Mid-term results of computer-assisted skip pedicle screw fixation for patients with Lenke type 1 and 2 adolescent idiopathic scoliosis: A minimum five-year follow-up study

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Abstract

Purpose: In skip pedicle screw fixation for adolescent idiopathic scoliosis (AIS), the mid-term effects of reducing screw number on correction and clinical results are uncertain. We clarified the mid-term outcomes of this technique in patients with Lenke type 1 and 2 AIS.

Methods: Thirty-four patients who underwent skip pedicle screw fixation (mean screw density: 1.35 screws) for Lenke type 1 and 2 AIS were retrospectively reviewed. The follow-up period was at least 5 years (mean follow-up period: 6.1 years), and the follow-up rate was 89.5%. Radiological parameters and clinical symptoms were evaluated before, immediately after, and at 2 years and 5 years after surgery.

Results: The mean Cobb angle of the main thoracic (MT) curve before, immediately after, at 2 years after surgery, and at the final 5-year minimum follow-up was 52.5°, 16.4°, 20.5°, and 19.4°, respectively. The Cobb angle of the MT curve was significantly improved immediately after, at 2 years after surgery, and at the final follow-up compared with that before surgery (p<0.01). The mean correction rate immediately after surgery was 69.0% and the rate of correction loss at the final follow-up was 8.3%. All Scoliosis Research Society-22 patient questionnaire (SRS-22r) sub scores 5 years after surgery were significantly improved compared with those beforehand (p<0.01).

Conclusions: Correction using skip pedicle screw fixation in AIS was well maintained from the initial follow-up measurements to the final follow-up. The SRS-22r sub scores at the final follow-up were significantly improved over preoperative levels.

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1. Introduction

Segmental pedicle screw fixation for patients with adolescent idiopathic scoliosis (AIS) was introduced by Suk et al. in 1995 [1] and has since been recognized as a useful option for deformity constructs. The posterior approach for scoliosis correction surgery has become the method of choice as it offers greater fixation strength by instrumentation from the posterior column to the anterior vertebral body. Moreover, segmental pedicle screw fixation in AIS enables a shorter fusion length and better correction [2].

Despite its advantages, pedicle screw fixation has been criticized for its risk of injury to neurovascular and visceral structures, including the spinal cord, nerve root, lung, and aorta [1,3–5]. To avoid such serious complications, we have developed skip pedicle screw fixation for AIS that requires fewer screws for correction (Fig. 1) [6–8]. However, there are few reports on the mid-term outcomes of skip pedicle screw fixation, and we are concerned about the longer-term loss of scoliosis correction and decreases in Scoliosis Research Society-22 patient questionnaire (SRS-22r) scores as a trade-off for reducing the number of pedicle screws used in curve correction. We previously described the minimum 2-year follow-up results of computer-assisted skip pedicle screw fixation in 62 consecutive patients with AIS representing all types of Lenke classification (apart from Lenke 5C) [9]. To further clarify the usefulness of our technique, we analyzed 34 patients with a more
limited type of AIS, Lenke type 1 or type 2 curves, with a longer minimum follow-up period of 5 years in this study.

2. Materials and methods

2.1. Patients

Of 38 consecutive patients who had undergone skip pedicle screw fixation guided by a computed tomography (CT)-based navigation system for Lenke type 1 or 2 AIS between August 2005 and February 2012, 34 patients (one man and 33 women; mean ± standard deviation [SD] age: 14.7 ± 2.1 years, range: 12–20 years), after excluding four patients who were not followed for 5 years, were retrospectively reviewed (follow-up rate: 89.5%), following approval by the Investigational Review Board of our hospital (No. 3500). Lenke classification was type 1A in 14 patients, type 1B in five patients, 1C in eight patients, 2A in five patients, and 2B in two patients. The mean follow-up period of the 34 studied patients was 6.1 ± 1.5 years (range: 5–10 years).

2.2. Navigation technique

A frameless stereotactic image-guidance system (StealthStation, StealthStation TREON, or StealthStation 7, Medtronic, Sofamor Danek, Memphis, TN) was adopted for planning the pedicle screw diameter and length to achieve correct screw placement and fixation of the thoracic and lumbar spine. Our registration procedure for matching surgically exposed spines with preoperative 3D CT-based images was performed on a “unit” of three consecutive vertebrae, instead of registering each vertebra separately, to shorten surgical time [6]. Specifically, we employed three reference points for each vertebra (the top of the spinous process and the tips of the bilateral transverse processes) for three consecutive vertebrae (i.e., adding up to nine reference points) in a single-time registration, which was repeated for the entire spine to be instrumented. If the pedicles of the adjacent unregistered vertebrae were narrow, screws were inserted into the three vertebrae and the upper and lower unregistered vertebrae, resulting in five instrumented vertebrae. If the pedicles were wide enough, screws were further inserted to the upper and/or lower unregistered vertebrae, resulting in six or seven instrumented vertebrae.

The following is the procedure for inserting screws from T2 to T12 to better illustrate this process. First, we register T3 to T5 (three vertebrae) and insert screws from T2 to T6. Next, we register T8 to T10 (three vertebrae) and insert screws from T7 to T12. Although the vertebral level of T12 is two vertebrae away from the registered vertebrae, we insert screws into T12 based on the registration results of T8 to T10 because the pedicle diameter of T12 is usually wide.

2.3. Surgical technique

Pedicle screw insertion into the upper and lower ends of the insertion area was performed bilaterally. Screw placement for the other vertebral levels was determined on the basis of the size and rigidity of the curve, and vertebrae were skipped when judged possible. We defined the planned correction angle as the difference between the Cobb angle in side bending and target Cobb angle, and the number of screws from the upper end to the lower end vertebrae (EV) in the main thoracic (MT) curve was determined with reference to the formula of planned correction angle/1.6 [10]. Pedicles that had an outer diameter less than the thinnest screw diameter were excluded during navigation planning. A hook was used if an upper end was skipped. If two or more vertebrae at other levels were skipped, sublaminar tape with an ultrapliable polyethylene cable (Nesplon Cable System, Alfresa Pharma Co., Osaka, Japan) was employed on the concave side of the MT curve. The anchor density was determined with reference to the formula of the number of screw, hook, and cable/fused vertebral levels. Titanium alloy rods of 5.0, 5.5, and 6.0 mm in diameter were used in 1, 25, and 1 cases, respectively. Cobalt chrome rods of 5.5 and 6.0 mm were used in four and three patients, respectively. Bone grafting was performed using local bone excluding iliac or artificial bone.

2.4. Ponté osteotomy technique

We added Ponté osteotomy to three to four intervertebral regions around the apex of the MT curve for rigid curves when
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