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ORIGINAL ARTICLE

Minimum five-year follow-up of posterior-only pedicle screw constructs for thoracic and thoracolumbar kyphosis

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Abstract

Study design Retrospective cohort study.

Objective To review/report 5-year follow-up data on patients diagnosed with thoracic and thoracolumbar kyphosis (TK/TLK) treated with posterior-only spinal fusion.

Summary of background data TK/TLK was initially treated with combined anterior/posterior spinal fusion, evolving into widespread treatment with posterior-only spinal fusion.

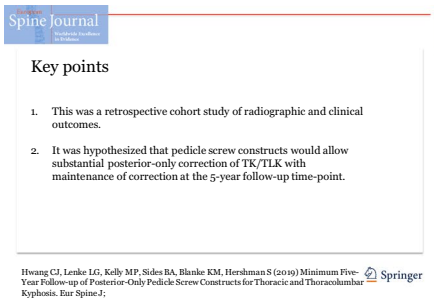
Methods Forty-three patients who underwent a posterior-only spinal fusion for a primary diagnosis of TK/TLK from 1999 to 2009 with > 5-year follow-up were identified. Preoperative/postoperative/final follow-up measurements were recorded from full-length standing radiographs. Prospectively collected outcome scores were reviewed for the same time points, and charts were examined for complications.

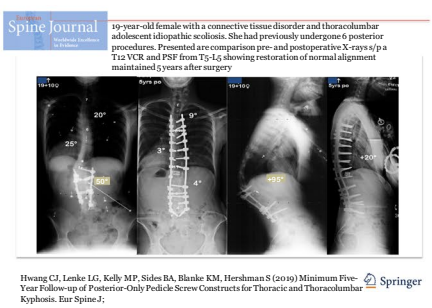
Results Patient age averaged 33 years (range 13–77), and follow-up averaged 5.6 years (range 5–12.2). Diagnoses included Scheuermann's disease ($N=15$, 35%), idiopathic ($N=10$, 23%), pseudarthrosis ($N=6$, 14%), iatrogenic ($N=4$, 9%), degenerative ($N=3$, 7%), post-traumatic ($N=3$, 7%), and congenital kyphosis ($N=2$, 5%). Average correction of 44.3° (46%; 92.8° preoperatively vs 48.5° postoperatively) was achieved through posterior-only surgery. Loss of correction averaged only 1° in the instrumented segments at final follow-up. Eleven patients had a complication; proximal junctional kyphosis was the most common ($N=3$, 7%). One patient lost intraoperative monitoring and one had temporary neurological deterioration postoperatively, but there was no permanent deficit. No pseudarthroses occurred. ODI scores improved 17.2 points on average ($p=0.01$). SRS scores improved in all domains (average 0.79, $p<0.001$).

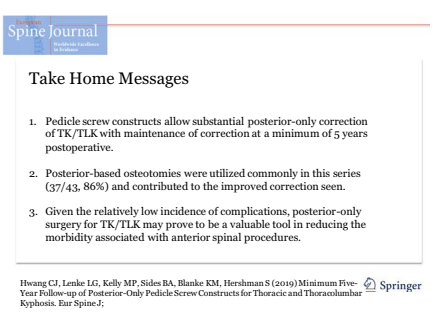
Conclusion Pedicle screw constructs permit effective posterior-only correction of TK/TLK that is maintained at the 5-year follow-up time point. Patients report improvement, via outcome questionnaires, at the same follow-up time points.

Graphic abstract

These slides can be retrieved under Electronic Supplementary Material.







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Keywords Thoracic kyphosis · Thoracolumbar kyphosis · Posterior-only surgery · Five-year follow-up

Introduction

Kyphosis can occur at any age and in any region of the spine. Many kyphotic deformities treated in adulthood are the result of pediatric disorders, such as Scheuermann's and congenital kyphosis. In addition, the conditions that may cause kyphosis include tumor, neuromuscular diseases, trauma, infection (Pott's disease), iatrogenic pathology (post-laminectomy or flatback syndrome), and skeletal dysplasia [1, 2]. The Scoliosis Research Society (SRS) reported normal values of kyphosis ranging from 10° to 40° measured from the superior endplate of T5 and inferior endplate of T12 [3]. More recently, attention has been given to spinopelvic parameters to dictate what would be considered "normal" for each individual [3]. In general, surgical treatment can be considered when the thoracic kyphosis (TK) exceeds 75° and thoracolumbar kyphosis (TLK) exceeds 65°. Indications for surgical treatment, irrespective of the magnitude of kyphosis, include the occurrence of a neurological deficit, a rapidly progressive deformity or pain and disability that are resistant to conservative treatment [2, 4–7].

TK/TLK was initially treated with combined anterior and posterior spinal fusion, followed by the increased use of posterior-only approaches as described in the literature. Instrumentation evolved over time from all hooks to hybrid to pedicle screw constructs [1, 2, 4–15]. To date, no intermediate or long-term studies have demonstrated the outcomes of posterior-only surgery with pedicle screw constructs for the treatment of TK/TLK. The purpose of this study was to review and report 5-year follow-up data on patients with a primary diagnosis of TK/TLK treated with posterior-only pedicle screw constructs.

Materials and methods

It was hypothesized that pedicle screw constructs would allow substantial posterior-only correction of TK/TLK with maintenance of correction at the 5-year follow-up time point. Following institutional review board approval, the databases of three hospitals within a single institution were searched. All patients within the institution over the age of 12 with a diagnosis of TK/TLK who were treated with a posterior-only spinal fusion using pedicle screw constructs (> 90% pedicle screws) between 1999 and 2009 were eligible for inclusion in the study. Patients were selected based on their diagnosis of TK/TLK with a sagittal Cobb angle > 65° and an apex above the L1-2 disc space. Some patients also had various degrees of scoliosis.

All etiologies of TK/TLK were eligible for review, including Scheuermann's, idiopathic, congenital, and iatrogenic kyphosis (proximal junctional and post-laminectomy kyphosis). All patients had a minimum of 5-year clinical and radiographic follow-up. Patients with less than 5-year follow-up, incomplete or missing preoperative or 5-year follow-up imaging, concurrent anterior spinal procedures of any kind, or underlying neuromuscular disorders were excluded.

All procedures were performed by one of two fellowship-trained spine surgeons who are members of the Scoliosis Research Society (SRS). After exposure with the patient in the prone position on a radiolucent frame, pedicle screws were placed bilaterally or unilaterally at each level. The senior authors were responsible for choosing the levels for the upper and lower instrumented vertebrae in all cases based on the standing lateral radiographs. The vertebral body most closely bisected by the sagittal vertical axis (SVA) was chosen as the lowest instrumented vertebra (LIV) [16]. The proximal level was chosen by extending the construct so that a symmetrical number of levels were included above and below the apex, provided that the disc above the theoretical upper instrumented vertebra (UIV) was lordotic. During the kyphosis correction procedures, the cantilever method as well as sequential segmental compression was performed to shorten the posterior column. Bone graft and recombinant human bone morphogenetic protein-2 (BMP, Infuse Bone Graft; Medtronic Sofamor Danek USA, Inc., Memphis, TN, USA) were used at the discretion of the attending surgeon.

Each patient's preoperative, early postoperative, and most recent full-length standing spinal radiographs were retrospectively reviewed. The maximum kyphosis and their sagittal balance (C7 plumb line to the posterior superior corner of the sacrum) were measured at those time points by a senior spine surgeon, independent of the operative team. Additional measurements included the kyphosis across the instrumented segments on the pre- and postoperative images. Medical records were reviewed with implant selection, bone graft choice, and osteotomy type noted for each patient. All preoperative comorbidities and postoperative complications were also reviewed. Proximal junctional kyphosis was defined radiographically as kyphosis greater than 10° between the UIV and the UIV + 2 [17]. Any intraoperative neuromonitoring change or loss was noted, as well as the ultimate neurological outcome of all patients. Additionally, SRS-30 outcome scores and Oswestry Disability Index (ODI) scores were examined at the preoperative and final follow-up time points.

All statistics were done using Excel (Microsoft, Seattle, WA). Two-tailed t tests were run for the majority of data

assuming unequal variances, initially confirmed with an *F* test. *p* values less than 0.05 were considered to be statistically significant.

Results

A total of 84 patients were identified as having undergone a posterior-only spinal fusion procedure for a diagnosis of TK/TLK using a pedicle screw-based construct during the study period. Of those, 43 (51.2%) fit the criteria for more than 5-year follow-up. Follow-up averaged 5.6 years (range 5–12.2 years). Fourteen of the 43 patients (32.6%) had a prior spinal procedure performed. The average age at the time of kyphosis surgery was 33 years (range 13–77 years). Preoperative halo traction was used in three patients. Five patients were treated with a two-stage procedure. The mean estimated blood loss (EBL) was 1403 mL (range 300–6500 mL), and eight patients had an EBL of more than 2L. The mean operative time was 7.9 h. (range 3.5–15.9 h.).

Scheuermann's kyphosis was the most prevalent etiology in our patient population and was seen in 15 of the 43 patients (34.9%). Other etiologies were idiopathic ($N=10$; 23.3%), pseudarthrosis ($N=6$; 14%), iatrogenic ($N=4$; 9.3%), degenerative ($N=3$; 7%), post-traumatic ($N=3$; 7%), and congenital kyphosis ($N=2$; 4.7%). The apex of the kyphosis occurred in the thoracic spine in almost three-quarters of the patients ($N=32$; 74.4%) and at the thoracolumbar junction in the remaining patients ($N=11$; 25.6%).

Instrumentation consisted of either a 5.5-mm stainless steel rod system ($n=27$), a 6.35-mm stainless steel rod system ($n=6$), or a 5.5-mm cobalt chrome rod system ($n=10$). Thirty-seven patients underwent a posterior-based osteotomy, 18 had both posterior column osteotomies (PCOs) and a vertebral column resection (VCR), 16 had PCOs alone (Figs. 1, 2, 3, 4, 5), and two underwent a VCR alone at the apical levels Figs. 6, 7). One patient underwent laminectomies due to cord compression.

BMP was used in 34 patients (79.1%). BMP dosages ranged from none in nine patients to 320 mg. Five patients received doses of BMP exceeding 144 mg (range 144–320 mg); excluding these five patients, the average amount of BMP used per case in the other 29 patients was 62.6 mg (range 12–132 mg).

The kyphoses averaged 92.8° (range 65°–152°) and were initially corrected to an average of 48.5° (range 4°–96°). Per cent correction averaged 46.3% (range 14–95%). At the time of final follow-up, an average of only 1° of correction across the instrumented segments was lost with the average kyphosis at 49.5° (Table 1). The largest loss of correction was 14°, which was seen in a patient who had a 90-degree kyphosis with an apex at the thoracolumbar junction. Her initial correction was to 38° (52°/58% improvement), but at

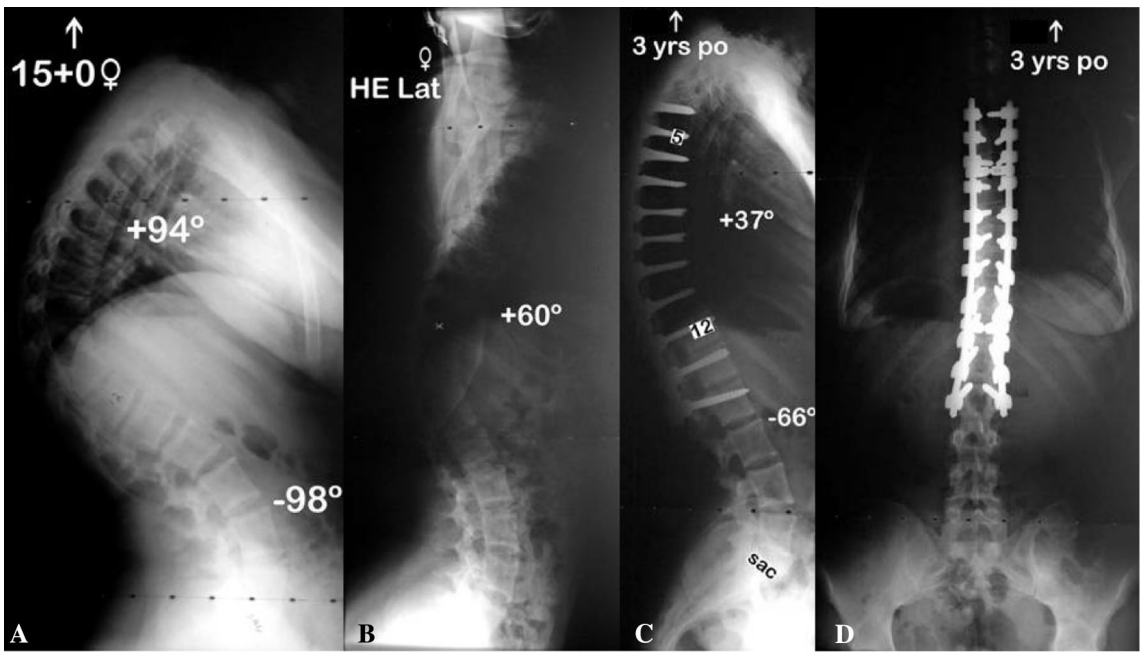

Fig. 1 15-year-old male with Scheuermann's kyphosis. Preoperative upright lateral (**a**) and supine hyperextension, (**b**) X-rays showing reduction of curve from 94° to 60°. Postoperative lateral (**c**) and AP (**d**) X-rays 3 years after a posterior spinal fusion (PSF) from T4–L2 with apical PCOs showing improved alignment

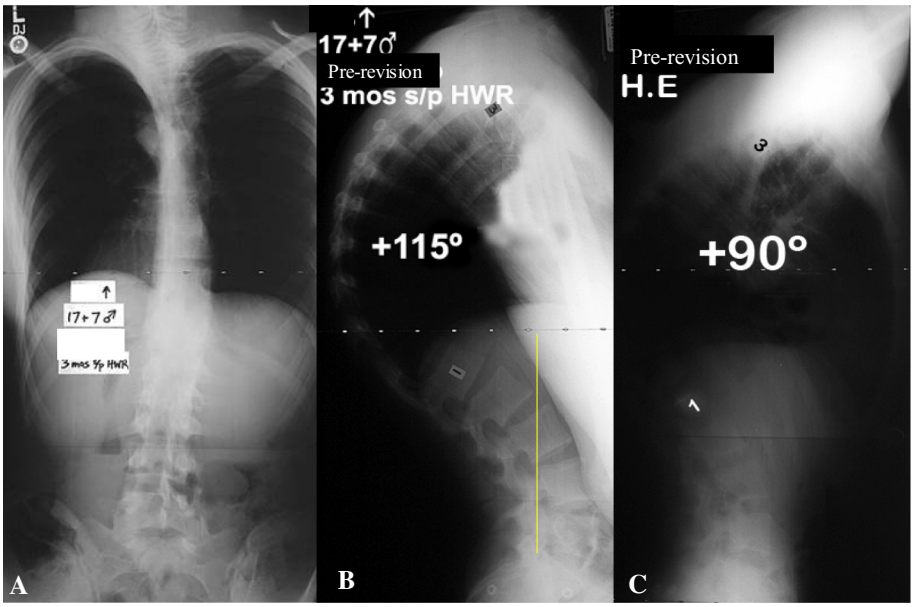

Fig. 2 Upright AP (**a**) and lateral (**b**) X-rays showing the return of a worsened deformity after implant removal due to the occurrence of a deep wound infection. Supine hyperextension X-ray (c) showing less flexibility than he had preoperatively

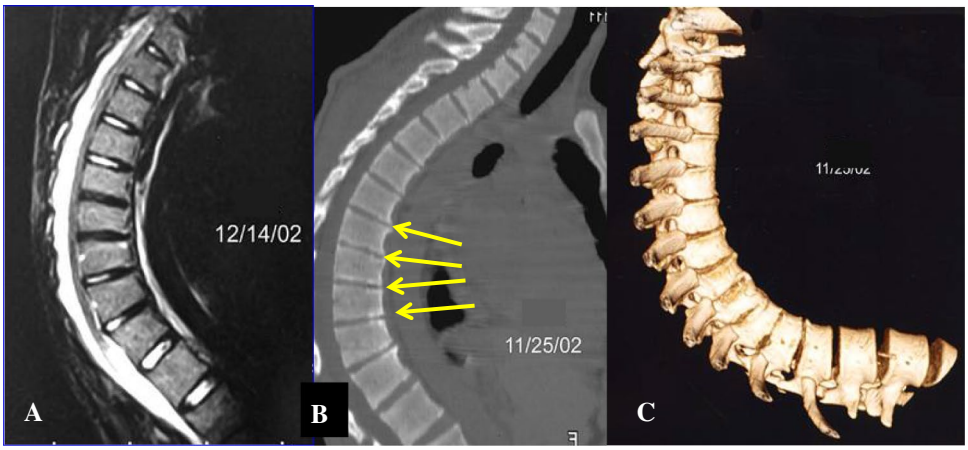

Fig. 3 Pre-revision sagittal MRI (**a**), 2D CT scan (**b**), and 3D CT scan (**c**) showing narrowed but unfused apical discs

final follow-up her spine settled to 52° of kyphosis (38°/42% correction).

The ODI was given to all patients age 18 or older ($N=27$; 62.8%); 24/27 patients (88.9%) had complete preoperative and postoperative ODI data. Preoperatively, ODI scores ranged from 0 to 82 and averaged 37.8; postoperatively, ODI scores decreased an average of 17.2 points to 20.6 (range 0–64, $p=0.01$). Because some patients underwent surgery before the availability of the SRS-30 questionnaire, we were only able to obtain the data on 33/43 patients (76.7%), but in these patients, SRS scores significantly improved in all domains (Table 2).

Eleven patients had a complication (Table 1). Proximal junctional kyphosis was seen in three patients (7%); two of them were asymptomatic and had not required revision at the time this manuscript was written. The other patient underwent revision surgery 8 years after the index procedure due to proximal and distal junctional kyphosis. Intraoperative neuromonitoring signals were lost in one patient following correction of the kyphosis. The correction was reversed, and the mean arterial pressure was increased. In this patient, a Stagnara wake-up test was performed demonstrating full strength in all myotomes of the bilateral lower extremities. The patient was then re-corrected, though not as aggressively as had initially been done. One patient, in whom monitoring data were absent from the start of the procedure due to severe myelopathy, had temporary neurological deterioration postoperatively. Fortunately, he recovered immediately after surgery without any significant change in his preoperative neurological examination. There was no complete permanent paralysis in this series. A small amount of screw pullout in the middle of the construct was seen at one level in one patient—this was observed but never treated. The patient went on to fuse, experienced no symptoms, and his correction was maintained with no loss of correction seen at the 5-year

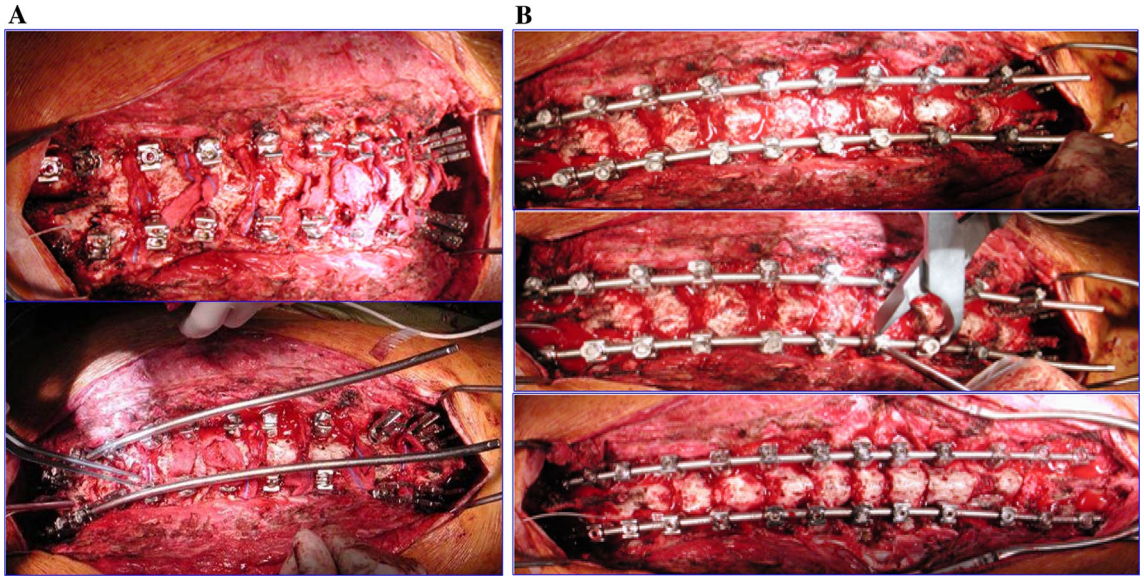

Fig. 4 **a** and **b** Intraoperative pictures showing implant placement and kyphosis correction by cantilever and compression forces with evidence of multiple PCOs

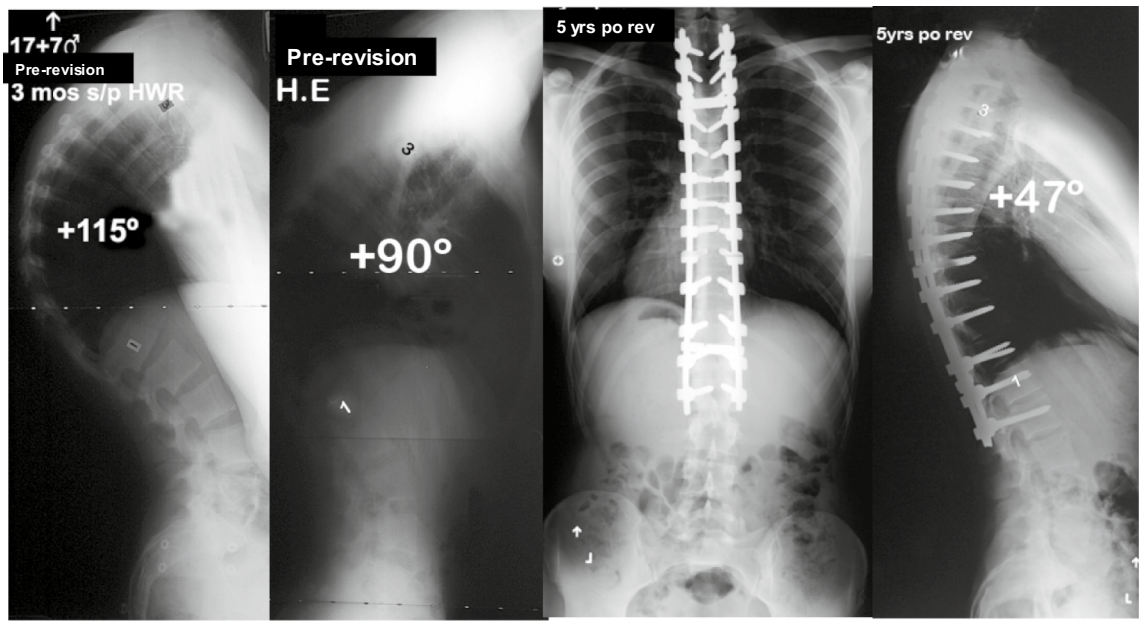

Fig. 5 Comparison X-rays showing pre- and 5-year postoperative X-rays after a revision PSF with PCOs x9. The combination of good bone and solid screws allowed for good deformity correction

time point. Other complications included pleural effusion (two patients, one of whom required chest tube placement), respiratory distress requiring reintubation postoperatively (one patient), tongue swelling with a small area of necrosis (one patient), and urinary tract infection (one patient). No pseudarthroses or wound-related infections occurred.

Discussion

TK/TLK has been traditionally treated with an apical anterior release and fusion followed by a posterior spinal fusion. The basis of this treatment originates from the work of Bradford et al. [18] in 1975, in which they

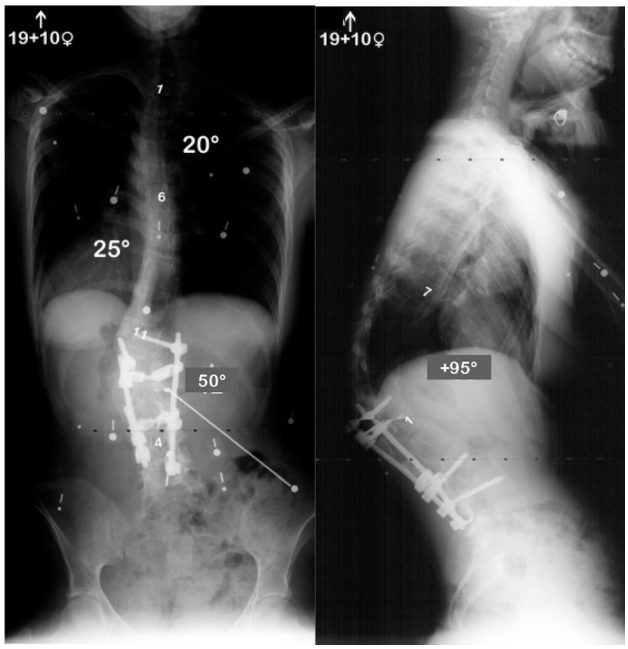

Fig. 6 Upright X-rays of a 19-year-old female with a connective tissue disorder and thoracolumbar adolescent idiopathic scoliosis. She had previously undergone six posterior procedures and presented to us with severe thoracolumbar kyphosis

reported an unacceptably high incidence of correction loss after posterior-only treatment of Scheuermann's kyphosis. The authors of that study recommended first performing an anterior column release and fusion and then fusing posteriorly to minimize loss of correction [19]. Anterior release has been advocated in curves that are large and stiff or ones that have anterior bony bridging in order to increase the ability to correct the spine and permit a greater surface area for fusion [20]. The combination of an anterior release with a concomitant posterior spinal fusion includes increases in operative time, blood loss, anesthetic time, and the compromise of pulmonary function in the perioperative period [10, 21]. However, with the advent of modern and stiff posterior instrumentation including pedicle screws, greater correction of spinal deformities is possible, theoretically allowing those corrections to be done from a posterior-only approach. In addition, posterior shortening procedures increase anterior disc height, and the addition of an anterior release does not appear to significantly alter the degree of correction [14]. Most of our patients also underwent a posterior-based shortening osteotomy including PCOs and/or a VCR [2, 22].

Recent studies have demonstrated the efficacy and safety of posterior-only treatment for spinal deformities. Lehman et al. [23] reported on 114 cases of adolescent idiopathic scoliosis treated with pedicle screw constructs via a posterior-only approach. They showed significant curve corrections can be obtained and that those corrections were maintained at a minimum of 3 years with a low incidence of complications. Koptan et al. [9] compared posterior-only pedicle screw-based constructs with two-stage hybrid constructs for the treatment of Scheuermann's kyphosis in

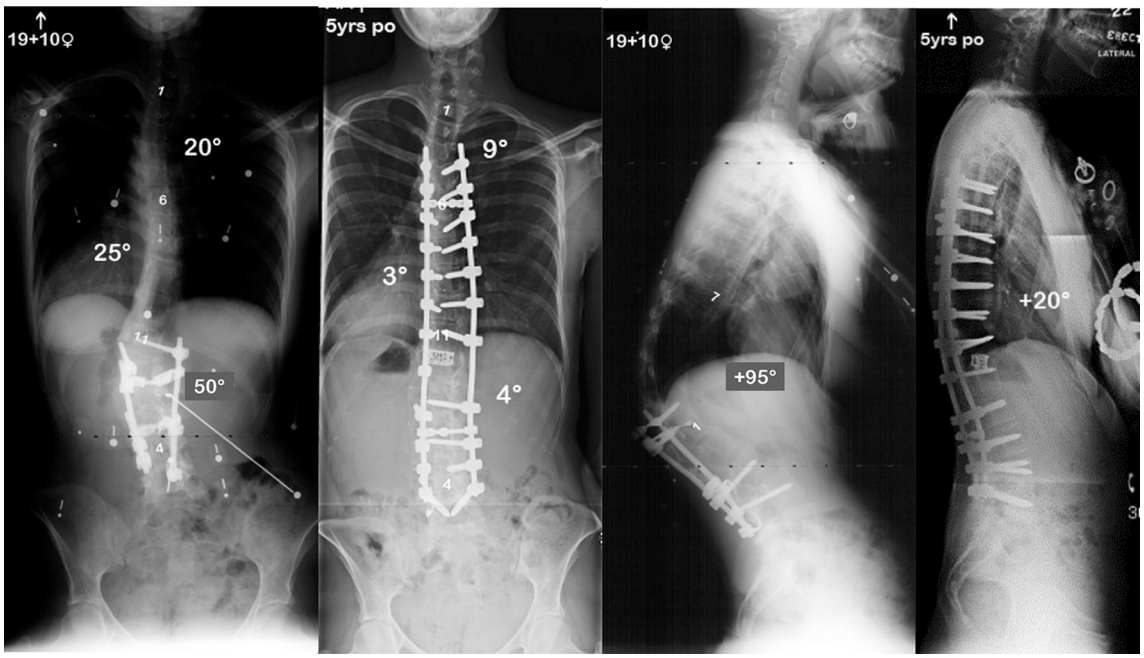

Fig. 7 Comparison pre- and postoperative X-rays s/p a T12 VCR and PSF from T5–L5 showing restoration of normal alignment maintained 5 years after surgery

Table 1 Demographic and radiographic data

Pt.	Age (years)	Sex	Diagnosis	F/U (years)	Osteotomy	Preoperative maximum kyphosis (°)	Initial PO maximum kyphosis (°)	Final PO maximum kyphosis (°)	% Correction	Loss of correction (°)	Complications
1	15	F	Idiopathic	5.3	PCO, VCR	152	52	52	66	0	Tongue swelling
2	27	F	Iatrogenic	5	PCO, VCR	97	52	55	46	3	
3	17	M	SK	5	PCO	132	47	46	64	−1	
4	15	F	SK	5	PCO	94	56	56	40	0	PJK
5	18	F	Idiopathic	5	VCR	90	39	37	57	−2	
6	17	F	SK	5	PCO, VCR	140	26	30	81	4	
7	17	M	SK	5	None	101	71	72	30	1	
8	29	M	SK	5	PCO	88	51	51	42	0	
9	16	M	SK	5	PCO	91	64	64	30	0	Screw pullout
10	67	F	Pseudarthrosis	5.1	None	71	57	57	20	0	
11	15	M	SK	5.3	PCO	102	46	47	55	1	Neuromonitoring signal loss
12	58	F	Idiopathic	5	PCO, VCR	109	40	37	63	−3	
13	45	F	SK	5.3	PCO	75	64	66	15	2	
14	74	M	Post-traumatic	5	PCO	129	69	67	47	−2	
15	17	F	SK	9.3	PCO, VCR	92	49	50	47	1	PJK
16	14	M	SK	5.2	PCO, VCR	65	50	50	23	0	
17	54	F	Idiopathic	5	PCO	85	55	55	35	0	PJK
18	77	F	Post-traumatic	5	VCR	74	46	47	38	0	
19	19	F	Iatrogenic	5	PCO, VCR	89	31	31	65	0	
20	60	F	Iatrogenic	5	PCO, VCR	88	36	36	59	0	
21	17	F	SK	5.2	None	83	57	58	31	1	UTI
22	44	M	Idiopathic	5.3	None	81	60	60	26	0	
23	52	F	Pseudarthrosis	5	PCO, VCR	82	36	34	56	−2	
24	50	F	Pseudarthrosis	5	PCO, VCR	92	41	31	55	−10	Pleural effusion
25	13	M	SK	5.4	PCO, VCR	76	4	3	95	−1	
26	13	F	Pseudarthrosis	6.1	PCO, VCR	115	61	65	47	4	Resp. distress
27	42	F	Idiopathic	5	PCO	109	63	63	42	0	
28	13	F	Idiopathic	5.1	PCO, VCR	95	37	42	61	5	
29	17	M	Congenital	5	PCO, VCR	91	78	69	14	−9	Pleural effusion
30	71	F	Degenerative	5.3	PCO	100	37	41	63	4	
31	50	F	Idiopathic	5	PCO	75	63	65	16	−2	
32	20	M	Congenital	5	PCO, VCR	65	19	20	71	1	
33	15	F	SK	9.7	None	71	34	45	52	11	
34	29	F	Post-traumatic	12.2	PCO	80	31	35	61	4	

Table 1 (continued)

Pt.	Age (years)	Sex	Diagnosis	F/U (years)	Osteotomy	Preoperative maximum kyphosis (°)	Initial PO maximum kyphosis (°)	Final PO maximum kyphosis (°)	% Correction	Loss of correction (°)	Complications
35	18	M	Pseudarthrosis	6.3	PCO, VCR	120	40	39	67	−1	
36	31	F	Iatrogenic	5.2	PCO, VCR	90	31	42	66	11	
37	53	F	Idiopathic	5.1	None	70	53	58	24	5	
38	34	F	Pseudarthrosis	9.3	PCO	100	51	49	49	−2	
39	68	F	Degenerative	5	PCO	90	38	52	58	14	
40	15	F	Idiopathic	5.4	PCO, VCR	112	96	91	14	5	
41	20	M	SK	5	PCO	70	43	50	39	7	
42	54	F	Degenerative	5.6	PCO	74	50	48	32	−2	
43	20	M	SK	6.7	Laminectomy	85	60	61	29	1	Temp. neurological deterioration

Pt. patient, *SK* Scheuermann's kyphosis, *F/U* follow-up, *PCO* posterior column osteotomy, *VCR* vertebral column resection, *PO* postoperative, *Resp.* respiratory, *Temp.* temporary

Table 2 Questionnaire results

	Preoperative	Postoperative	*p* value
ODI, average	37.8	20.6	0.01
SRS, average	3.23	4.02	< 0.001
SRS, pain	3.35	3.87	0.042
SRS, image	2.56	3.32	< 0.001
SRS, function	3.41	3.87	0.044
SRS, satisfaction	3.21	4.59	< 0.001
SRS, mental	3.64	4.08	0.025

ODI Oswestry Disability Index, *SRS* Scoliosis Research Society

33 patients. They found shorter operative time and lower amounts of blood loss in the posterior-only group, with larger, though not statistically different, corrections obtained and maintained in the posterior-only group at a minimum follow-up of 2 years. Similarly, Lee et al. [10] published their results of minimum 2-year follow-up on 14 posterior-only versus 16 anterior/posterior procedures to treat Scheuermann's kyphosis. They reported less blood loss, shorter operative times, and better maintenance of correction with the posterior-only pedicle screw constructs. They also reported a significantly lower incidence of complications in the posterior-only group versus the circumferentially fused patients. Geck et al. [8] discussed their results of pedicle screw-based, posterior-only procedures in the treatment of Scheuermann's kyphosis. They prospectively examined the results of Ponté osteotomies and pedicle screw fixation in the treatment of 17 patients. The posterior-only group fared as well as anterior/posterior historical controls and demonstrated excellent correction without significant loss of correction at minimum 2-year follow-up. They concluded that pedicle screw constructs via a posterior-only approach avoided the morbidity and extended operative time attributed to anterior approaches.

In order for posterior-only surgery to be recommended as a standard procedure, its results must compare favorably to those of the anterior/posterior procedure, and correction should be durable. In the previous studies, posterior-only procedures have largely shown higher correction rates compared with anteroposterior surgery. Although most of the studies were about Scheuermann's kyphosis and the selection criteria for each group were not well defined, correction rates for posterior-only surgery have been reported to range from 46 to 54%, while correction rates for anteroposterior surgery were less than 50% [7–10, 13, 15]. In terms of correction magnitude, the results from our study were comparable to those of the previous studies despite the inclusion of all types of kyphosis. Nonetheless, there is a paucity in the literature regarding whether posterior-only correction can be maintained long term over several decades. Given the eventual widespread adoption of this technique, the results

of posterior-only procedures with pedicle screw instrumentation for the treatment of thoracic and thoracolumbar kyphosis at a minimum 5-year follow-up have not yet been reported. Concerns about loss of correction and pseudarthrosis persist, but our findings demonstrate that these constructs are able to maintain the substantial corrections initially obtained.

It is very important to handle the soft tissues and bony/ligamentous structures at the cephalad end of any construct very carefully to avoid PJK. Thus, we strive to minimize any tissue disruption at the cephalad end of our constructs by minimizing superior facet exposure and avoiding any ligamentous disruption as well.

Reports on TK/TLK have mostly concentrated on Scheuermann's kyphosis. Although inclusion of all ages and types of thoracic and thoracolumbar kyphosis may be an advantage of this study, its heterogeneity may limit the application of our results to any particular diagnosis or case. Our study is also limited by the availability of complete HRQOL data. Good results were observed for those patients completing the outcomes questionnaires, though we may overestimate the benefits and durability of surgery in those patients that failed to return for follow-up. Being a tertiary referral center with a reputation for complex deformity, a significant portion of our patients come from more than 100 miles away and we feel that 51% follow-up at 5-year postoperative is acceptable understanding the geographic limitations. Finally, our study is limited by the wide-ranging doses of BMP used, with five patients receiving ≥ 144 mg. As the appropriate dose remains unknown, it is important to note that good results were seen in those patients receiving a smaller dose or no BMP.

Conclusion

Pedicle screw constructs allow substantial posterior-only correction of TK/TLK with maintenance of correction at a minimum of 5-years postoperative. Posterior-based osteotomies were utilized commonly in this series (37/43, 86%) and contributed to the improved correction seen. Patient-reported outcomes were significantly improved in these patients. Given the relatively low incidence of complications, posterior-only surgery for TK/TLK has proven to be a valuable tool in reducing the morbidity associated with anterior spinal procedures.

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Compliance with ethical standards

Conflict of interest The authors declare that they have no competing interests.

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