fixation for type II odontoid fractures. J Clin Orthop 11 (2008) 500–501.
12. A. Alfieri. Single-screw fixation for acute Type II odontoid fracture. J Neurosurg Sci 45 (2001) 15–18.
13. K.A. Greene, C.A. Dickman, F.F. Marciano, J.B. Drabier, M.N. Hadley, V.K. Sonntag. Acute axis fractures. Analysis of management and outcome in 340 consecutive cases. Spine 22 (1997) 1843–1852.
14. M.D. Mazur, M.L. Mumert, E.F. Bisson, M.H. Schmidt. Avoiding pitfalls in anterior screw fixation for type II odontoid fractures. Neurosurg Focus 34 (2011) E7.
15. J.N. Johnson, M.Y. Wang. Stress fracture of the lumbar pedicle bilaterally: surgical repair using a percutaneous minimally invasive technique. J Neurosurg Spine 11 (2009) 724–728.
16. S.T. Canale. Campbell's operative orthopaedics, vol. 3, Mosby, St. Louis; 1998.
17. K.N. Fountas, E.Z. Kapsalaki, I. Karampelas, C.H. Feltes, V.G. Dimopoulos, T.G. Machinis, L.G. Nikolakakos, et al. Results of long-term follow-up in patients undergoing anterior screw fixation for type II and rostral type III odontoid fractures. Spine 30 (2005) 661–669.