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Original Article

Revision surgery outcomes of proximal junctional failure in surgically treated patients with posterior long instrumented spinal fusion

Hui Wang*, Lei Ma*, Dalong Yang*, Rui Xue*, Tao Wang*, Sidong Yang, Wenyuan Ding

*Department of Spine Surgery, Third Hospital of Hebei Medical University, Shijiazhuang, China. *Equal contributors.*

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Abstract: Objective: The purpose of this study was to identify the revision surgery outcome of fusion extensions proximally and anterior reconstruction for proximal junctional failure in surgically treated patients with long instrumented posterior spinal fusion. Method: 286 consecutive patients treated at a single institution were enrolled in this study, patients with PJF at follow up and received revision surgery (fusion extensions proximally and anterior reconstruction) were enrolled as PJF group, patients without PJF at follow up were enrolled as N-PJF group. Age, sex, body mass index (BMI), comorbidities, bone mineral density (BMD), pre- and postoperative sagittal spino-pelvic parameters were investigated. Clinical outcomes were evaluated by Oswestry Disability Index (ODI) at time points of preoperative, before revision surgery and final follow up. Results: Seventeen patients (5.9%) developed PJF and received revision surgery. There was statistically significant difference between the two groups in BMI (P<0.01) and BMD (P<0.01). No significant differences were detected in age (P=0.0.53), sex (P=0.0.21), pre- and immediate post-operative sagittal spino-pelvic parameters between the two groups. The lower instrumented vertebrae including the sacrum was more common in PJF group than that in N-PJF group (P<0.01). There was no statistically significant difference between the two groups in preoperative ODI (*P*=0.74). The PJF patients experienced significant ODI increase before revision surgery and ODI decrease at final follow up when compared to the preoperative data. The ODI decrease from preoperative to the final follow up demonstrate significant difference between the two groups in favor of N-PJF group (*P*<0.01). Conclusions: The revision strategy of fusion extensions proximally combined with anterior reconstruction can effectively alleviate pain and improve neurological function for PJF patients, the overall surgical outcome at final follow up is better than preoperative data, but less than N-PJF patients.

Keywords: Revision surgery outcomes, proximal junctional failure, long instrumented posterior spinal fusion

Introduction

Proximal junctional failure (PJF) is a recognized complication followed by long-segment instrumentation for correction of spinal deformity [1, 2]. The incidence of PJF varied from 1.4% to 35%, depending on the study population, the duration of follow-up, and the differences in the diagnostic criteria for PJF [3-6]. It is distinct from proximal junctional kyphosis (PJK), in that it always include both kyphosis and structural failure of the vertebral body [7]. Fracture was indicated as the most common mechanism of PJF (56%), followed by soft-tissue failure (35%), and screw pullout (9%) [8-10]. The PJF patients always present severe anterior column defect derived from the uppermost instrumented vertebrae (UIV) or UIV+1 fracture, and the subsequent angular kyphotic deformity, may carry a significantly high risk of spinal cord injury, pain, spinal instability, ambulatory difficulty, and inability to maintain horizontal gaze [11-15]. Although some PJF patients may be successfully followed without surgical intervention, there is a close relationship between progression of PJF and a need for revision surgery, since PJF has a strong possibility of neurological deficit [16].

Previous studies mainly focus on the pathology, radiographical characteristics and risk factors of PJF, little is mentioned on the revision surgery strategy and the outcomes of revision surgery for PJF. The purpose of this study is there-

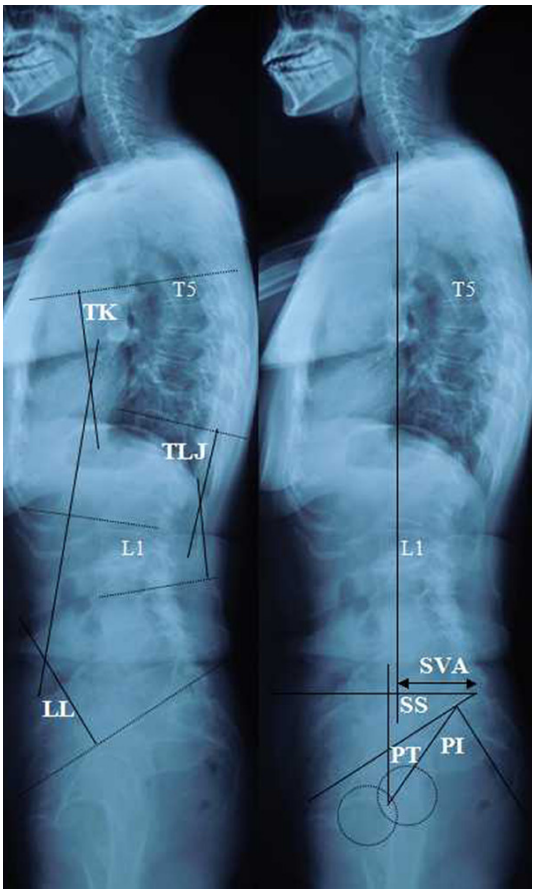

Figure 1. Sagittal spinal parameters including lumbar lordosis (LL), thoracic kyphosis (TK), thoracolumbar junction (TLJ) were measured in each whole spine lateral view. Sagittal pelvic parameters including pelvic incidence (PI), sacral slope (SS), pelvic tilt (PT) and sagittal vertical axis (SVA) were measured in each whole spine lateral view.

fore to identify the characteristics and revision surgery outcomes of proximal junctional failure in surgically treated patients with long instrumented posterior spinal fusion.

Materials and methods

Patients

This is a prospective review of 286 consecutive patients treated at a single institution between 2005 and 2013 who met both the inclusion and exclusion criteria. The study was approved by the Institutional Review Board of the Third Hospital of Hebei Medical University before data collection and analysis. The inclusion criteria include: 1. Patients who were treated with posterior instrumented spinal fusion at a minimum of 5-motion segments. 2. Complete radiographic data include pre-operation, early post-operation and final follow up antero-posterior (A/P) and lateral standing 36 inch long cassette radiographs of the whole spine. 3. The endplates at the proximal junction could be clearly visible for measurement. The exclusion criteria include: 1. Congenital or idiopathic scoliosis. 2. Thoracolumbar or lumbar kyphosis caused by spinal fracture, tumor, or tuberculosis. 3. Intervertebral disc inflammation, diffuse idiopathic skeletal hyperostosis, brucellic disease. There were 65 male and 221 female, with mean age of 51.8 years (rang from 40 to 69). The diagnosis was DLS in 65 patients, and multi-level LDH in 221 patients.

Radiological and clinical evaluation

Radiographic measurements were done in PACS (Picture Archiving Communications System). On the lateral radiographs, the sagittal vertical axis (SVA) was measured as the distance from the C7 plumb line to the perpendicular line drawn from the superior posterior endplate of the S1 vertebral body. Thoracic kyphosis (TK) was measured from the upper endplate of T5 to the lower endplate of T12. Lumbar lordosis (LL) was measured from the upper endplate of L1 to the upper endplate of S1. The pelvic incidence (PI) was measured from the angle subtended by a perpendicular line from the cephalad endplate of S1 and a line connecting the center of the femoral head to the center of the cephalad endplate of S1. Sacral slope (SS) was the angle between the S1 superior endplate and a horizontal line. Pelvic tilt (PT) was defined as the angle between a vertical line originating at the center of bi-coxofemoral axis and a line drawn between the same point and the middle of the superior endplate of S1 (**Figure 1**). The proximal junctional (PJ) angle was determined as the Cobb angle between the two level cephalad endplates to the upper instrumentation vertebrae (UIV) and the caudal endplate of the UIV (**Figure 2**). PJF was identified based on 10° post-operative PJ angle increase, along with fracture of the vertebral body of UIV or UIV+1 [7].

Patients with PJF at follow up period and received revision surgery were enrolled as PJF group, patients without PJF at follow up were enrolled as N-PJF group. Age, sex, body mass index (BMI, weight [kg]/height^2 [m^2]), comorbidities, bone mineral density (BMD), UIV loca-

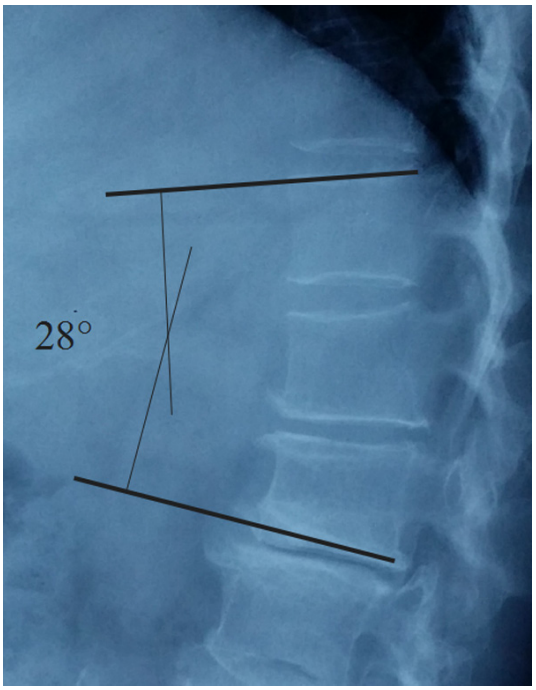

Figure 2. The proximal junctional (PJ) angle measurement.

tion, fusion to sacrum, complications were investigated. Clinical outcomes were evaluated by Oswestry Disability Index (ODI), which contains ten topics concerning intensity of pain, lifting, ability to care for oneself, ability to walk, ability to sit, sexual function, ability to stand, social life, sleep quality, and ability to travel.

Revision surgery technique

The indication of the revision surgery for PJF was the patients who have disabling back and/or leg pain, spinal imbalance and failed all reasonable conservative treatment for at least 3 months. All revision surgeries were performed by the same surgery team under general anesthesia. A standard posterior exposure of the spine was given, covering the previous surgical incision and three levels above the UIV. The pedicle screws within L5, S1 and UIV were taken out after remove the rods, pedicle screws were inserted three levels above the UIV, a temporary stabilizing rod contoured to the shape of the deformity was placed on one side. Careful subperiosteal dissection was carried out on contra-lateral side (opposite to the stabilizing rod) to follow the lateral wall of the UIV vertebral body until the anterior aspect was reached, the disc above the UIV was resected and followed by resection of upper part of the UIV and lower part of the UIV+1. Then the stabilizing rod was replaced by rods precontoured to the desired (corrected) contour, and a mesh cage was placed within the intervertebral space to act as anterior construct. Adequate hemostasis was ensured and wound was thoroughly irrigated with saline, the surgical wound was closed layer-by-layer. (Case see **Figure 3**).

Statistical analysis

Data were analyzed using Statistical Product and Service Solutions software (version 13; SPSS, Chicago, IL), *p* values are based on the Student t test for continuous variables. χ^2 tests were used on ordinal and nominal data when more than 5 observations were expected in each category, and Fisher exact tests were used on ordinal and nominal data when fewer than 5 observations were expected in each category. A $P<0.05$ with a confidence interval of 95% was considered significant.

Results

Characteristics of PJF in surgically treated patients with posterior long instrumented fusion

Among 286 patients treated with posterior long-instrumented spinal fusion, 17 patients (5.9%) developed PJF (2 males and 15 females) and received revision surgery. The mean PJ angle was 22.7±5.4° at the time PJF was identified. The mean time to PJF from the surgery was 13.2±1.7 months (range, 8-17 months), 10 patients (58.8%) showed PJF within 1 year postoperatively. The PJF symptoms consisted of intolerable back pain (n=13), neurological deficits (n=4). The instrumentation consisted of posterior pedicle screw constructs in all patients. Fourteen patients were osteopenic; 3 patients had normal bone mineral density, and no patients were osteoporotic. Six patients were considered obese (BMI>30 kg/m^2), no patients were underweight (BMI<18.5 kg/m^2).

There were no statistically significant difference between the two groups in age at operation (P=0.0.53), sex (P=0.0.21). The mean BMI of the PJF group was (27.7±2.1) kg/m^2, and the N-PJF group's was (24.0±3.7) kg/m^2, there was statistically significant difference between the two groups (P<0.01). The mean BMD of the PJF group was (-1.6±0.5) g/cm^2, and the N-PJF group's was (-0.8±0.4) g/cm^2, there was also

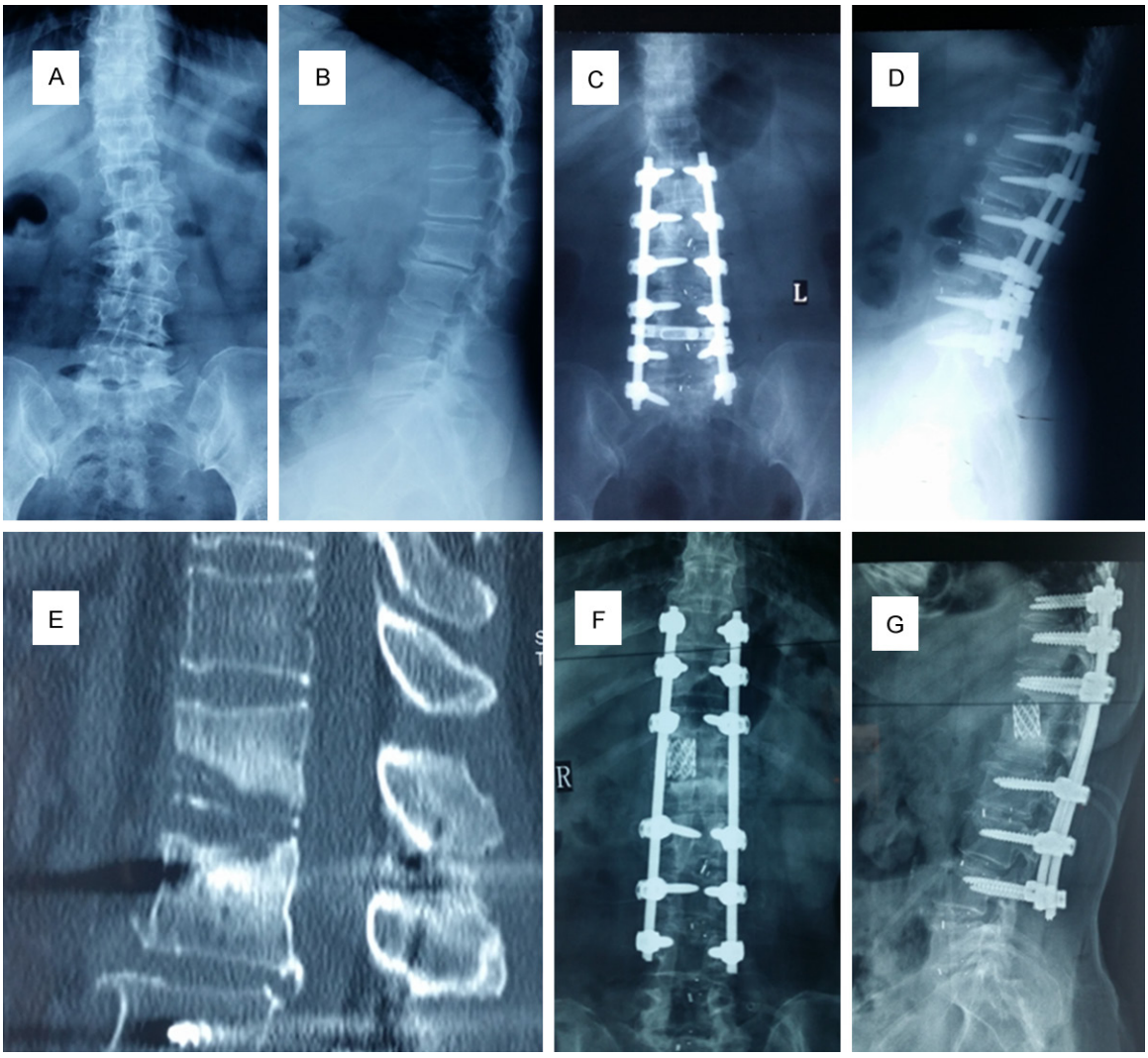

Figure 3. Serial radiographs with preoperative, initial postoperative X-ray, the PJ angle increased from 5.8 degrees preoperative to 9.6 degrees in immediate post operation. (A-D) The sagittal plane CT showed both UIV and UIV+1 vertebral fracture before revision surgery. (E) X-ray at final follow up indicated that intervertebral fusion of L4-5 or L5-S1 have been achieved, the pedicle screws within L5, S1 and L1 were taken out, pedicle screws were inserted within T10, T11, T12. The T12-L1 disc, upper part of the UIV and lower part of the UIV+1 were resected and a mesh cage was placed to reconstruct the anterior column (F, G).

statistically significant difference between the two groups (P<0.01) (**Table 1**). No significant differences were detected in preoperative and immediate post-operative sagittal spino-pelvic parameters between the two groups (**Table 2**). The lower instrumented vertebrae including the sacrum was more common in PJF group than that in Non-PJF group (*P*<0.01) (**Table 3**).

Surgical outcome of PJF in surgically treated patients with posterior long instrumented fusion

In the PJF group, the mean duration from revision surgery to the final follow up was 18.8±3.1 months (range, 12-26 months), no patient had additional PJK/PJF at the new UIV or required additional revision surgical procedures at the final follow up. In the N-PJF group, the mean follow up duration was 26.3±6.2 months. The PJF patients experienced significant ODI increase before revision surgery (67.9%±9.8%, *P*<0.01) and ODI decrease at final follow up (17.5%±4.8%, *P*<0.01) when compared to the preoperative data (48.4%±9.1%) (**Table 4**). There was no statistically significant difference between the two groups in preoperative ODI (48.4%±9.1% in PJF group vs. 51.2%±11.3% in N-PJF group, *P*=0.74). Although both the two groups got sig-

Table 1. Comparison of age, sex, BMI, BMD, comorbidities and diagnosis between two groups

	PJF (n=17)	N-PJF (n=269)	*P* value
Age	53.5±4.7	51.3±5.2	*P*=0.53
Sex (M/F)	2/15	63/206	*P*=0.21
BMI (kg/m^2)	27.7±2.1	24.0±3.7	*P*<0.01
BMD (g/cm^2)	-1.6±0.5	-0.8±0.4	*P*<0.01
Comorbidities			
Hyper-tension	3	57	*P*=0.51
Diabetes	4	41	*P*=0.27
COPD	1	15	*P*=0.64
Diagnosis			
Multi-level lumbar disc herniation	12	209	*P*=0.49
Degenerative lumbar scoliosis	5	60	

Table 2. Comparison of preoperative sagittal spino-pelvic parameters between the two groups

	PJF (n=17)	N-PJF (n=269)	*P* value
PJA	3.1±0.5	2.9±0.9	*P*=0.79
TK	17.6±2.8	19.2±3.2	*P*=0.73
TLJ	7.6±1.1	8.1±2.4	*P*=0.67
LL	18.6±2.7	20.6±5.3	*P*=0.63
SVA	4.5±0.4	3.8±0.9	*P*=0.31
PI	48.6±6.2	51.2±9.1	*P*=0.70
PT	22.7±4.7	21.2±6.5	*P*=0.83
SS	26.4±4.3	29.6±6.4	*P*=0.53

nificant ODI decrease at final follow up when compared to the preoperative data, the ODI decrease demonstrate significant difference between the two groups in favor of N-PJF group at final follow up (30.7%±8.8% vs. 42.9%± 13.6%, *P*<0.01) (**Table 5**).

Discussion

In the current study, the majority of patients got significant pain relief and neurological status improvement at final follow up. However, 5.9% of the patients are found to be PJF at mean duration of 13.2 months postoperatively.

Our study demonstrated that low mineral density, obesity and lower instrumented vertebrae including the sacrum are possible risk factors for PJF, which is consistent with previous literature. It has been confirmed that BMI is a risk factor for adjacent segment disease in patients undergoing lumbar fusion for degenerative spine diseases [17]. Osteopenic is characterized by the reduction of the bone mass and the modification of the bone architecture, and increases the risk of vertebral fracture. Rigid segmental pedicle screw constructs including the sacrum would result in a concentration of mechanical stress on the UIV or un-fused adjacent segments, then leading to the vertebrae fracture of UIV or UIV+1 [13]. Therefore, controlling body weight and increasing the bone density before and after surgery, as well as preventing lower instrumented vertebrae to be sacrum may provide opportunities to reduce the incidence of PJF and to improve therapeutic outcomes.

Currently, instrumentation extensions to a more proximal level is the main surgical option for PJF patients, and several studies have reported the neurological improvement and pain relief after revision surgery. In a series of 23 patients with PJF, all patients underwent revisions with fusion extensions to a more proximal thoracic level, and the neurological status improved from 5 in Frankel C and 1 in Frankel B preoperatively to 1 in Frankel C, 4 in Frankel D, and 1 in Frankel E at the final follow-up [5]. However, fusion extensions without intervention to the anterior structural failure may not be the proper revision strategy for PJF. On the one hand, the kyphotic deformity could not be effectively corrected due to the incomplete release of spinal structure after posterior instrumentation. On the other hand, the anterior reconstruction by cage or titanium is critical for preventing implant failure, long term stability and overall surgical outcome. Therefore, both fusion extensions proximally and anterior reconstruction are of the same importance in the revision surgery for PJF.

In the current study, the key steps of the revision strategy for PJF are summarized as follows: First, the pedicle screws within L5, S1 and UIV were taken out after remove the rods, pedicle screws were inserted three levels above the UIV, since intervertebral fusion of L4-5 or L5-S1 have been achieved in all the PJF patients before revision surgery, without need for the

Table 3. Comparison of immediate post-operative sagittal spino-pelvic parameters between the two groups

	PJF (n=17)	N-PJF (n=269)	*P* value
PJA	3.4±0.7	3.3±0.8	*P*=0.81
TK	18.9±2.5	19.7±3.0	*P*=0.84
TLJ	7.0±0.8	7.5±1.3	*P*=0.69
LL	22.8±3.4	25.8±4.9	*P*=0.36
SVA	4.0±0.5	3.5±0.7	*P*=0.47
PI	48.3±6.5	52.0±10.3	*P*=0.42
PT	17.2±5.0	15.7±5.8	*P*=0.50
SS	30.8±5.2	36.5±2.3	*P*=0.25
Upper instrumented vertebrae			
Above T10	5	46	*P*=0.70
T11-L1	10	213	
Below L2	2	10	
Lower instrumented vertebrae			
Above L5	2	153	*P*<0.01
S1	15	116	

Table 4. The ODI change from preoperative to final follow up in PJF group (%)

	Preoperative	Before revision surgery	Final follow up
Pain	3.3±0.4	4.2±0.4	1.5±0.3
Lifting	3.0±0.3	3.2±0.4	0.9±0.1
Ability to care for oneself	2.3±0.2	3.0±0.3	0.8±0.1
Ability to walk	3.1±0.4	3.5±0.5	0.6±0.1
Ability to sit	1.5±0.2	2.8±0.4	0.5±0.1
Sexual function	1.2±0.1	3.0±0.3	0.5±0.1
Ability to stand	1.6±0.2	2.9±0.4	0.6±0.1
Social life	2.0±0.3	3.8±0.6	0.8±0.1
Sleep quality	3.2±0.3	3.6±0.5	0.7±0.1
Ability to travel	2.8±0.3	3.8±0.4	1.2±0.1
Overall	48.4±9.1	67.9±9.8	17.5±4.8

Table 5. Comparison of ODI from preoperative to final follow up between two groups (%)

	PJF	N-PJF	*P* value
Preoperative	48.4±9.1	51.2±11.3	*P*=0.74
Beforre revision surgery	67.9±9.8	-	
Final follow up	17.5±4.8	8.7±2.5	*P*<0.01

instrumentation (**Figure 3**). Second, a temporary stabilizing rod contoured to the shape of the deformity was placed on one side, covering the pedicle screws three levels above the UIV and providing stability in the revision procedure. Third, the disc between the UIV and UIV +1 was resected and followed by resection of upper part of the UIV and lower part of the UIV+1. Fourth, a mesh cage with an autograft inside is inserted into the intervertebral gap to act as a hinge for closing the wedge and also to provide solid anterior reconstruct. The purpose of decompressing the spinal cord, correcting the local kyphosis and anterior reconstruction can be achieved through fusion extensions proximally combined with anterior reconstruction.

Pain is one of the main surgical indications for PJF, and it may be caused by the fractured vertebrae, the degenerated disc, or paraspinal muscle fatigue due to the local kyphosis [22]. In the current study, all the PJF patients realized obvious pain relief at final follow up when compared to that before revision surgery, without any surgery related complications. The other topics of ODI, concerning lifting, ability to care for oneself, ability to walk, ability to sit, sexual function, ability to stand, social life, sleep quality, and ability to travel were confirmed to improve at final follow up when compared to both preoperative and before revision surgery, indicating that fusion extensions proximally combined with anterior reconstruction is an effective and safe revision strategy for PJF. It is recognized that further PJF was a commonly occurred event after the revision surgery. In a study by Mitsuru Yagi [5], 23 PJF patients underwent revisions with fusion extensions to a more proximal thoracic level, 11 patients had additional PJK/PJF at the new UIV, and 9 patients required additional revision surgical procedures. In the current study, we did not find any additional PJK/PJF at the new UIV after revision surgery for PJF, and the possible reason may be that the pedicle screws within L5 and S1 were taken out in the revision surgery. As we have mentioned above, rigid segmental pedicle screw constructs including the sacrum will lead to a concentration of mechanical stress on the UIV or un-fused adjacent seg-

ments, then followed by the vertebrae fracture of UIV or UIV+1 and the additional PJK/PJF.

There are some limitations to this study. First, this was a single-center study and only 17 of the 286 patients (5.9%) developed PJF, only degenerative lumbar scoliosis and multi-level lumbar disc herniation patients were enrolled in this study, the mean duration from revision surgery to the final follow up was 18.8 months, selection bias may exist and long term follow up is required. Second, all the PJF patients received revision strategy of fusion extensions proximally combined with anterior reconstruction in this study, no patient received fusion extensions to a more proximal level only, no comparison can be made between the two techniques. However, we report the first prospective study to evaluate revision surgery outcomes of proximal junctional failure in surgically treated patients with posterior long instrumented spinal fusion, and confirm that the revision strategy of fusion extensions proximally combined with anterior reconstruction can effectively alleviate pain and improve neurological function for PJF patients, the overall surgical outcome at final follow up is better than preoperative data, but less than N-PJF patients. Moreover, controlling body weight, increasing the bone density, and preventing lower instrumented vertebrae including sacrum may be helpful to prevent PJF.

Disclosure of conflict of interest

None.

Address correspondence to: Wenyuan Ding, Department of Spine Surgery, Third Hospital of Hebei Medical University, Shijiazhuang, China. E-mail: dingwenyuan2012@126.com

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