Title: Growing rod technique with prior foundation surgery and sublaminar taping for early-onset scoliosis

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Abstract

OBJECTIVE The aim of this study was to show the surgical results of growing rod (GR) surgery with prior foundation surgery (PFS) and sublaminar taping at an apex vertebra.

METHOS Twenty-two early-onset scoliosis (EOS) patients underwent dual GR surgery with PFS and sublaminar taping. PFS was performed prior to rod placement, including exposure of distal and proximal anchor areas and anchor instrumentation with a local bone graft. After a period (3-5 months) for the anchors to become solid, dual rods were placed for distraction. The apex vertebra was exposed and fastened to the concave side rod by sublaminar tape. Preoperative, after GR placement, and final follow-up radiographic parameters were measured. Complications during the treatment period were evaluated based on the clinical records.

RESULTS The median (range) age at initial surgery was 55.5 (28-99) months, and the median follow-up period was 69.5 (25-98) months. The scoliosis was 81.5° (39-126) preoperatively, 30.5° (11-71) after GR placement, and 33.5° (12-87) at final follow-up. The thoracic kyphosis was 45.5° (7-136) preoperatively, 32.5° (15-99) after GR placement, and 42° (11-93) at final follow-up. The T1-S1 length was 240.5 (188-305) mm preoperatively, 286.5 (232-340) mm after GR placement, and 337.5 (206-423) mm at final follow-up. Complications occurred in 6 patients (27%). Three patients had implant complications, 2 patients had alignment complications, and 1 patient had a wound complication.

CONCLUSIONS Dual GR technique with PFS and sublaminar taping showed effective correction of scoliosis curves and a lower complication rate than previous reports using conventional dual GR technique.

KEY WORDS

scoliosis, early onset scoliosis, growing spine, growing rod, growth preservation surgery,

postoperative complication

Introduction

Surgical intervention is indicated for progressive and severe early-onset scoliosis (EOS) that does not respond to nonoperative treatment. The surgical technique includes distraction-based systems and guided growth constructs.[1,2,6,10,15] Growing rod (GR) technique is a widely spreading distraction-based technique that shows effectiveness in spinal deformity correction, spinal growth, and thoracic growth.[1,2,15] On the other hand, the postoperative complication rates of GR technique remain high, and implant-related complications were reported as the most common in past studies.[4,17] Staged insertion of a GR to enhance anchor site strength was reported in some papers, but implant-related complications have not been resolved.[7,13] Sublaminar wires are used in the Luque trolley method for multiple anchors,[8] but this method has resulted in unwanted fusion and is not a standard method today.[9] However, multiple anchors would make a more stable construct than fewer anchors.

Our GR procedures have included prior foundation surgery (PFS) to enhance anchor site strength and sublaminar tape fastening of only the apex vertebra to the concave-side rod with the intention of increasing the stability of the instrument. Since GR technique with both PFS and sublaminar taping has not been proposed in previous studies, the effectiveness of the combination of the two techniques is unclear.

This study was conducted to determine the surgical results of GR technique with both PFS and sublaminar taping for treating EOS, and to evaluate the efficacy of the technique, focusing on postoperative complications.

Methods

This was a single-institutional, retrospective study of patients undergoing dual GR with PFS and sublaminar taping for EOS between the years 2007 and 2016. All patients were followed-up for

at least 2 years. Demographic and surgical data were retrospectively reviewed from patients' clinical charts. Preoperative, after GR placement, and final follow-up radiographic parameters were measured. Radiographic parameters included main scoliosis Cobb angles (Cobb), maximal thoracic kyphosis (TK), T12-S1 lumbar lordosis (LL), T1-S1 length, and Campbell's space available for lung (SAL) ratio.[5] All radiographic measurements were taken using measurement software (Centricity™ Enterprise Web, version 3.0, GE Healthcare Japan, Tokyo, Japan).

Postoperative complications, including implant-related, alignment-related, wound-related, and neurological injuries, were evaluated.

The Wilcoxon rank-sum test was used to compare radiographic parameters. The level of significance was set at 0.05. Statistical analyses were performed using a software package (JMP 9.0, SAS, Cary, NC).

Surgical Technique

PFS was developed to enhance anchor site strength. In PFS, proximal and distal anchor areas were exposed in a subperiosteal fashion, anchor instruments (hook or screw) were inserted with local bone grafts around the implants, and short rods connecting the instruments were placed. Local bone grafts were taken from spinous process in anchor area. The choice of anchor levels depended on curve characters. The upper anchor levels were usually at T2 or T3. The lower anchor levels were at around stable vertebra.

Following an interval of about 4 months after PFS for the foundation to become solid, the long rods for distraction between the 2 anchors were placed intramuscularly. The proximal and distal rods were connected by tandem or side-to-side connectors. The connectors were placed at the thoracolumbar level (T10-L2) which is the inflection region of the thoracic kyphosis and lumbar lordosis. The lamina of only the apex vertebra was also exposed in a subperiosteal fashion and

fastened to the concave side rod by sublaminar tape (ultrahigh molecular weight polyethylene fiber cable, 3.5 mm in width). The exposure was limited in the upper, lower edge and center part of lamina to avoid damage to the facet joint capsule which might cause unwanted spontaneous fusion. If the connectors would disturb fastening the apex lamina and rod, the next lamina was used. Sublaminar tape was tightened as much as the lamina could tolerate to enhance scoliosis correction.

Rod lengthening was performed at intervals of around 6 months, continuing until the spine was mature enough to proceed with final fusion (Fig. 1). No patients were prescribed a brace during the postoperative period.

Results

Patient Demographics

Twenty-two EOS patients (4 boys and 18 girls) with a median age at initial surgery of 55.5 months (range, 28-99 months) were included. The median treatment period was 69.5 months (range, 25-98 months). EOS etiologies included 10 idiopathic, 10 syndromic, 1 neuromuscular, and 1 congenital. Curve types were 5 double thoracic, 10 main thoracic, 2 thoracolumbar, and 5 double major. The proximal foundations used a hook in 19 and a pedicle screw in 3. The distal foundations used a hook in 13 and pedicle screw in 9. The patients had 8 (range, 4-15) rod-lengthening procedures; 18 patients are still undergoing lengthening, and 4 patients underwent final fusion (Table 1). In total, 188 surgeries were performed, excluding PFS.

Radiographic Parameters

The median Cobb angle was 81.5° (range, 39-126°) preoperatively, 30.5° (range, 11-71°; median correction rate, 62.5%) after GR placement, and 33.5° (range, 12-87°; median correction rate,

58.9%) at final follow-up. The median TK was 45.5° (range, 7-136°) preoperatively, 32.5° (range, 15-99°) after GR placement, and 42° (range, 11-93°) at final follow-up.

The median LL was 44.5° (range, 13-88) preoperatively, 36° (range, 7-64) after GR placement, and 59° (range, 31-83) at final follow-up. The median T1-S1 length was 240.5 mm (range, 188-305 mm) preoperatively, 286.5 mm (range, 232-340 mm) after GR placement, and 337.5 mm (range, 206-423 mm) at final follow-up. The median SAL was 86% (range, 67-98%) preoperatively, 95.5% (range, 82-99%) after GR placement, and 96% (range, 86-99%) at final follow-up (Table 2, 3).

Postoperative Complications

Six postoperative complications occurred in 6 patients (27%). No PFS related complication occurred and all complications occurred in rod lengthening period. Implant-related complications included 1 screw fracture, 1 hook dislodgement, and 1 rod fracture. Alignment-related complications included 1 lumbar curve progression with flat-back and 1 junctional kyphosis. A deep infection occurred in 1 patient. The procedure complication rate was 3.2% (6 complications / 188 procedure). Only a deep infection was managed with unplanned surgery. No patient had neurological complications (Table 3).

Discussion

Because single GR surgery for EOS had poor outcomes and a high complication rate,[4,11] dual GR technique was developed by Akbarnia,[1] and it resulted in fewer complications than single GR technique.[3] However, several papers reported that the postoperative complication rate in dual GR remains high. Watanabe et al[17] reported that 50 (57%) of 88 patients and 22% of surgical procedures had complications, with a 3.9-year follow-up period. Bess et al[4] reported that 38 (55%)

of 69 patients had complications, with complications in 18% of all procedures during dual GR surgery with a 53.8-month follow-up period. Recently, Schelfaut et al[13] reported staged insertion of dual GR series; 9 of 15 patients (60%) had complications, and 14 complications occurred (0.93/patient) with 49.5 months of follow-up. In the current study, 6 of 22 patients (27%) had complications, and complication rate per surgical procedure was 3.2%, with a median of 8 rod-lengthening procedures and a 69.5-month treatment period. The complication rate in the current study was much lower than previously reported complication rates.

To show the characteristics of our GR technique with combined PFS and sublaminar taping, it is necessary to focus discussion on implant complications. Dual GR series from the Growing Spine Study Group database showed that 29 (42%) of 69 patients had implant complications (16 patients (23%) had foundation-related complications, and 18 patients (26%) had rod breakage).[4] To the best of our knowledge, only 2 previous studies[7,13] reported the implant complication rates in dual GR technique with PFS. Gomez et al[7] reported 4 foundation-related complications and 6 rod breakages in 8 patients. Schelfaut et al[13] reported that 4 of 15 patients (27%) had implant complications (no foundation-related complications and 6 rod breakages in 4 patients). In the current study, 3 of 22 patients (14%) had implant complications (1 patient (5%) with a foundation-related complication, 1 patient (5%) with rod breakage, and 1 patient (5%) with screw breakage). The implant complication rate was clearly lower in the current study than previously reported. Our dual GR procedure combined with PFS and sublaminar taping would make a stronger construct that results in fewer implant complications. A possible reason for hook dislodgement (case 17) is great preoperative hyperkyphosis (TK: 136˚). Previous studies reported that implant complications are more common in hyperkyphotic patients and increase linearly with increasing kyphosis.[14,17]

Rod breakage is a common complication even in the dual GR procedure, with a reported rate of

greater than 20% in several past studies.[4,13,17] Though a recently reported dual GR study with PFS used a 6-mm rod, the breakage rate was not decreased.[13] The rod breakage rate in the current study was clearly lower (i.e. 5%) than in the past. Moreover, all patients in the current study had no external support (e.g., brace or body cast) during the entire treatment course. These results mean that dual GR technique using only PFS could reduce foundation-related complication, but not reduce rod breakage; on the other hand, with combined PFS and sublaminar taping, both foundation-related complications and rod breakage could be reduced. To the best of our knowledge, there have been no published reports of dual GR surgery using sublaminar taping. Though no previous study has shown the mechanical effect of apical sublaminar taping in GR surgery, we speculate that fixing an apex of scoliosis curve to the rod would be crucial to stabilize the construct and reduce the mechanical stress that causes rod breakage.

The Cobb angle correction rate from pre- to post-rod placement was reported to be 32% to 53% in previous dual GR studies.[1,13,17] In the current study, the correction rate was 62.5%, higher than in previous reports. PFS could make a stronger anchor site, which could tolerate huge correction forces, and sublaminar taping could produce translation force to the apex vertebra of scoliosis. The reason for the good correction rate in the present study is that the combination of PFS and sublaminar taping could provide greater correction force than conventional dual GR technique.

The median TK and LL increased between GR placement and final follow-up in the current study. This trend of sagittal alignment change is similar to the data in previous studies on conventional dual GR technique.[1,15] Shah et al reviewed 43 children treated with dual GR technique, and it was stated that the trend of increase in TK and LL with age seen in normal children was also observed after lengthening of GR.[15]

One of the possible adverse effects of sublaminar taping might be auto fusion due to exposure of the lamina for placing the tape. Sublaminar wire and rods without fusion [8] in growing children

have been shown to inhibit spinal growth due to subperiosteal dissection causing heterotopic bone and autofusion.[9] On the other hand, McCarthy et al[10] reported that apical instrumentation and fusion including 3 to 4 segments are crucial for controlling the curve and compared favorably with GR in terms of growth of spinal length. In the current study, an increase in spinal growth of 15.5 mm/y was seen at T1-S1 from preoperative to final follow-up, which is comparable to previous conventional dual GR reports.[1,12] It may safely be said that sublaminar taping at an apex lamina does not inhibit spinal growth.

There are several limitations of this study. First, this was retrospective study with a small sample size and no control group. Second, this study did not control the selection of anchor implant type. Hooks were used for all patients at the beginning of this series and recently for patients having too narrow a pedicle to place a screw. Improved stability at foundation caused by PFS using hook has been reported by Schelfaut et al.[13] Now, pedicle screws are used in every patient when possible, because an immature animal model confirmed that prior pedicle screw insertion improved stability at bone-implant interface by osseointegration.[16] Therefore, we consider that PFS with both hook and screw efficiently enhances anchor stability, and the difference in implant types would not have affected the results of this study. Third, the majority of patients were still in growing phase and had not reached final fusion surgery at the time point of final follow-up. Thus, it is debatable how many complications will occur during extended follow-up. However, follow-up period in this study was 69.5-month which was longer than the period in the past dual GR studies.[1,2,4,13,17] Thus, we think that extended follow-up until final-fusion would have little impact on the results of this study.

Conclusions

In this study in which 22 EOS patients were treated with dual GR with PFS and sublaminar taping

combined, the Cobb angle correction rate was 62.5%, and postoperative implant complications affected 14% of the patients. These results mean that this technique could bring good correction of the scoliosis curve with less complications.

Disclosure

The authors report no conflict of interest concerning the materials or methods used in this study or the findings specified in this paper.

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Figure Legends

FIG. 1. Clinical example in the treatment of a 3 + 9-year-old girl with idiopathic scoliosis. A and B, after prior foundation surgery, posteroanterior (PA) and lateral radiographs (scoliosis Cobb angle 83˚). C and D, after rod placement surgery, PA and lateral radiographs (scoliosis Cobb angle 30˚). The T10 lamina is fastened to the left side rod by sublaminar tape. E and F, after 8 lengthenings, PA and lateral radiographs (scoliosis Cobb angle 33˚)