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# Occipito-cervical fusion using posterior titanium plates

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**Abstract** Occipito-cervical fusion may be indicated for instability of the occipito-cervical junction or atlanto-axial spine secondary to a wide spectrum of pathology. Many techniques exist to stabilize the spine until fusion is achieved. Recent reports of plate fixation have been favorable. In this study we set out to determine the effectiveness and advantages of titanium plate fixation when used to stabilize the occipito-cervical junction. Thirteen patients with occipito-cervical instability or atlanto-axial instability underwent occipito-cervical fusion using posterior titanium plates. The plates were contoured to the occipito-cervical junction and fastened to the skull with screws, and to the spine with lateral mass screws. The patients were followed prospectively clinically and radiographically to a minimum of 24 months. Outcome parameters included peri-operative morbidity and complications, hardware integrity, spinal alignment, fusion, and neurological status. Twelve of thirteen patients went on to solid fusion radiologically and clinically, and recovered or improved from their myelopathy. One patient did not. Three patients had radiographic evidence that two screws were loose and one screw was broken. There were no instances of plate breakage. We conclude that titanium plate fixation of the occipito-cervical junction is versatile and stable. The plates maintain axial correction and allow for future MR imaging.

**Key words** Occipito-cervical fusion · Spinal instrumentation · Plate fixation · Myelopathy

## Introduction

Occipito-cervical fusion may be indicated for instability of the occipito-cervical junction or atlanto-axial spine secondary to a wide spectrum of pathology. During the 1970s and 1980s, to stabilize the spine until fusion was achieved, the surgeon had to rely on external immobilization in the form of a halo, or on internal stabilization using sublaminar and skull wires. During the 1980s Roy-Camille [10] introduced the concept of occipito-cervical plating with screws in the skull base and in the lateral cervical masses. Smith et al. [11] in 1990 reported their favorable results of occipito-cervical fusion using contoured stainless steel, 3.5-mm AO reconstruction plates. In 1994 Grob et al. [4] reported their comparison of Y-plate fixation to a posterior wiring technique for occipito-cervical fusion in rheumatoid arthritis, and concluded that plate screw fixation was superior. In this article we report our indications and results using a similar technique to that described by Smith et al. [11], but with 3.5-mm notched titanium plates and screws.

## Patients and methods

From May 1991 to May 1994 13 patients with occipito-cervical instability or atlanto-axial instability underwent occipito-cervical fusion using a standard posterior technique as promoted by the senior author (J.K.W.). The patients were typically intubated and positioned prone while awake. The skull base and spine was exposed from the posterior occipital protuberance to the appropriate level of the cervical or thoracic spine through a midline approach. Any associated procedures, such as decompression or osteotomy, were then performed. The subaxial facet joints were exposed, curetted, and bone grafted to promote fusion. Care was taken to ensure that the cervical spine was maintained in an acceptable sagittal alignment, with the mal-aligned segment in a reduced neutral position. This was verified using image intensification. The plates were then contoured to the appropriate shape using bending irons and malleable templates as a guide. The 3.5-mm AO notched titanium plates (Synthes Spine, Paoli, USA) are available in 8 mm and 12 mm hole spacing (Fig. 1). The plate with the hole spacing that best suited the lateral masses was selected. The pedicles of C2 were then drilled with a reciprocating drill under image intensification using the technique described by Magerl et al. [8]. The plates were then applied to the spine and fastened loosely to C2 with titanium screws of the appropriate length. Holes were then drilled into the base of the skull through the plates and the plates were screwed to the skull. The remaining holes were then drilled through the plates into the lateral masses aiming parallel to the facet joints and approximately 25° laterally. The plates were then fastened to the subaxial spine with the appropriate length screws. All the screws were then sequentially tightened. When the fixation extended into the thoracic spine the screw holes were drilled and the screws were placed as pedicle screws with a 5°–10° caudad inclination and a 5°–10° medial orientation. This was judged clinically according to the vertebral morphology and verified with the image intensifier. The holes were probed to ensure a bony tunnel.

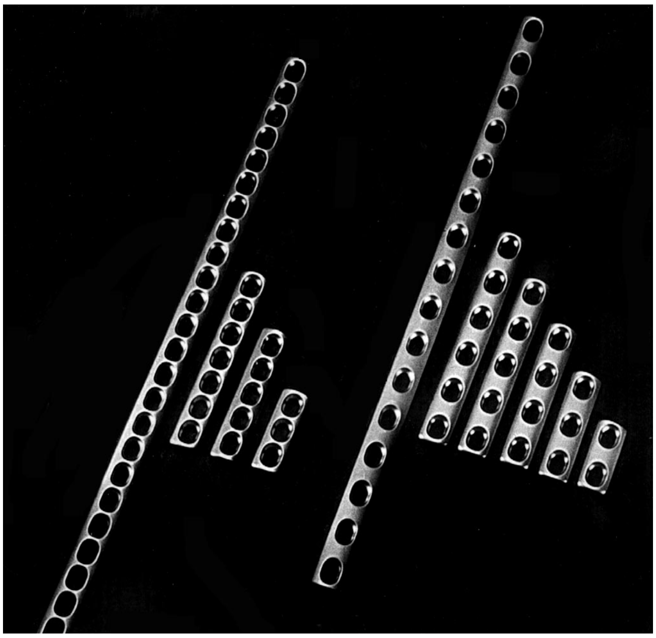

**Fig. 1** A-O, 3.5-mm notched titanium plates, 8 and 12 mm hole spacing

Once the plates were secure, the skull base and spine were decorticated and the large bed between the plates was packed with abundant autogenous bone graft. All patients wore a moulded collar for a minimum of 8 weeks post-operatively.

The titanium screws are fully threaded 3.5-mm cancellous screws. The aim was to achieve bicortical hold in both the skull and the lateral masses. Regarding screw placement in the skull, there exists a safe zone below the posterior occipital protuberance and beyond 1 cm lateral to the midline on each side [2, 6]. In this location the skull thickness is usually adequate to accept a screw of 8 mm length with bicortical purchase, and the venous sinuses are not in a vulnerable position. Occasionally blood from between the inner and outer tables may mimic the profuse bleeding expected from the venous sinuses. If one maintains the correct anatomic orientation the risk of venous sinus penetration will be minimized. Should cerebro-spinal fluid or blood be encountered while drilling, the hole should be filled with bone wax before the appropriate length screw is placed.

Table 1 outlines the patient demographics. Eight patients had atlanto-axial rheumatoid involvement of the spine, four with associated subaxial instability and/or cervical canal stenosis. Two patients had multiple myeloma involving the atlas, one patient had spondylo-epiphyseal dysplasia with atlanto-axial instability, one

**Table 1** Patient demographics

| No. | Age (years) | Date of Surgery | Diagnosis | Lower limit of fusion | Additional procedures | Neurology | Outcome |
|---|---|---|---|---|---|---|---|
| 1 | 47 | May ’91 | Pathologic fracture and multiple myeloma | C4 | | Nil | Solid fusion |
| 2 | 64 | Nov ’91 | Rheumatoid | C5 | | Myelopathy | Solid fusion, neurology improved |
| 3 | 63 | Jul ’92 | Rheumatoid | T1 | | Myelopathy | Solid fusion, neurology improved |
| 4 | 78 | Sep ’92 | Rheumatoid | T2 | | Myelopathy | Solid fusion, neurology improved |
| 5 | 64 | Dec ’92 | Rheumatoid | C6 | | Myelopathy | Solid fusion, neurology improved |
| 6 | 72 | Jan ’93 | Rheumatoid | C7 | C3 decompression | Myelopathy | Solid fusion, neurology improved |
| 7 | 66 | Apr ’93 | Rheumatoid | C7 | | Myelopathy | Solid fusion, neurology improved |
| 8 | 68 | May ’93 | Ankylosing spondylitis | T3 | C1 decompression C7 osteotomy | Myelopathy | Solid fusion, neurology improved |
| 9 | 57 | Jun ’93 | Rheumatoid | T1 | C3 decompression | Myelopathy | Solid fusion, neurology improved |
| 10 | 18 | Jul ’93 | Spondylo-epiphyseal dysplasia | C6 | | Myelopathy | Solid fusion, neurology improved |
| 11 | 37 | Nov ’93 | Klipple-Feil | C5 | Anterior dens resection | Myelopathy | Solid fusion, neurology improved |
| 12 | 60 | Apr ’94 | Multiple myeloma | T1 | | Myelopathy | Pseudoarthrosis, neurology persisted, died 16 months post-op |
| 13 | 58 | May ’94 | Rheumatoid | T1 | | Myelopathy | Solid fusion, neurology improved |

patient had ankylosing spondylitis with atlanto-axial instability and a severe cervico-thoracic deformity, and one patient had a Klipple-Feil abnormality of C2 and C3 with an occipitalized atlas and basilar invagination of the dens into the foramen magnum. Twelve patients presented with a cervical myelopathy. Eight patients were initially treated with halo traction to reduce the maligned segment and to allow for neurological recovery. The traction was maintained from 1 to 6 weeks, depending on neurological response. Once the best anatomical reduction was achieved a vest was applied and the patients were allowed to ambulate. One further patient (no. 8) was initially treated with a halo because of severe chin on chest deformity; however, due to a methicillin-resistant staphylococcal pinsite infection this had to be abandoned. All the patients underwent posterior plating with autogenous iliac crest bone grafting. One patient (no. 11) underwent an initial trans-oral odontoid resection during the same session. One patient (no. 8) underwent C7 posterior realignment osteotomy. Three patients (nos. 6, 8, 9) underwent posterior cervical decompressions at the same session.

The minimum follow-up was 24 months in 12 of the 13 patients. All patients were assessed clinically for neurological recovery and radiologically to assess alignment and integrity of the hardware. Pre-operative and post-operative plain radiographs were compared for changes in the atlanto-axial interval or progression of basilar invagination.

## Results

Twelve patients went on to solid fusion radiologically and clinically (Fig. 2), and recovered or improved from their myelopathy. At the latest follow-up two of these patients had radiographic evidence of two loose screws and one broken screw. They were all still judged as having a solid fusion on clinical grounds. There were no instances of plate breakage, and no evidence of plate loosening from the skull. In no patient did the basilar invagination progress or was the reduction of the atlanto-axial interval lost. There were two superficial wound infections in the rheumatoid patients.

All patients in this series had combinations of occipito-cervical, atlanto-axial, and/or sub-axial pathology, requiring a long instrumented segment. In some of the patients the long instrumentations were also necessary to maximize the fixation in osteoporotic bone.

One patient (no. 12) went on to a pseudoarthrosis with no progression of basilar invagination or loss of reduction at the atlanto-axial interval. She did not, however, recover from her myelopathy. On her latest plain radiographs there was evidence of a loose screw and she still reported neck pain. She had severe multiple myeloma and was being treated with chemotherapy and radiation therapy. We suspect that her outcome was due to a combination of prolonged neural compression and her underlying pathology. She eventually died, 16 months post-operatively.

Intra-operatively on the skull side there was one instance of venous sinus penetration and three instances of dural penetration. In the sub-axial spine there was one instance of vertebral artery injury. The venous sinus injury was from a hole drilled above the nuchal line. The hole was filled with bone wax, the plate was repositioned, and new anatomically appropriate holes were drilled. The vertebral artery injury occurred at the C5 level secondary to a misdirected drill hole. This was filled with bone wax and a new hole was drilled aiming further laterally. The dural tears were treated with bone wax followed by screw placement. No patient developed any immediate or long-term sequelae as a result of these intra-operative complications.

## Discussion

Many methods of occipito-cervical fusion have been reported [3–7, 9–12]. These rely on various combinations of

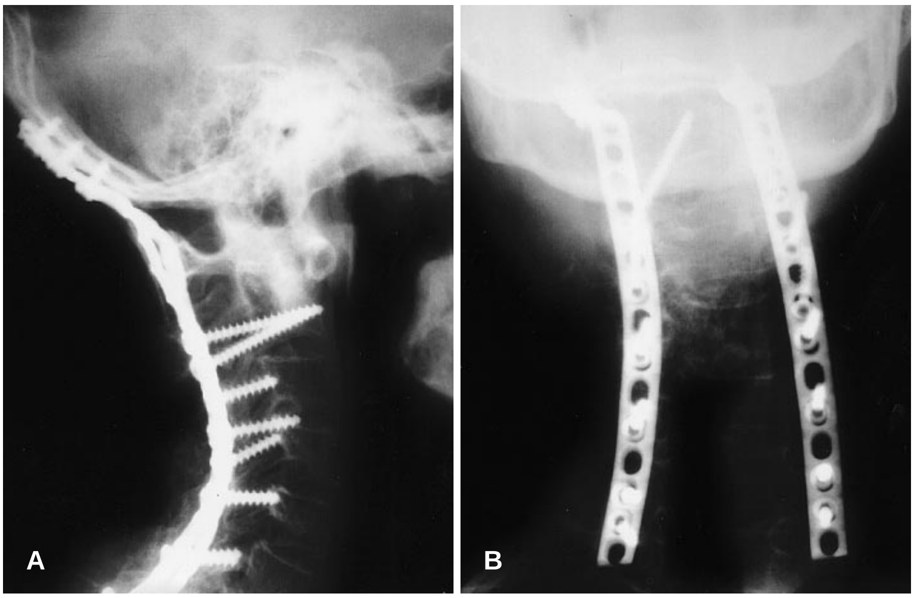


**Fig. 2 A, B** Case 13. **A** Lateral plain film at 2-year follow-up. **B** Anteroposterior plain film

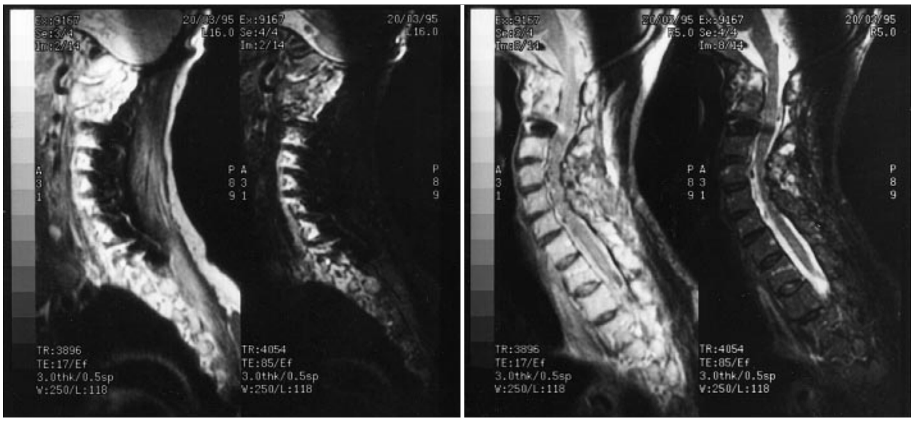

**Fig. 3** Postoperative MRI scan. Example of scan with titanium hardware in situ: *left* sagittal view through lateral masses, *right* sagittal view through midline

wiring, onlay bone grafts, contoured rods, and rigid post-operative immobilization in a halo. Until recently, screw fixation to the skull and cervical spine has not been commonplace. With the recent advances in implant design and the appreciation of the local anatomy, screw placement in the skull and cervical spine are becoming routine. These techniques have been legitimized anatomically, biomechanically, and clinically [1–4, 10]. Screw plate constructs allow for immediate rigid internal fixation to stabilize the spine until solid biological fusion is achieved. They also eliminate the need for a halo vest post-operatively.

In this series we had five intra-operative complications. Despite the three dural and two vascular injuries, no patients had any long-term sequelae. These five complications represent our initial learning curve. This report (although describing an initial and numerically small series), in combination with the reports of Smith et al. [11], Heywood et al. [6], Magerl et al. [8], and Grob et al. [3, 4], indicates that with experience and an appreciation of the anatomy this technique can be safely accomplished.

In this review we used titanium plates and screws. The principal advantage of titanium is MRI compatibility. If necessary one can now obtain post-operative MR images of the vertebral column and canal contents with only minimal distortion and artifact (Fig. 3). There does, however, exist a theoretical concern regarding the plate and screw strength. In our series no plates broke after a minimum of 24 months follow-up. One patient did develop a pseudoarthrosis, but the plate was intact. There were two loose screws and one broken screw, all in the sub-axial spine, but these were not clinically significant. Similar to the results of Grob et al. [4] and Smith et al. [11], in all our patients the spinal alignment was maintained by the plate screw construct.

From this study we conclude that the titanium plate system is versatile and sufficiently stable when used to achieve occipito-cervical fusion. It allows a large area for the application of bone graft across the occipito-cervical junction. The plates were able to maintain the initial axial traction applied to the occipito-cervical junction by the halo and were stable enough to preclude the use of a halo post-operatively. The plates also allowed for stable fixation to be extended beyond the cervico-thoracic junction. To avoid complications in the application of these plates vigilant care must be taken when applying screws to the skull and lateral masses. The most significant advantage of titanium plate fixation is that it allows future MR imaging in these complex neurologically involved patients.

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