The failure of attempted ACF operations to heal has been reported in up to 20% of cases after single-level surgery and up to 50% of cases after multi-level surgery. This complication can be salvaged by a revision of the anterior fusion or by a de novo posterior fusion. It remains controversial whether the anterior or posterior approach is better. Posterior techniques usually involve spinous process wiring or lateral mass screw fixation.

A spinous process plate system (S-plate; Kisco DIR Co., Ltd., Osaka, Japan) has been developed to conduct short in situ fusions in selected patients. In this fixation procedure, the spinous processes are securely sandwiched between a pair of plates with thorns, which are squeezed together by tightening screws that extend through the plates. The authors salvaged six failed ACFs (nonunion of bone graft, plate migration, or bone graft dislodgment) by conducting this fixation without bone grafting, or with an anterior or posterior local bone graft only. Anterior bone union was attained within 6 months in all cases. This technique is easy to perform and probably provides more mechanical strength than does conventional spinous process wiring, resulting in prompt fusion without the need for a new massive bone graft. This technique is a practical option in salvage operations for failed ACF.

**Clinical Material and Methods**

**The S-Plate Fixation Technique**

The S-plate is a titanium plate (8 mm wide and 34–98 mm long) with holes and thorns (Fig. 1 upper). Spinous processes and part of the laminae of the cervical vertebrae are exposed without further lateral dissection. The spinous processes to be fixed are sandwiched between a pair of plates of the same length, using screws that extend through the plates and nuts to tighten the screws. The screws can either penetrate the spinous processes or the interspinous ligaments. By tightening the screws, the two plates squeeze the spinous processes firmly, thus securing fixation (Fig. 1 lower).

**Patient Population**

We used the S-plate fixation as a salvage operation for failed ACF operations (symptomatic nonunion, plate migration, or dislodgment of the graft) after 1998. A retrospective chart review revealed that up until 2003 six patients in such a situation underwent S-plate fixation. All patients were followed up for at least 18 months after the procedure. The pertinent radiographs of these patients’ spines were reviewed and the status of bone union was
estimated. The radiographic criteria for successful bone union included no angular motion visible in lateral flexion and extension views, as well as the presence of trabeculae between the grafted bone and the recipient vertebrae.

Results

The details of the six cases are shown in Table 1. The cases included four instances in which nonunion of the grafted bone had occurred with or without plate migration (nonunion cases) and two in which dislodgment of the grafted bone had occurred (dislodgment cases). In all cases except Case 5, an anterior cervical plate was used. In four cases, the plate was removed during the revision surgery because of loosening and migration. In the nonunion cases, no thorough resection or refreshment of the pseudarthrosis was performed and no bone graft was harvested from other sites. In the two dislodgment cases, the original bone graft was replaced without bone graft (Fig. 2 upper right). A collar fixation was performed and maintained for approximately 3 months after this operation, and radiographs demonstrated continuous trabeculae at both ends of the graft 5 months after the revision surgery (Fig. 2 lower left).

Illustrative Case

Case 2

This 60-year-old man with severe myelopathy underwent anterior cervical decompression and fusion from C-3 to C-7. A fibular strut graft was fixed to the vertebrae using an Orion plate (Medtronic Sofamor Danek, Memphis, TN) and halo vest therapy was undertaken for 2 months after the operation. Although his myelopathy improved, radiographs demonstrated nonunion at both the upper and lower ends of the grafted bone, and gradual anterior migration of the plate was observed (Fig. 2 upper left). Revision surgery was performed 16 months after the initial operation. The plate was removed through an anterior approach, and posterior fusion using S-plates was performed without bone graft (Fig. 2 upper right). A collar fixation was performed and maintained for approximately 3 months after this operation, and radiographs demonstrated continuous trabeculae at both ends of the graft 5 months after the revision surgery (Fig. 2 lower left).

Discussion

The failure of ACF operations (that is, nonunion or dislodgment of the grafted bone) has been salvaged by a revision of the anterior fusion or by a de novo posterior fusion. Although there are merits and demerits to both revision approaches, some researchers support a posterior rather than an anterior approach because of higher fusion rates. Spinous process wiring is the most popular posterior fusion technique for failed ACF operations, although lateral mass screw fixation is sometimes used. Spinous process wiring is mechanically unreliable, however, especially in patients with osteoporosis, and lateral mass screw fixation is technically demanding and bears the risk of major complications such as vertebral artery or nerve root injury.

Spinous process plate fixation has not yet been described as a salvage technique for failed ACF operations. Although we have no biomechanical data on S-plate fixation, we believe it may provide more mechanical strength than posterior wiring because it restricts spinous process motion in all directions. Mihara, et al., compared four posterior cervical fixation techniques biomechanically: the Wavy Rod system, Rogers posterior wiring, Bohlman triple wiring, and lateral mass plate fixation. They concluded that the Wavy Rod system was the most effective technique in stabilizing a cervical motion segment. It was more effective than, or comparable to, lateral mass plate fixation. The Wavy Rod system is based on the same con-
TABLE 1
Details of initial and revision surgery for each case*

<table>
<thead>
<tr>
<th>Case</th>
<th>Age (yrs), Sex</th>
<th>Diagnosis</th>
<th>Previous Fusion Levels</th>
<th>Failure Status</th>
<th>Timing of PCF (period after ACF)</th>
<th>Fusion Level</th>
<th>Concomitant Operation</th>
<th>Bone Graft</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>57, F</td>
<td>OPLL</td>
<td>C4–7</td>
<td>N, PM</td>
<td>13 mos</td>
<td>C4–7</td>
<td>removal</td>
<td>none</td>
</tr>
<tr>
<td>2</td>
<td>62, M</td>
<td>CSM</td>
<td>C3–7</td>
<td>N, PM</td>
<td>16 mos</td>
<td>C3–7</td>
<td>removal</td>
<td>none</td>
</tr>
<tr>
<td>3</td>
<td>57, M</td>
<td>CSM (adjacent stenosis after C3–6 fusion)</td>
<td>C6–7</td>
<td>N, PM</td>
<td>10 mos</td>
<td>C5–7</td>
<td>removal</td>
<td>local bone (ant)</td>
</tr>
<tr>
<td>4</td>
<td>73, F</td>
<td>CSA</td>
<td>C3–6</td>
<td>D</td>
<td>4 mos</td>
<td>C3–6</td>
<td>removal, replace</td>
<td>local bone (ant)</td>
</tr>
<tr>
<td>5</td>
<td>69, M</td>
<td>pyogenic spondylitis</td>
<td>C4–5</td>
<td>D</td>
<td>10 days</td>
<td>C3–6</td>
<td>replace</td>
<td>local bone (pst)</td>
</tr>
<tr>
<td>6</td>
<td>32, F</td>
<td>CDH</td>
<td>C5–6</td>
<td>N</td>
<td>17 mos</td>
<td>C5–6</td>
<td>foraminotomy</td>
<td>none</td>
</tr>
</tbody>
</table>

* Ant = anterior; CDH = cervical disc herniation; CSA = cervical spondylotic amyotrophy; CSM = cervical spondylotic myelopathy; D = dislodgment of grafted bone; N = nonunion; OPLL = ossification of the posterior longitudinal ligament; PCF = posterior cervical fusion; PM = plate migration; pst = posterior; removal = removal of the anterior cervical plate; replace = replacement of the original bone graft.

Fig. 2. Case 2. **Upper Left:** Lateral radiograph of the cervical vertebrae prior to the revision surgery of posterior fixation. The anterior cervical plate was dislodged. **Upper Right, Lower Left, and Lower Right:** Radiographs obtained at 6 days, 5 months, and 66 months after the posterior fixation, respectively.
Spinous process plate fixation for failed ACF

except as the S-plate system; that is, spinous processes are sandwiched between a pair of wave-shaped rods, limiting interspinous motion without anchoring to the bone structures. The S-plate system may provide more rigid fixation than the Wavy Rod system because the contact area of the spinous process is much larger and because the squeezing strength is superior (screws and nuts compared with wiring). Furthermore, the S-plate fixation technique is much easier and safer to perform, and damage of the posterior soft tissue is reduced, compared with lateral mass screw fixation. In the cases described in the present report, prompt bone union was obtained with no complications; thus, S-plate fixation seems to be a promising option as a salvage technique for failed ACF operations.

No bone grafts, other than local ones, were placed in the cases described in this retrospective review, even more than 1 year after the initial operation. In revisions of anterior fusion operations, resection of the pseudarthrosis and new autografts or allografts are mandatory for reconstruction. In performing posterior fusion, many authors report using a newly harvested autograft or allograft. Fuji, et al., reported on nine patients in whom unsuccessful ACF operations were treated with interspinous wiring without a bone graft; however, only seven of them experienced consolidation of the anterior arthrodesis. Siambanes and Miz reported that anterior bone fusion occurred in 12 of 14 patients who underwent salvage operations involving posterior wiring and bone grafts. In contrast, Farey, et al., reported that posterior and subsequent anterior bone fusion was confirmed in all 19 patients in whom unsuccessful ACF operations were treated with interspinous wiring and a posterior bone graft (however, they also reported that complications at the bone graft donor site occurred in three patients). It is ideal if 100% bone union is attained without harvesting a new bone graft. The present retrospective review includes only a small number of patients, and it is unclear whether a new bone graft would always be unnecessary when using the S-plate system. The strong fixation it provides may have contributed to our results; that is, prompt solid fixation of the anterior pseudarthrosis site was obtained in all cases despite little, if any, bone graft.

A major drawback of spinous process fixation is that its strength depends on the size and quality of the spinous processes. One attendant difficulty is that lordosis is created at revision surgery and is kept until bone fusion. Wire cutout is sometimes observed in spinous process wiring. The S-plate holds the entire spinous process and therefore may resist loosening. In our series, regional kyphosis observed after revision surgery in one case (Case 4) was attributable to the loosening of the fixation of the C-3 spinous process, although bone union occurred within 6 months. The bone of this patient was very osteoporotic, which probably caused the vertebral body fracture and subsequent graft dislodgment after the initial operation, as well as the loosening of the C-3 spinous process after the revision surgery. This case points to the need for careful follow up after revision surgery, particularly when a patient has osteoporotic bone or small, thin spinous processes.

Conclusions

In conclusion, S-plate fixation is a technically easy and safe procedure that provides rigid fixation, causing anterior bone union with or without a local bone graft. It is a promising option in salvage operations for failed ACF.

Disclaimer

No benefits in any form have been, or will be, received from a commercial party related directly or indirectly to the subject of this manuscript.

References


Address reprint requests to: Masashi Neo, M.D., Ph.D., Department of Orthopaedic Surgery, Kyoto University Graduate School of Medicine, 54 Kawahara-cho, Shogoin, Sakyoku-ku, Kyoto 606-8507, Japan. email: neo@kuhp.kyoto-u.ac.jp.