Journal of Orthopaedic Science xxx (2016) 1–6

Contents lists available at ScienceDirect

Journal of Orthopaedic Science

journal homepage: http://www.elsevier.com/locate/jos

Original Article

Computer-assisted skip pedicle screw fixation for adolescent idiopathic scoliosis

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ARTICLE INFO

Article history:
Received 3 July 2016
Received in revised form
21 October 2016
Accepted 15 November 2016
Available online xxx

ABSTRACT

Study design: A retrospective single-center and single-surgeon study.
Objectives: This study investigated the clinical and radiological results of skip pedicle screw fixation for adolescent idiopathic scoliosis (AIS).
Summary of background data: At present, the generally used technique for pedicle screw fixation for the surgical correction of AIS entails inserting a pedicle screw into every segment on the corrective side and into every or every other segment on the supportive side. To reduce operation time, blood loss, and cost, we developed skip pedicle screw fixation to achieve correction of AIS using fewer pedicle screws.
Methods: We evaluated 62 consecutive patients who had undergone computer-assisted skip pedicle screw fixation from August 2005 to June 2014. All patients were followed up for at least two years. We investigated the clinical results of skip pedicle screw fixation for AIS.
Results: The mean number of fused vertebrae was 10.3 ± 2.0, the mean surgical time was 242 ± 78 min, and the mean blood loss volume was 1060 ± 688 ml. The mean Cobb angle of main thoracic (MT) curve two years after surgery improved significantly compared with that before surgery ($p < 0.01$). The mean correction rate of MT curve immediately after surgery was 62.4 ± 12.4% and correction loss of MT curve at two years after surgery was 1.9 ± 5.8°. The SRS-22 subtotal score two years after surgery improved significantly compared to that before surgery ($p < 0.01$). Although no patients experienced major complications, eight (12.9%) encountered minor complications (two [3.2%] had massive blood loss [>3000 ml], three [4.8%] had a broken screw, one [1.6%] had a set-screw that dropped out, one [1.6%] experienced deep vein thrombosis, one [1.6%] experienced acute renal failure, and one [1.6%] experienced intercostal neuralgia). Revision surgery was not performed.
Conclusions: Subjects with AIS who underwent skip pedicle screw fixation had significantly improved clinical and radiological parameters at two years after surgery, indicating that skip pedicle screw fixation could be used to successfully treat AIS.
Level of evidence: Level 4

1. Introduction

The most important issues in adolescent idiopathic scoliosis (AIS) surgery include cosmesis, as well as respiratory dysfunction and back pain, which may occur during adulthood. However, high rates of complications of scoliosis correction surgery have been reported because of the high surgical invasion resulting from prolonged operative times, extensive soft tissue dissection, long fusion, and significant bone bleeding during instrumentation and decortications (Table 1) [1–4]. In particular, the rate of complications from a combined anterior and posterior approach during surgery is higher than the independent use of anterior or posterior approaches [1].

Segmental pedicle screw fixation for AIS patients was introduced by Suk et al., in 1995 [5]. Pedicle screws have been recognized as a powerful option for deformity constructs. The posterior approach for scoliosis correction surgery has become the preferred method, as it offers greater fixation strength placement owing to fixation from the posterior column to the anterior vertebral body.

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http://dx.doi.org/10.1016/j.jos.2016.11.012
0949-2658/

Table 1
Radiological results of the surgery.

Radiological evaluation	Before surgery	2 Years after surgery	*p* value
Cobb angle of MT curve	53.8 ± 12.3° (41–94)	22.0 ± 8.0° (4–40)	<0.01
Apical trunk rotation of MT curve	14.8 ± 6.6° (4–43)	9.2 ± 4.1° (2–20)	<0.01
Thoracic kyphotic angle (T5–T12)	11.0 ± 8.9° (−8–33)	21.0 ± 7.6° (4–39)	<0.01

MT: main thoracic.

Furthermore, segmental pedicle screw instrumentation in AIS enables a shorter fusion length and a better correction [6]. However, pedicle screw fixation has been criticized for the potential risk of serious injury to both neurovascular and visceral structures such as the spinal cord, nerve root, lung, and aorta [5,7–9]. To avoid such serious risks, we developed skip pedicle screw fixation for AIS that required fewer pedicle screws to ensure correction (Fig. 1) [10–12]. The purpose of this study was to investigate the clinical results and rate of complications after skip pedicle screw fixation using CT-based navigation system for AIS.

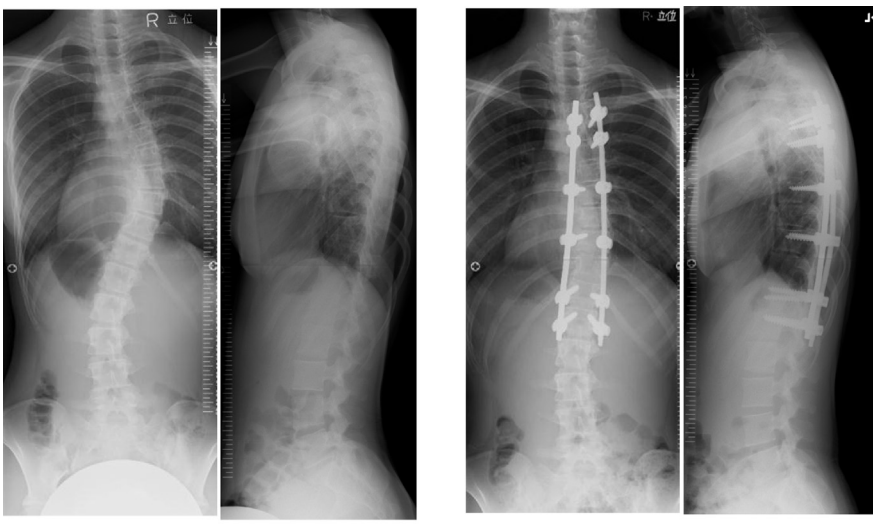
2. Materials and methods

2.1. Patients

After approval by the investigational review board of our hospital (approval number: 3070), 91 consecutive patients who underwent pedicle screw fixation for AIS guided by a computed tomography (CT)-based navigation system from August 2005 to June 2014 were retrospectively reviewed. Twenty-seven patients were excluded because they were Lenke type 5 and had previously undergone segmental pedicle screw fixation. Sixty-two (four males, 58 females, mean age, 14.7 ± 2.3 years [range, 11–21]) of the remaining 64 patients who underwent skip pedicle screw fixation for AIS were retrospectively reviewed. Two patients who were followed up for only nine months or 14 months were excluded. The remaining 62 patients were followed up at least two years (mean follow-up period, 5.3 ± 2.3 years [range, 2–10]). The follow-up rate was 96.9%. All patients underwent a postoperative CT to evaluate screw position. Each pedicle was assigned a grade from Grade 0 to 3. The grading scale is as follows: 0 reflected no perforation of the pedicle, 1 indicated less than 2 mm of perforation of the pedicle with one screw thread out of the pedicle, 2 represented 2–4 mm of perforation of the pedicle, and Grade 3 reflected greater than 4 mm [13].

2.2. Navigation and pedicle screw insertion technique

A frameless stereotactic image-guidance system (StealthStation TREON, and StealthStation 7, Medtronic, Sofamor Danek, Memphis, TN) was used for planning the pedicle diameter and length, as well as for correcting screw placement and fixation of the thoracic and lumbar spine. This procedure uses nine registration points for three consecutive vertebrae to shorten the surgical time [11,14]. Pedicle screws were inserted into consecutive three to seven vertebrae, moving from the upper to the lower end. We inserted pedicle screws into consecutive two vertebrae, when the screw diameter in the upper and lower ends was smaller than 4.5 mm. Screw insertion at other levels was determined in accordance with the size and rigidity of the curve, and the screw was skipped when deemed unnecessary. We defined corrective angle as the difference between Cobb angle in side bending preoperatively and target Cobb angle, and the number of screws from upper end vertebra to lower end vertebra on main thoracic curve was determined by reference to following formula; corrective angle/1.6 [15]. In addition, pedicles that had an outer diameter less than the thinnest screw were excluded, as evaluated during navigation planning. If an upper end was skipped, a hook was used, and if two or more vertebrae were skipped, sublaminar cable with an ultrapliable polyethylene cable (Nespron cable system, Alfresa Pharma Co., Osaka, Japan) was used on the concave side of the main thoracic curve. If three or more



(a) (b)

Fig. 1. Sample of skip pedicle screw fixation for adolescent idiopathic scoliosis. (a) Preoperative Cobb angle of the main thoracic (MT) curve was 43°, and that of the thoracolumbar (TL) curve was 31°. (b) We performed skip pedicle screw fixation from T5 to L1. Postoperative Cobb angle of MT and TL improved to 10 and 13°, respectively.

Please cite this article in press as: Uehara M, et al., Computer-assisted skip pedicle screw fixation for adolescent idiopathic scoliosis, Journal of Orthopaedic Science (2016), http://dx.doi.org/10.1016/j.jos.2016.11.012