Prevention of Proximal Junctional Kyphosis After Posterior Surgery of Scheuermann Kyphosis

An Operative Technique

Hakan S. Yanik, MD, Ismail E. Ketenci, MD,* Atilla Polat, MD,† Ayhan Ulusoy, MD,* Gokmen Deniz, MD,‡ Ozkan Kose, MD,§ and Sevki Erdem, MD**

Study Design: A prospective randomized study.

Objective: To introduce an operative technique that prevents proximal junctional kyphosis (PJK) in Scheuermann disease after a segmental posterior spinal instrumentation and fusion.

Summary of Background Data: PJK is the progression of kyphotic deformity at the proximal end of a construct >10 degrees, and it can be seen up to 30% after posterior Scheuermann kyphosis surgery. After posterior fusion the biomechanics of the spine changes and the loss of motion at the fused levels is compensated by increased motion at other unfused segments. As a result significant amount of additional force is placed on the proximal junction. With our operative technique, we aimed to have a smooth passage from rigid to mobile segments and to decrease the stress on proximal junction during cantilever reduction to prevent PJK.

Methods: A total of 60 consecutive patients (mean age: 18.27 ± 3.19, male/female: 28/32) who were surgically treated for Scheuermann kyphosis in our institution were recruited into this study and were prospectively evaluated. Patients were divided into 2 groups according to upper-most screw fixation technique. In group 1, a standard screw insertion technique was used (ST group). The technique was modified in group 2 (MT group), leaving 2 threads out of the posterior cortex. There were 29 patients in group 1 (ST) and 31 patients in group 2 (MT). Patients had an average follow-up time of 24.2 months (range, 19–48 mo). Evaluated radiographic parameters were preoperative and postoperative kyphosis angle, and proximal junctional angle (PJA) at last visit. PJA was defined as the angle between the caudal endplate of the upper instrumented vertebra and the cephalad endplate of 2 suprajacent vertebrae above the upper instrumented vertebra. PJA exceeding 10 degrees was accepted as PJK. Quality of life measurement was assessed preoperatively and postoperatively with SF-36 questionnaire.

Results: Correction amounts in ST group and MT group were 46.8% and 43.7%, respectively, which was statistically insignificant. The mean PJA was 8.08 ± 2.96 degrees and 4.44 ± 1.55 degrees in ST and MT groups, respectively, which demonstrated a statistically significant difference ($P = 0.001$). Five patients in ST group had a PJA exceeding 10 degrees (PJK), whereas PJK was not seen in MT group ($P = 0.022$). The improvement in physical component summary of SF-36 was significantly better in MT group; however, mental component summary was similar in both groups.

Conclusions: This study introduces a new technique that may have an effect in preventing PJK. Our results seem to be satisfactory, but additional studies with more patients and longer follow-up times are needed to further delineate the feasibility of this technique.

Key Words: Scheuermann kyphosis, proximal junctional angle, proximal junctional kyphosis, posterior instrumentation, surgical technique

(*J Spinal Disord Tech* 2015;28:E101–E105)

Traditionally operative treatment of Scheuermann kyphosis (SK) consisted of apical anterior release and fusion followed by posterior spinal fusion.[1] With the improvement of pedicle screw–based constructs, applying of stronger forces and more rigid fixation became possible, and the need for anterior surgery decreased.[2] Better correction was achieved and preserved with the use of all-pedicle screw constructs.[3] Unfortunately, a rigid spinal fusion alters the normal biomechanics of the spine and the loss of motion at the fused levels is compensated by increased motion at other unfused segments. As a result, a significant amount of additional force is placed on the facet joints at the unfused levels.[4] In addition, posterior surgery may alter the integrity of the posterior ligamentous structures and paraspinal musculature support, causing increased proximal junctional flexion.[5]

Received for publication January 22, 2014; accepted July 11, 2014.

From the *Department of Orthopaedics and Traumatology, Haydarpasa Numune Education and Research Hospital; †Department of Orthopaedics and Traumatology, Umraniye Education and Research Hospital, Istanbul; ‡Department of Orthopaedics and Traumatology, Medical Park Hospital, Batman; and §Department of Orthopaedics and Traumatology, Antalya Education and Research Hospital, Antalya, Turkey.

The study is conducted under the permission of Haydarpasa Numune Education and Research Hospital Ethics Committee.

The authors declare no conflict of interest.

Reprints: Hakan S. Yanik, MD, Department of Orthopedics and Traumatology, Haydarpasa Numune Education and Research Hospital, Tibbiye Caddesi No: 40 34668, Uskudar, Istanbul, Turkey (e-mail: dr.serhatyanik@hotmail.com).

Proximal junctional kyphosis (PJK) is the progression of kyphotic deformity at the proximal end of a construct, which can lead to progressive decompensation in the sagittal plane.[6] Risk factors for PJK have been defined and techniques have been described to minimize it; however, PJK can be seen up to 30% after posterior SK surgery.[6–8]

Our aim in this study was to introduce an operative technique to prevent PJK after posterior instrumentation of SK. At the uppermost vertebra, we left both pedicle screws 2 threads out of the posterior cortex. Hence we aimed to have a smooth passage from rigid to mobile segments and to decrease the stress on proximal junction during cantilever reduction. We hypothesized that this technique would decrease PJK after posterior SK surgery.

MATERIALS AND METHODS

Patients and Groups

A total of 60 patients with SK who were treated by posterior segmental instrumentation and fusion were recruited into this study and were prospectively evaluated. The diagnosis was SK with a Cobb angle of ≥ 70 degrees in all of the patients. Exclusion criteria included patients with tumors, infections, traumatic spine pathology, connective tissue disorders, and those who had revision surgery. Patients were randomly allocated into 2 groups by random number generator according to upper-most screw fixation technique, with 29 patients in group 1 (standard technique: ST) and 31 patients in group 2 (modified technique: MT). Patients were informed about the treatment techniques and agreed to undergo the procedure.

Surgical Technique

All of the surgeries mentioned in this study were performed by the 1 senior spine surgeon (S.E.). Patients were placed in the prone position on a radiolucent table. After a standard midline incision, subperiosteal dissection of the posterior soft tissues was performed to the tips of the transverse processes. During exposure, care was taken to preserve posterior ligamentous structures especially at the upper and lower levels. Pedicle screws were placed bilaterally at every level using a free-hand technique. In MT group we left the upper-most screws 2 threads out of the posterior cortical surface, whereas we did not leave any exposed threads in ST group (Fig. 1). Other steps of the procedure were same in both groups. After facetectomies and Ponte osteotomies were performed, the deformity was corrected using cantilever reduction and apical compression. The nuts were tightened from distal to proximal gradually. The laminae and transverse processes were thoroughly decorticated. Allograft artificial bone material was used for fusion.

After surgery, none of the patients in either group was immobilized in a brace. All patients practiced ambulation within first day after surgery. Stressful activities were avoided for at least 2 months after surgery.

Radiographic Measurements

Measurements were taken on 36-inch long cassette anteroposterior and lateral radiographs of the spine with the patient standing. A senior spinal surgeon who was independent of the operative team made all radiographic measurements. Patients were asked to stand naturally with their shoulders flexed forward approximately at 30 degrees so that their upper thoracic vertebral bodies could be visualized on the lateral radiograph. The endplates at the proximal junction had to be clearly visible for study inclusion.

The parameters examined included Cobb measurement of thoracic kyphosis (upper-most to lower-most tilted end vertebrae, including the total kyphosis) and proximal junctional angle (PJA). PJA was defined as the angle between the caudal endplate of the upper instrumented vertebra (UIV) and the cephalad endplate of 2 suprajacent vertebrae above the UIV, as previously described.[6] PJA >10 degrees was accepted as PJK (Fig. 2).

Patient Outcomes

The quality-of-life measurements of the patients were evaluated using SF-36 scale during preoperative and last follow-up periods. We completed the questionnaire by face-to-face interview. We calculated the score as physical component summary (PCS) and mental component summary (MCS).

Statistical Analysis

All statistical analysis was conducted using SPSS software (Statistical Package for Social Sciences 21.0 for Windows). The Student t test was used to assess differences in means between groups for normally distributed continuous variables. Statistical comparisons between groups preoperatively and postoperatively were performed using the Mann-Whitney U test. Paired samples t test was used for comparison of preoperative and postoperative measurements. A P-value of <0.05 was considered as statistically significant.

RESULTS

Mean age of the patients was 18.3 years (range, 11–26 y) at the time of surgery. A total of 32 patients were female and 28 were male. There were no differences between 2 groups in terms of age, sex, and follow-up time (Table 1). The comparison of preoperative kyphosis angles between groups revealed statistically similar results, and this was also same for comparative analysis of postoperative kyphosis angles (Table 2). Correction amounts in ST group and MT group were 46.8% and 43.7%, respectively, which was statistically insignificant. The mean PJA was 8.08 ± 2.96 and 4.44 ± 1.55 degrees in ST and MT groups, respectively, which demonstrated a statistically significant difference ($P = 0.001$). In none of the patients in MT group the PJA exceeded 10 degrees, whereas 5 patients exceeded this angle in ST group ($P = 0.022$). Preoperative and postoperative MCS component of SF-36 questionnaire were similar in both of the groups. The improvement in PCS component was better

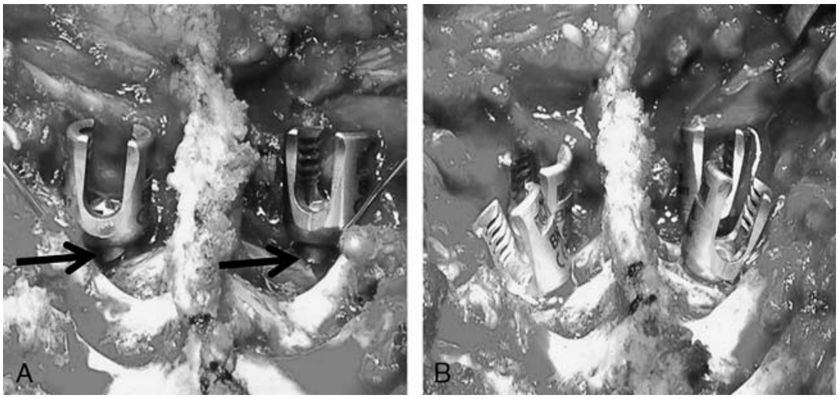

FIGURE 1. A, The arrows show the upper-most screws that are left 2 threads out of the posterior cortical surface in MT group. B, No exposed threads were left in ST group. MT indicates modified technique; ST, standard technique.

in MT group, and the difference was statistically significant (Table 2).

None of the patients who had PJK required revision surgery after a mean follow-up time of 2 years. No implant-related or neurological complications were observed. Moreover in MT group, none of the patients complained of feeling the head of the screw under the skin.

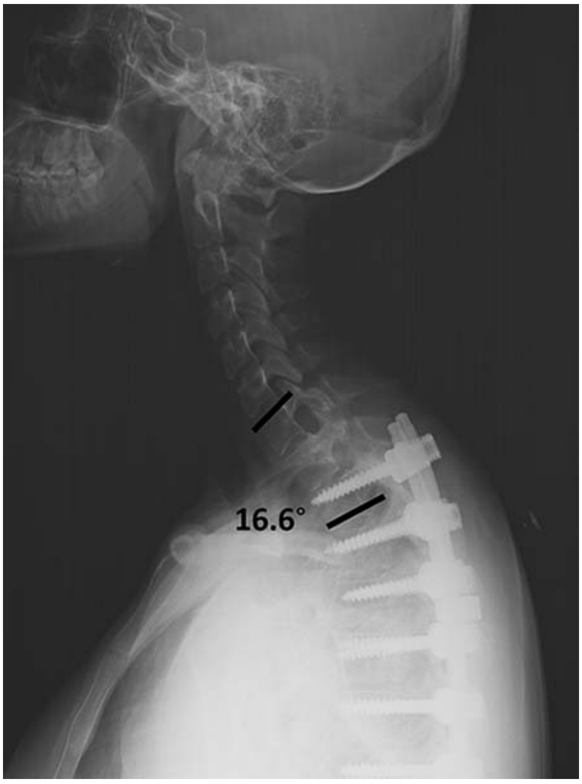

FIGURE 2. A 20-year-old female patient with proximal junctional kyphosis at 22 months after surgery.

DISCUSSION

PJK is probably the major instrumentation-related complication after the surgical correction of kyphotic deformities, and its reported incidence after surgical treatment of SK is around 30%.[6–8] According to the recent studies, PJK is mainly attributed to junctional ligamentous disruption and failure to incorporate the proximal end vertebra into the fusion.[7,8] PJK is also found to be related to high magnitude of preoperative and postoperative kyphosis angle as well as high pelvic incidence.[8] The authors in these studies advocated that PJK can be minimized by selecting appropriate fusion levels, by a careful exposure leaving the posterior ligamentous structures intact, and by careful evaluation of sagittal parameters.[7,8] However, PJK still remains a complication in SK surgery. This may be attributed to the change in the biomechanics of the spine due to the abrupt passage from a rigid to a mobile segment.[4,9] Hence a smoother passage is needed to decrease the stress on the bone and soft-tissue structures at this junctional region. By leaving the uppermost pedicle screws 2 threads out of the posterior cortex, we tried to provide this smooth passage.

Our correction amounts were as good as reported in the literature.[2,3,7,8] Our PJK amount, however, was much less than reported in these studies. This may have several explanations. During exposure we paid attention to preserve the posterior ligamentous structures at every level and we always included the proximal end vertebra of Cobb angle in the fusion. Another reason for this may be that our mean correction amount is $< 50\%$.[10] However, we did not observe PJK in patients which were corrected over 50%. Anyhow correction over 50% is not accepted as a risk

TABLE 1. Patient Demographics

Characteristics	Group 1 (ST)	Group 2 (MT)	*P*
Age (mean ± SD)	18.8 ± 2.8	17.7 ± 3.4	0.165
Sex (male/female)	13/16	15/16	0.163
Follow-up time (mo)	24.9 ± 5.3	23.4 ± 2.7	0.160

TABLE 2. Radiographic and Quality of Life Measurements

	Mean ± SD		
	Group 1 (ST)	Group 2 (MT)	*P*
Preoperative kyphosis (deg.)	73.8 ± 5.3	73.4 ± 4.2	0.742
Postoperative kyphosis (deg.)	39.2 ± 4.9	41.3 ± 7.3	0.200
Preoperative SF-36 PCS	33.2 ± 4.1	35.8 ± 5.7	0.054
Preoperative SF-36 MCS	41.5 ± 5.9	43.7 ± 1.9	0.068
Postoperative SF-36 PCS	47.4 ± 4.7	44.5 ± 4.4	0.015*
Postoperative SF-36 MCS	52.8 ± 6.7	54.1 ± 3.9	0.412

* indicates statistical significance.
MCS indicates mental component summary; MT, modified technique; PCS, physical component summary; ST, standard technique.

factor for PJK by some authors.[7,8] The effect of our technique in decreasing the PJK expresses itself on the difference of PJK amounts between 2 groups. There was no PJK in MT group, whereas all PJK cases were seen in ST group.

The technique of operative treatment of SK has been implicated as possible cause of junctional kyphosis.[10] We used combination of cantilever reduction and apical compression technique and posterior segmental instrumentation in both groups. Theoretically, in cantilever reduction technique the forces are concentrated at the ends of the construct increasing the risk of junctional kyphosis. It also imparts significant force upon the implants and can ultimately lead to the pedicle screw loosening and pull-out.[11] We also used apical compression technique that spreads out the force of the reduction over the entire construct instead of concentrating the forces at the junctional levels. In addition, leaving the upper-most screws 2 threads out of the posterior cortex decreased the traction force applied to the UIV during cantilever reduction (Fig. 3). With this technique we were able to obtain a smooth and physiological passage at the junctional region in terms of load sharing. Moreover, we tightened the nuts from distal to proximal gradually. This further decreased the pull-out force on the upper-most screws. Leaving exposed screw may seem to increase the bending moment applied to proximal shaft of the screw. However, we did not observe any screw breakage in our cases. This may be related to a good ventral load sharing due to proper screw trajectories and successful fusion.

The results of posterior-only treatment of SK were unsuccessful in former studies, and combined anteroposterior fusion was recommended.[1,12] After the popularization of pedicle screw instrumentation, several studies have shown similar results with posterior-only treatment of adolescent kyphosis using hybrid constructs.[13,14] Moreover, recent studies comparing posterior segmental all-pedicle screw instrumentation with 2-staged procedures showed similar results in terms of correction and maintenance of it.[2,3] Our results support these studies. The PJK incidence after SK correction according to anterior or posterior surgeries has not been reported in previous studies, but the type of the instrumentation may have an effect on PJK. In our opinion, disruption of the posterior soft tissues required to place supralaminar hooks or double claw constructs may produce a detrimental effect on the proximal junction. We

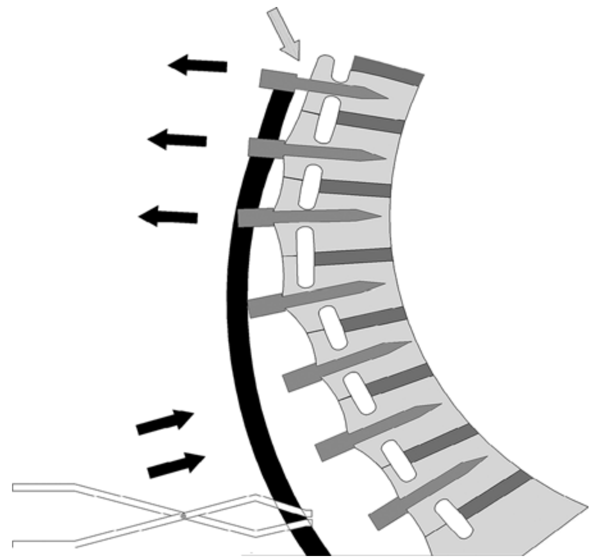

FIGURE 3. Illustration of cantilever reduction maneuver. White arrow shows the exposed part of the upper-most screw. Black arrows show the forces acting on the rod.

eliminated this effect by using pedicle screws at the upper level in both groups.

PJK did not appear to adversely impact patient-perceived health-related quality of life. Kim et al[15] supported this finding in their study for those who had PJK <20 degrees. Also in our study, in none of the patients PJK exceeded 20 degrees. This may explain why the 5 patients with PJK did not have clinical complaints. They also did not require a revision surgery. These data should not be misconstrued that PJK is not a serious issue. It may have a negative effect on patients' self image, which was seen in our study as lower PCS scores. Moreover, when the development of PJK leads to proximal junctional failure, multiple extensive revision surgeries may be required to avoid serious neurological sequelae. In the study by Denis et al,[7] 4 of 20 patients who had PJK required revision, mainly due to prominent proximal instrumentation. In our study, prominent instrumentation was not seen in both of the groups.

The strong points of this study are uniform surgery and number of patients. All surgeries were performed by a single spinal surgeon at the same hospital. Surgical procedures, types of implants, and surgical goals were all relatively uniform. The weakness of this study is that we did not compare early and late postoperative correction amounts. This was due to the unavailability of some early postoperative radiographs.

CONCLUSIONS

There is no doubt that PJK after SK surgery is multifactorial. Careful surgical exposure and proper selection of fusion levels are mandatory to avoid this complication. In this study, we introduce a new technique that may have an effect in preventing PJK. Our results seem to be satisfactory, but additional studies with more patients and longer follow-up times are needed to further define the effect of this technique. This study may guide spine surgeons in their surgical management of SK to reduce the occurrence of PJK.

REFERENCES

1. Bradford DS, Ahmed KB, Moe JH, et al. The surgical management of patients with Scheuermann's disease: a review of twenty-four cases managed by combined anterior and posterior spine fusion. *J Bone Joint Surg Am*. 1980;62:705–712.
2. Lee SS, Lenke LG, Kuklo TR, et al. Comparison of Scheuermann kyphosis correction by posterior-only thoracic pedicle screw fixation versus combined anterior/posterior fusion. *Spine*. 2006;31:2316–2321.
3. Koptan WM, Elmiligui YH, Elsebaie HB. All pedicle screw instrumentation for Scheuermann's kyphosis correction: is it worth it? *Spine J*. 2009;9:296–302.
4. Lee CK, Langrana NA. Lumbosacral spinal fusion: a biomechanical study. *Spine*. 1984;9:574–581.
5. Hollenbeck SM, Glattes RC, Asher MA, et al. The prevalence of increased proximal junctional flexion following posterior instrumentation and arthrodesis for adolescent idiopathic scoliosis. *Spine*. 2008;33:1675–1681.
6. Glattes RC, Bridwell KH, Lenke LG, et al. Proximal junctional kyphosis in adult spinal deformity following long instrumented posterior spinal fusion: incidence, outcomes and risk factor analysis. *Spine*. 2005;30:1643–1649.
7. Denis F, Sun EC, Winter RB. Incidence and risk factors for proximal and distal junctional kyphosis following surgical treatment for Scheuermann kyphosis. *Spine*. 2009;34:E729–E734.
8. Lonner BS, Newton P, Betz R, et al. Operative management of Scheuermann's kyphosis in 78 patients. Radiographic outcomes, complications, and technique. *Spine*. 2007;32:2644–2652.
9. Kim YJ, Lenke LG, Bridwell KH, et al. Proximal junctional kyphosis in adolescent idiopathic scoliosis after three different types of posterior segmental spinal instrumentation and fusions: incidence and risk factor analysis of 410 cases. *Spine*. 2007;32:2731–2738.
10. Hosman AJ, Langeloo DD, de Kleuver M, et al. Analysis of the sagittal plane after surgical management for Scheuermann's disease: a view on overcorrection and the use of an anterior release. *Spine*. 2002;27:167–175.
11. Chang KW. Cantilever bending technique for treatment of large and rigid scoliosis. *Spine*. 2003;28:2452–2458.
12. Bradford DS, Moe JH, Montalvo FJ, et al. Scheuermann's kyphosis. Results of surgical treatment by posterior spine arthrodesis in twenty-two patients. *J Bone Joint Surg Am*. 1975;57:439–448.
13. Otsuka NY, Hall JE, Mah JY. Posterior fusion for Scheuermann's kyphosis. *Clin Orthop Relat Res*. 1990;251:134–139.
14. Papagelopoulos PJ, Klassen RA, Peterson HA, et al. Surgical treatment of Scheuermann's disease with segmental compression instrumentation. *Clin Orthop Relat Res*. 2001;386:139–149.
15. Kim YJ, Bridwell KH, Lenke LG, et al. Proximal junctional kyphosis in adult spinal deformity after segmental posterior spinal instrumentation and fusion. *Spine*. 2008;33:2179–2184.