

Use of Screw-Rod System in Occipitocervical Fixation

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Background: This study retrospectively reviewed 9 patients who underwent occipitocervical fixation with a newly developed screw-rod fixation system between April 2004 and November 2005. The objective was to evaluate the clinical result of occipitocervical fixation with the screw-rod fixation system, including symptom relief, fusion rate and complications.

Methods: All 9 patients received occipitocervical fixation surgery with screw-rod fixation system and autologous bone grafts for fusion. Fusion was assessed by plain cervical X-ray films, and the myelopathy by Nurick scale.

Results: Four males and 5 females were enrolled into this study. Mean age was 58.8 years, and mean follow-up period was 15 months. One female patient experienced surgical site infection with instrument pullout 20 months after surgery; she received a second operation for instrument revision. The overall fusion rate was 100%. The mean Nurick scores were 3 preoperatively and 2.1 postoperatively, with advancement of 0.9 points on average. Seven of 9 patients experienced pain or myelopathy improvement. There were no complications except for the 1 infection mentioned above.

Conclusion: The fusion rate, complication rate and improvement in neurological function of occipitocervical fixation surgery using the screw-rod system were comparable to those of the widely used wire-rod system and screw-plate system. [J Chin Med Assoc 2009;72(1):20–28]

Key Words: cervical spine, instrumentation, occipitocervical fixation, occiput

Introduction

Occipitocervical fixation is a challenging field in spinal surgery. Many authors report excellent results from occipitocervical fixation by using various internal fixation instruments, including wire-rod system and plate-screw system, which are currently widely used. We present our clinical experience of occipitocervical fixation using the newly developed screw-rod system.

Methods

Between April 2004 and November 2005, 9 patients received occipitocervical internal fixation surgery in the neurosurgical department of Taipei Veterans General Hospital. Their medical records and imaging studies were reviewed. These patients included 4 males and

5 females, with a mean age of 58.8 years (range, 30–77 years). The mean follow-up period was 15 months (range, 6–26 months). The etiologies of their occipitocervical instability were trauma, degeneration, tumor growth, rheumatoid arthritis and os odontoideum. The radiologic findings and surgeries they received are summarized in Table 1. Four of them had occipitocervical malalignment, and wore halo-vest for external fixation pre- and postoperatively; the other patients wore rigid neck collar (Miami J collar, Philadelphia, PA, USA) postoperatively until fusion was achieved.

All patients received awake intubation, and the surgical position was prone, with head fixed with Mayfield head holder. Four patients with occipitocervical malalignment wore halo-vest for turning from supine position to prone position, the others wore rigid neck collars for turning position. The incisions were at midline, from external occipital protuberance



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Table 1. Clinical data of patients who received occipitocervical fixation surgery

Patient	Sex	Age (yr)	Etiology	Radiologic findings	Preop traction and postop halo-vest fixation	Surgery	Follow-up	Preop/postop Nurick scale	Fusion time
1	F	66	Trauma	C1 burst fracture, C2 Hangman's fracture type III, basilar impression, posterior compression of cervicomedullary junction at the level of foramen magnum	Yes	Partial suboccipital craniectomy, total laminectomy from C1 to C6, fixation of C0-4-5-6, PLF	7 mo	5/2	3 mo
2	M	70	Degeneration	C1-2 instability with severe stenosis at the level of cervicomedullary junction and C1, right-side high-riding vertebral artery	No	Partial suboccipital craniectomy, C1 laminectomy, fixation of C0-2-3-4, PLF	6 mo	4/3	6 mo
3*	F	58	Trauma	C1 posterior arch defect, C1-2 subluxation, basilar impression, posterior compression of cervicomedullary junction	1 st operation: yes; 2 nd operation: no	1 st operation: partial suboccipital craniectomy, C1 laminectomy, fixation of C0-2-4-5, PLF; 2 nd operation: revision with new fixation of C0-2-3, PLF	26 mo	1 st operation: 4/3; 2 nd operation: 3/3	1 st operation: nonunion; 2 nd operation: 6 mo
4	F	59	Tumor	A dumbbell-shape tumor mass in left C2-3 intervertebral foramen with left C2 lateral mass erosion	No	Laminectomy of C1-2-3 with tumor removal; fixation of C0-3-4; PLF	24 mo	0/0, pain eliminated	5 mo
5	F	54	Rheumatoid arthritis	C1-2 subluxation, spondylotic change of C2-3-4, posterior compression at C1 level, right side high-riding vertebral artery	No	Laminectomy of C1, fixation of C0-2-3-4, PLF	20 mo	1/1, pain and hand numbness improved	6 mo
6	M	74	Trauma	C1-2 subluxation with cranial settling, left-side high-riding vertebral artery, spinal stenosis at C1 and C4-5 to C6-7 level	No	Total laminectomy of C1 to C6, fixation of C0-2-3-4, PLF	12 mo	2/1, hand clumsiness and spastic gait improved	5 mo
7	M	77	Os odontoides with trauma	C1-2 and C3-4 subluxation, cranial settling, severe spinal stenosis from foramen magnum to C5 level	No	Partial suboccipital craniectomy, total laminectomy from C1 to C5, fixation of C0-2-4-5, PLF	16 mo	5/5	7 mo

(Continued)

Table 1. (Continued)

Patient	Sex	Age (yr)	Etiology	Radiologic findings	Preop traction and postop halo-vest fixation	Surgery	Follow-up	Preop/postop Nurick scale	Fusion time
8	M	41	Rheumatoid arthritis with basilar impression, received odontoidectomy	Basilar impression, C3-4 subluxation	Yes	Partial suboccipital craniectomy, total laminectomy of C2 to C4, fixation of C0-2-3-4, PLF	12 mo	4/4	4 mo
9	F	30	Rheumatoid arthritis	C1-2 subluxation, C1 posterior arch aplasia	Yes	Fixation of C0-2-3-4, strut bone fusion between C0 and C2, PLF between C2 and C4	12 mo	2/0	4 mo

*Patient 3 received a second operation due to infection and instrument pullout after the first operation. Preop = preoperative; postop = postoperative; C0 = occiput; PLF = posterolateral bone fusion.

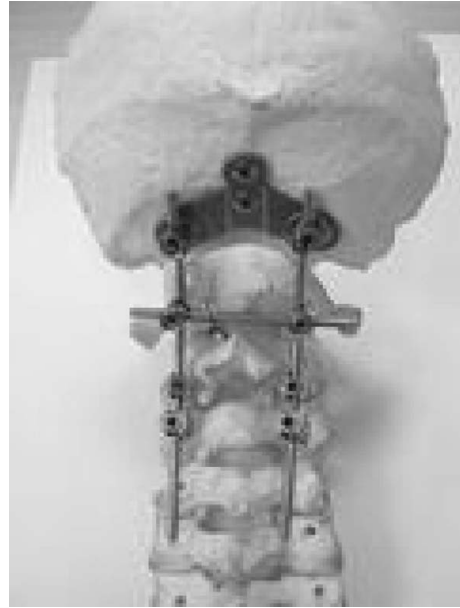


Figure 1. The model shows an occipital plate fixed to the suboccipital area with 2 screws placed on the midline suboccipital ridge, which is the thickest portion of the occiput, providing the most pullout strength. The plate is connected to the rods bilaterally.

to cervical area. After adequate exposure of suboccipital and posterior cervical areas, the subaxial lateral mass screws, C2 pars screws or C1-2 transarticular screws, and the occipital screws with plate were placed under the fluoroscope, then cervical total laminectomy with or without suboccipital craniectomy was done, followed by assembly of rods, nuts and cross-links. Finally, the autologous bone grafts with or without artificial bone substitute granules (Triosite, Zimmer, Berlin, Germany) were put in their places. All patients used titanium screw-rod fixation system (SummitTM occipito-cervico-thoracic spinal fixation system, DePuySpine, Rayham, MA, USA). The levels of cervical laminectomy depended on the imaging findings and clinical symptoms and signs which indicated spinal stenosis.

Occipital fixation was achieved by a plate fixed on suboccipital bone with 2 screws placed on the midline suboccipital ridge; the plate was then connected to the rods (Figure 1). The upper screw was placed just below the external occipital protuberance. The lengths of the occipital screws in this series were 8–10 mm; the screws purchased the suboccipital midline ridge bicortically.

The cervical fixation screws were C2 pars screws (6 patients) or C1-2 transarticular screws (only patient 9) at the supra-axial level, and lateral mass screws at the subaxial level.

All of the patients received autologous bone graft. Patient 9 received additional Triosite artificial bone

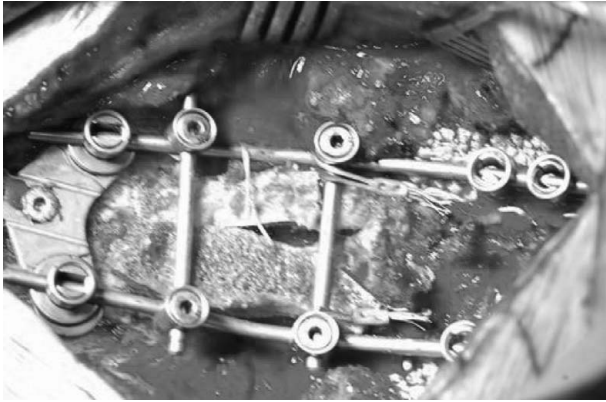


Figure 2. Intraoperative picture of patient 9 shows fixation of occiput-C2-C3-C4 with C1-2 transarticular screws and C3-4 lateral mass screws. The bone grafts included the strut bone bridge grafts resting against the occiput and C2 laminae and posterolateral fusion of C3-4 with Triosite bone substitute granules. C2 sublaminar wiring was also performed.

substitute granules for posterolateral bone fusion. The source of bone grafts came from laminectomy performed during operation or harvested from cervical spinal processes or the posterior iliac crest. Eight patients received posterolateral bone fusion only, while 1 patient (patient 9) received posterolateral bone fusion and strut bone bridge fusion between the occiput and C2. Posterolateral bone fusion was performed by putting the fragmented bone pieces on the dorsal surface of the lateral mass lateral to the rods; the touched area on the dorsal surface of the lateral mass was decorticated. In the strut bone bridge fusion, the graft was harvested from the posterior iliac crest, the graft was then split into 2 pieces, then the strut bone pieces were put in the gap between the occiput and C2 laminae (in this case, there was agenesis of the atlas posterior arch), with the upper borders of the grafts resting against the suboccipital bone and the lower borders of the grafts resting against the C2 laminae. A soft wire was passed beneath the C2 laminae to fix the laminae and grafts on the rods (Figure 2).

Four patients with occipitocervical malalignment wore halo-vest for external fixation after surgery until fusion was completed, and the others wore rigid cervical collar postoperatively.

Fusion was assessed by cervical X-ray study (Figure 3). Fusion was defined as successful if 2 criteria were met: (1) there was no relative movement between the fused motion segments in flexion and extension views of cervical X-ray study; (2) the bone grafts became a uniform bone mass in anteroposterior or lateral views of cervical X-ray study.¹⁻⁵ After surgery, each patient was followed-up by X-ray study once a month until fusion was achieved, then they were followed-up every

2-3 months until the end of the first year, and then followed-up every 6 months thereafter. The Nurick scale (Table 2) was used to assess neurological function pre- and postoperatively.

Results

In this study, a total of 9 patients received 10 occipitocervical internal fixation surgeries (patient 3 received a second operation for revision due to infection and instrument pullout); 8 patients had presented with myelopathy before surgery, and 1 had presented with neck and shoulder pain only (patient 4). No patient experienced deterioration in neurologic function after surgery. The mean preoperative Nurick score was 3. At the end of follow-up after surgery, the mean Nurick score was 2.1, with an advancement of 0.9 points on average. For patient 4, who presented with neck and shoulder pain only, the pain was almost completely eliminated after surgery.

One of the patients (patient 3) experienced surgical site infection with screw pullout 20 months after surgery (Figure 4). The infection caused some turbid fluid accumulation in the epifascial layer. She received surgery for debridement followed by empiric intravenous antibiotic treatment; the culture did not show bacterial growth. After the course of antibiotic treatment, she received another operation for instrument revision, and fusion was achieved 6 months later. There were no other complications in this series.

All of the patients had solid fusion within the follow-up period; the fusion rate was 100%. The mean fusion time of these 9 patients was 5.1 months (range, 3-7 months; Table 3). For the patients who wore halo-vest postoperatively, the mean fusion time was 3.7 months (range, 3-4 months); for the patients who wore neck collar postoperatively, the mean fusion time was 5.8 months (range, 5-7 months).

Discussion

Treatment of occipitocervical instability is a challenging field in neurosurgery. Occipitocervical instability may be caused by trauma, degeneration, neoplastic disease, inflammatory disease, infectious disease, congenital anomalies and other pathologic processes. The common result is cervicomedullary neural tissue compression, with development of symptoms and signs of cervical myelodysplasia, such as neck pain, limbs and trunk muscular weakness and sensory impairment, spastic gait, and even ventilation impairment due to brain stem compression.

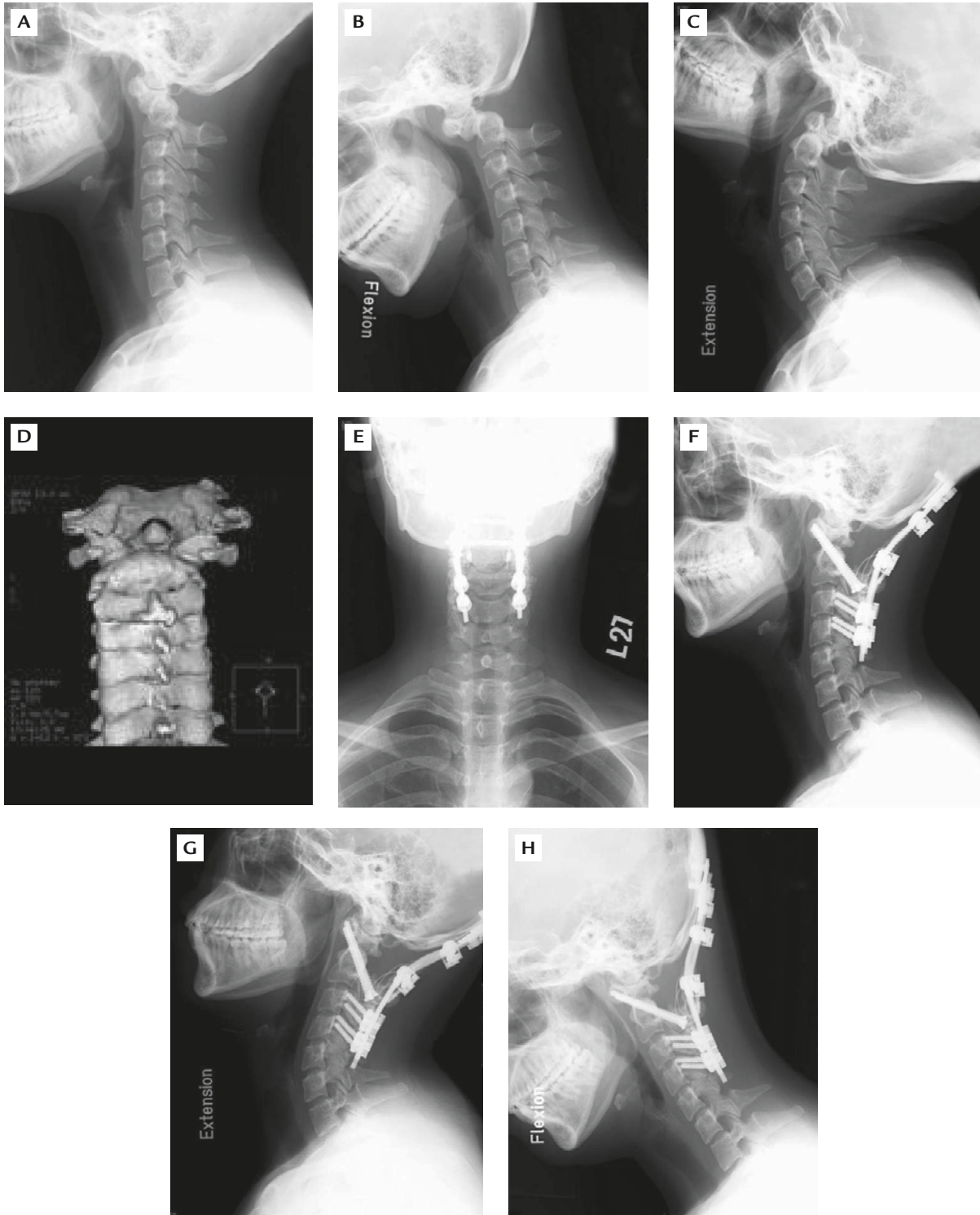


Figure 3. Preoperative and postoperative images of patient 9. (A–C) Preoperative dynamic cervical X-ray films show C1-2 subluxation with atlas posterior arch defect. (D) Preoperative computed tomography with 3-dimensional reconstruction shows aplasia of the atlantal posterior arch. (E) Four months after fixation surgery, solid bone fusion can be seen bilaterally. (F) Four months after fixation surgery, the lateral film shows fusion of the strut bone bridge between the occiput and C2 laminae. (G, H) Four months after fixation surgery, dynamic view shows no relative movement between the fused motion segments.

Table 2. Nurick scale for myelopathy assessment

Score	Description
0	Sign or symptom of root involvement but no evidence of cord disease
1	Sign of cord disease but no difficulty in walking
2	Slight difficulty in walking but not preventing full-time employment
3	Difficulty in walking that prevents full-time employment or the ability to do housework, but not so severe as to require someone's help to walk
4	Able to walk with someone's help or with the aid of a frame
5	Chair-bound or bedridden

Currently, the solution to occipitocervical instability is occipitocervical fixation with bone fusion. The indications for occipitocervical fixation include rheumatoid arthritis causing occipitocervical instability, basilar impression, occipitocervical dislocation, congenital anomalies involving the craniocervical junction, patients receiving odontoidectomy, atlantoaxial instability for which C1-2 wiring or transarticular screw placement is contraindicated, such as posterior elements defect or need to be removed for decompression, or abnormal course of vertebral arteries.^{6,7}

The goals of occipitocervical fixation are regaining normal alignment, ensuring adequate neural tissue decompression and achieving structural stability. In the following paragraphs, we will discuss different occipitocervical fixation instruments, including wire-rod, screw-plate and screw-rod construct. The latter 2 are collectively called "screw-based" construct.

The technique of occipitocervical fixation was first described by Foerster in 1927,⁶⁻⁸ who used simple onlay bone graft for occipitocervical fusion with fibular grafts. This fixation was not rigid, and had a high rate of fusion failure. Sonntag and Dickman⁶⁻⁸ described the wire-rod technique; they used a grooved titanium fixation rod which was bent into a "U" shape and contoured to fit the cervical curvature. The closed end of the rod rested against the suboccipital bone, and the 2 free arms rested on bilateral laminae of cervical motion segments which were to be fused, then wires passed sublaminarly were used to fix the cervical laminae and the rod together on the cervical sides, and wires passed suboccipitally (through suboccipital burr holes) were used to fix the occipital bone and the rod together on the occipital side. The fusion rate of this sublaminar wire-rod construct is 90–100%.¹

Recent biomechanical studies have shown that the screw-based construct is more rigid than the wire-rod construct.^{2,9-15} In the screw-based construct, occipital

screws are used to fix suboccipital bone and the instrument, at the cervical side, lateral mass screws are used for subaxial motion segments fixation, and C1-2 transarticular screws or C2 pedicle or pars screw are used for C2 fixation. The fusion rate of the screw-plate construct is 95–100%.¹

One of the key points of the screw-based construct is the placement of occipital screws,^{5,16-18} which has 2 aspects that should be considered: (1) the effect of thickness of screw purchase; and (2) the area of suboccipital region which provides adequate thickness for screw purchase.

The pullout strength of occipital screws is proportional to the thickness of screw purchase, and the pullout strength of bicortical screw purchase is 50% greater than that of unicortical screw purchase.¹⁷ The thickest portion of the occipital bone is the suboccipital midline ridge, which has an average thickness of 14 mm (range, 10–18 mm); the thickness becomes thinner rapidly as it goes bilaterally, with the thickness of lateral occipital bone being only 2–6 mm. The point of maximal thickness is at the external occipital protuberance (EOP), which has a thickness of 11.5–15.1 mm in males and 9–12 mm in females. Ebraheim et al¹⁶ suggested an area that is thick enough to place a screw of 8 mm in length; this is in the region of the superior nuchal line, extending 2 cm laterally from the center of the EOP, 1 cm from the midline at a level 1 cm inferior to the EOP, and 0.5 cm from the midline at a level 2 cm inferior to the EOP. The conclusion of various occipital bone anatomy and pullout strength studies is that the ideal location of occipital fixation is the suboccipital midline ridge, which provides the most pullout strength and allows bicortical screw purchase safely. To avoid screw penetration, some authors suggest the "inside-outside" techniques for occipital screw placement; although safer than bicortical screw placement, there is no biomechanical evidence to show that this technique is as stable as bicortical screw placement.^{3,5,19}

The ideal location for occipital fixation is the suboccipital midline ridge just below the EOP, but the so-called "midline ridge" is not always on the anatomic midline. Mullett et al's²⁰ study showed that the ridge was located on the anatomic midline in just 52% of patients, while it deviated to the right or left by 2–5 mm and 5–10 mm from the anatomic midline in 28% and 20% of patients, respectively. Because we have to put the occipital plate on the anatomic midline, the issue we are concerned about is that if the midline suboccipital bone is not thick enough, it may be penetrated during the procedure of occipital screw insertion. Skull penetration in this region may cause injury to the underlying dural sinus, which is sometimes fatal due to epidural

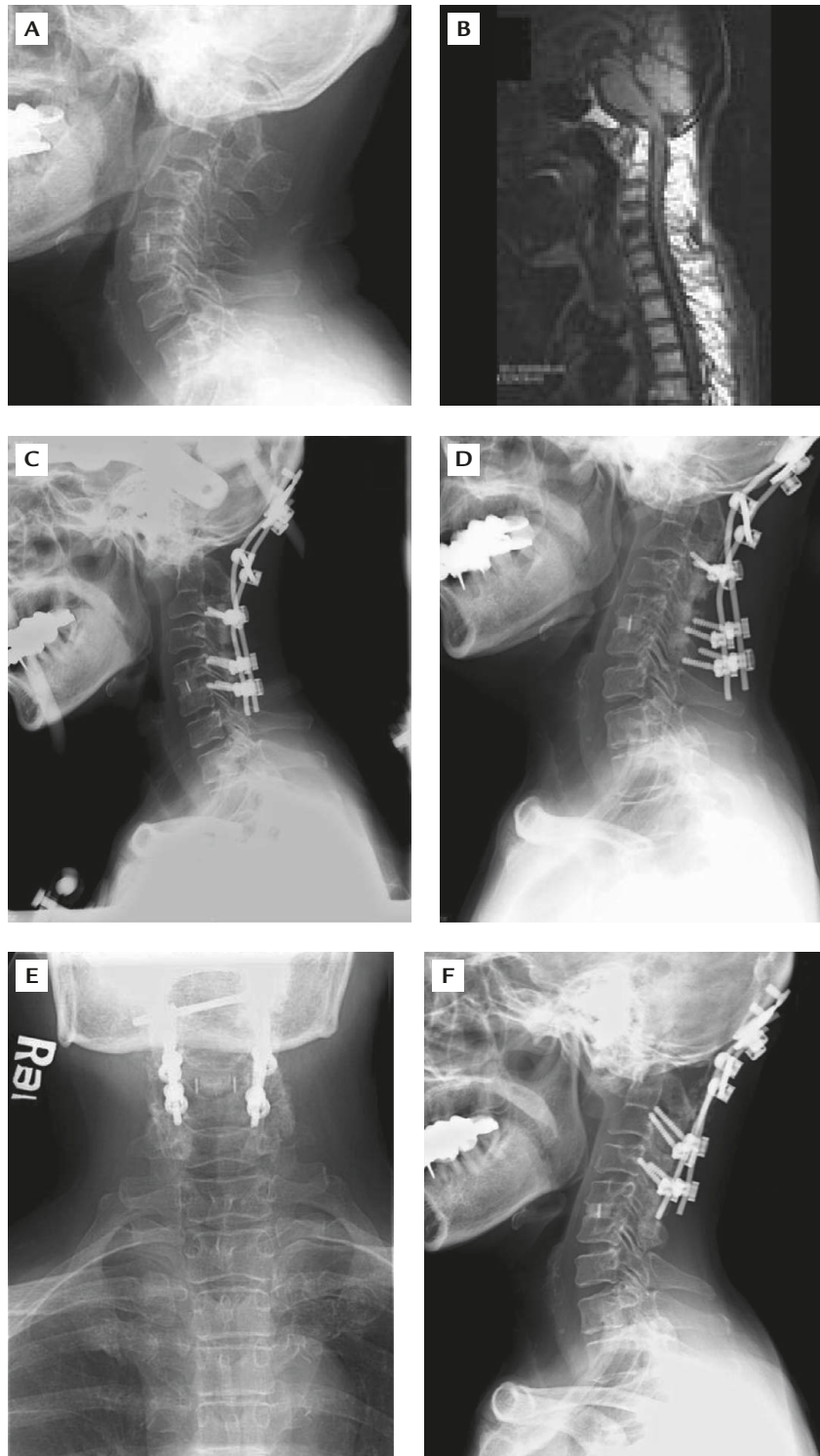


Figure 4. Postoperative films of patient 3. She had received previous C4-5 disectomy with fusion. (A, B) Preoperative plain film and magnetic resonance imaging show significant basilar impression. Cervical traction followed by halo-vest external fixation was performed before her first operation. (C) One month after fixation surgery, the basilar impression had improved. (D) Twenty months after fixation surgery, she experienced surgical site infection and instrument pullout. (E, F) Six months after revision surgery, bone fusion was achieved.

Table 3. Comparison of fusion time between patients who wore a halo-vest or neck collar postoperatively

	Mean fusion time (mo)	Mean age (yr)
All 9 patients*	5.1	58.8
Halo-vest group [†]	3.7	44.3
Neck collar group [‡]	5.8	65.3

*For patient 3, only data from the second operation was included in the calculation (the nonunion of the first operation could be attributed to infection); [†]this group included 3 patients—patients 1, 8 and 9 (although patient 3 wore a halo-vest postoperatively after her first operation, she was excluded from this group due to infection); [‡]this group included 6 patients—patients 2, 3, 4, 5, 6 and 7 (patient 3 wore a neck collar after her second operation).

hemorrhage of the posterior fossa.⁵ Although there was no preoperative skull computed tomography done in our series, we still suggest that preoperative skull computed tomography with sagittal reconstruction be used to evaluate the orientation of the suboccipital ridge, the thickness of the midline suboccipital bone and the location of the dural sinuses since there is potential catastrophic outcome if the skull is penetrated with subsequent dural sinus injury; this procedure will be included in our treatment protocol of occipitocervical fixation in future.

There are advantages and disadvantages of the wire-rod construct and screw-based construct. The wire-rod construct does not provide immediate postoperative stability, and postoperative rigid external fixation such as halo-vest is necessary,^{4,6-8} usually for at least 12 weeks. Passing wire through the occiput can be dangerous—a 25% incidence of dural tears has been reported for this procedure.¹⁵ This construct also needs intact posterior cervical elements for sublaminar wiring, and is not suitable for patients whose posterior elements are defective or have to be removed for decompression. The advantages of the wire-rod construct include being technically simple, safe and economical. For patients with poor bone quality, such as rheumatoid arthritis with osteoporosis, this technique may be the surgery of choice because the screw purchase is not secured.

The screw-based construct provides immediate postoperative stability, so postoperative rigid external fixation is not needed in most cases, which makes patients more comfortable. This construct provides more rigidity biomechanically than the wire-rod construct, and can be applied to patients whose posterior elements are defective or need to be removed for decompression. The disadvantages include potential vertebral artery and cervical root injury due to cervical screw purchase.

Comparing the screw-plate system and screw-rod system, the screw-rod system offers more advantages. The screw-plate system usually fixes the occiput on lateral sides of the suboccipital bone, which is relatively

thin in bone thickness and provides less pullout strength. The plates have to be contoured in multiple planes to fit the cervical curvature, and the screw holes in the plates may not just rest on the ideal entry point of cervical screw placement, which produces suboptimal cervical screw fixation. In contrast, the screw-rod system is more rigid biomechanically.⁹ The rod is contoured only in the sagittal plane, and the cervical screw can be inserted from its ideal entry point, resulting in optimal screw purchase with less incidence of neurovascular tissue injury. The rod is secured in an occipital plate fixed in the suboccipital midline ridge, which provides the strongest pullout strength for occipital fixation.

Although most authors suggest that postoperative rigid fixation is not necessary for the screw-based construct, 4 patients with preoperative malalignment wore a halo-vest postoperatively. The mean fusion time was 3.7 months for those who wore the halo-vest and 5.8 months for those who wore the neck collar (Table 3). Whether or not postoperative halo-vest external fixation shortened the fusion time was not clear because of the limited sample size, and the younger mean age of the patients who wore the halo-vest could have been a contributing factor (Table 3). Every patient in our series reached bony union after fixation surgery, regardless of whether they wore a halo-vest or neck collar postoperatively. It was shown that for the screw-rod construct, postoperative use of a halo-vest is not necessary, and neck collar-wearing only is adequate.

In conclusion, although the case number in this series is small, the preliminary results show that the fusion rate of the screw-rod system in occipitocervical fixation is comparable to that of the sublaminar wire-rod system and screw-plate system. There is no “best” method for occipitocervical fixation. Which method should be used for a given patient depends on the type of instability, the integrity of posterior cervical elements, the extension of decompression, comorbidities, individual anatomic variation, and the surgeon’s familiarity with the techniques. In our experience, the screw-rod device offers some advantages, including strong occipital screw purchase, ideal cervical screw entry, easy contour of the rod to fit the occipitocervical curvature, and allowing cervical decompressive procedures.

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