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Clinical Study

The impact of surgical reduction of high-grade lumbosacral spondylolisthesis on proximal femoral angle and quality of life

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Abstract

BACKGOUND CONTEXT: Abnormal proximal femoral angle (PFA) was recently found to be associated with deteriorating sagittal balance and quality of life (QoL) in high-grade spondylolisthesis (HGS). However, the influence of PFA on the QoL of patients undergoing surgery remains unknown.

PURPOSE: This study compares the pre- and postoperative measurements of sagittal balance including PFA in patients with lumbosacral HGS after surgery. It also determines if PFA is a radiographic parameter that is associated with QoL in patients undergoing surgery.

STUDY DESIGN: Retrospective cohort study.

PATIENT SAMPLE: Thirty-three patients (mean age 15.6 ± 3.0 years) operated for L5-S1 HGS between July 2002 and April 2015. Thirteen had in situ fusion and 20 had reduction to a low-grade slip.

OUTCOME MEASURES: The outcome measures included PFA and QoL scores measured from the Scoliosis Research Society SRS-30 QoL questionnaire.

METHODS: The minimum follow-up was 2 years. PFA and QoL were compared pre- and postoperatively. Statistical analysis used nonparametric Mann-Whitney and Wilcoxon Signed Rank tests, Chi-square tests to compare proportions, and bivariate correlations with Spearman's coefficients.

RESULTS: A decreasing PFA correlated with less pain ($r = -0.56$, $p = .010$), improved function ($r = -0.51$, $p = .022$) and better self-image ($r = -0.46$, $p = .044$) postreduction. Reduction decreased PFA by 5.1° ($p = .002$), whereas in situ fusion did not alter PFA significantly. Patients with normal preoperative PFA had similar postoperative QoL regardless of the type of surgery, except for self-image, which improved further with reduction (3.73 ± 0.49 to 4.26 ± 0.58, $p = .015$). Patients with abnormal preoperative PFA tended to have a higher QoL in all domains after reduction.

CONCLUSION: Decreasing PFA correlates with less pain, better function and self-image. Reduction of HGS decreases PFA. Reduction also relates to a better postoperative QoL when the

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preoperative PFA is abnormal. When the preoperative PFA is normal, in situ fusion is equivalent to reduction except for self-image, which is better improved after reduction.

Keywords: In situ fusion; Lower extremity parameters; Pelvic parameters; Proximal femoral angle; Quality of life; Reduction; Sagittal balance; Spinal deformity; Spondylolisthesis.

Introduction

High-grade spondylolisthesis (HGS) can be a major cause of impairment of sagittal balance and posture [1]. It most frequently occurs at L5-S1 and can be associated with an abnormally high lumbar lordosis and lumbosacral kyphosis [2]. For young patients, previous studies have mainly focused on the sagittal alignment of the spine and pelvis [3]. In particular, the Spinal Deformity Study Group (SDSG) has developed a classification of developmental lumbosacral spondylolisthesis in which children, adolescents, and young adults with HGS are classified based on a balanced and/or unbalanced pelvis and spine [4,5]. Type IV patients have a balanced pelvis, whereas Type V and VI patients have an unbalanced pelvis according to the nomogram provided by Hresko et al. [6]. Type V and type VI patients refer to a balanced or unbalanced spine respectively, where the C7 plumb line falls behind or in front of the hip axis, respectively. Type V is further subclassified into A or B, according to the severity of the lumbosacral kyphosis angle (LSA).

However, the sagittal alignment of the lower extremities remains poorly documented in these patients, although it is well known that gait abnormalities and contractures of lower extremities are frequently observed on physical examination [7,8]. Different authors have suggested that evaluating the sagittal alignment of the lower extremities in patients with spinal pathologies is important in order to assess the compensatory mechanisms from the lower extremities that can further lead to additional postural or degenerative problems [9–12]. In particular, few studies have reported about hip flexion among other gait changes in a small number of adolescents with HGS treated surgically [8,13].

The proximal femoral angle (PFA, Fig. 1) was recently shown to be increased in patients with HGS [14]. The PFA is measured from lateral standing radiographs of the spine and pelvis typically obtained for evaluating HGS. It is positive when the proximal femur tilt is anterior with respect to the vertical line distally; it is negative when the proximal femur tilt is posterior. The PFA measurement is associated with excellent intra-rater and inter-rater reliability [14]. Moreover, PFA $\geq +10^{\circ}$ was considered abnormal, and has been associated with deteriorating sagittal balance and quality of life (QoL) [14]. Nevertheless, the influence of PFA on the QoL of patients undergoing surgery remains unknown.

This study compares the pre- and postoperative measurements of sagittal balance including PFA in patients with lumbosacral HGS with a minimum 2-year-follow-up after surgery. It also determines if PFA is a radiographic parameter that is associated with QoL in this population. Finally, this study examines the impact of surgical reduction on QoL in relationship with the PFA.

Material and methods

Patient selection

A retrospective study of a prospective cohort of 33 patients operated for lumbosacral HGS at a single pediatric hospital between July 2002 and April 2015 was performed. The study has been approved by the institutional review board. The inclusion criteria for the HGS group were: (1) presence of a HGS at

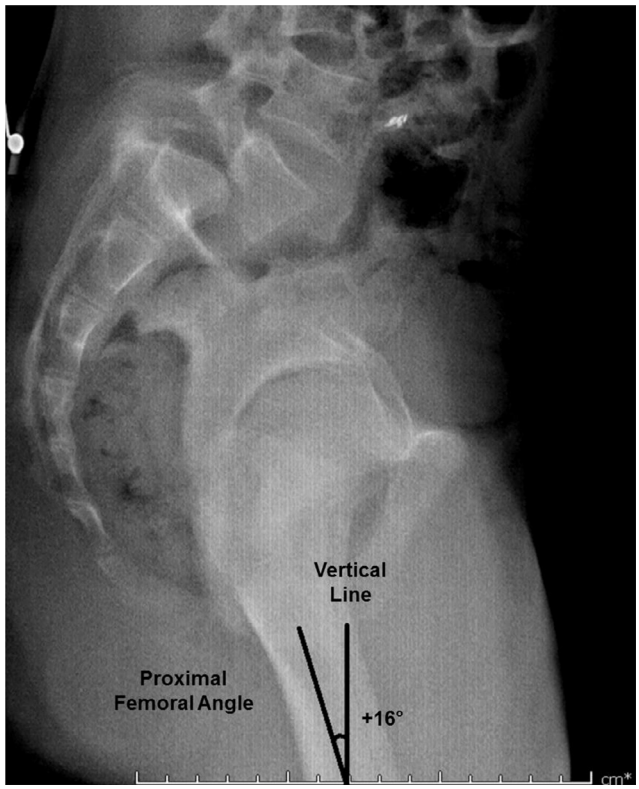

Fig. 1. Measurement of proximal femoral angle (PFA) for each femur. A positive PFA indicates an anterior tilt of the proximal femur with respect to the vertical line distally, whereas a negative PFA indicates a posterior tilt. A PFA $\geq +10^{\circ}$ is abnormal.

L5-S1 with a slip percentage greater than 50%, as measured from the technique described by Bourassa-Moreau et al. [15], (2) age at surgery less than 25 years, (3) availability of a standing lateral radiograph showing the spine, pelvis, and proximal femurs before surgery and at last follow-up, (4) availability of QoL measures before surgery and at last follow-up, (5) absence of previous spine, pelvic or lower extremity surgery, and (6) minimum follow-up of 2 years after surgery.

Initially, 37 patients were identified from the prospective database of patients operated for HGS. However, after reviewing the radiographs, 4 patients with HGS at L4-L5 were excluded. Therefore, the study cohort consisted of 33 subjects (24 females and 9 males) aged 15.6 ± 3.0 years (range 7.9–23.9 years). The mean follow-up was 4.7 ± 1.7 years (range 2–7.4 years). All included subjects had available assessment of their pre- and postoperative QoL using the Scoliosis Research Society (SRS)–30 questionnaire.

Surgical intervention

In this cohort, 20 patients were referred as the reduction group and 13 were referred as the in situ fusion group.

Reduction group

Reduction surgery aimed at achieving a low-grade spondylolisthesis with a slip percentage less than 50%. After a standard posterior approach, pedicle screw fixation at L5 and S1 (and occasionally at L4 and/or the ilium) was obtained. Gill laminectomy at L5 and bilateral L5-S1 foraminotomies were performed in all 20 cases. Progressive reduction was performed until reaching a low-grade slip. Then, L5-S1 discectomy and preparation of the endplates were done for unilateral transforaminal interbody fusion with a polyetheretherketone cage filled with autograft. The cage was aimed centrally over the S1 superior endplate, making sure that the anterior border of the cage is aligned with the anterior border of S1 superior endplate whereas the posterior border of the cage is 4–5 mm anterior to the thecal sac and fully in contact with L5 inferior endplate and S1 superior endplate. Transforaminal interbody fusion was not possible in only one case, where the disc space was too narrow for a cage to be inserted safely. Iliac crest bone marrow mixed with calcium triphosphate granules and local bone graft were routinely placed posterolaterally to achieve solid fusion after decortication of transverse processes and upper sacral alae. Instrumented fusion at L5-S1 was performed in 15 cases. In 4 cases, instrumented fusion was extended up to up L4, and in a single case from L4 to the ilium.

In situ fusion group

In this group, no additional maneuver was performed other than the prone positioning on the operating table with slight hip extension. Gill laminectomy at L5, bilateral L5-S1 foraminotomies, and posterolateral fusion using local and iliac autologous bone grafting were performed in all patients from L4 to S1. Pedicle screw fixation with rods was used in all 13 patients. Instrumentation was carried out from L4 to S1 for 10 patients and from L4 to the ilium in 3 patients.

Radiographic measurements

PFA was measured by a single observer from the orientation of the proximal femur with respect to the vertical line on long standing lateral radiographs as described by MacThiong et al. [14] (Figure 1). A positive PFA indicates an anterior tilt of the proximal femur with respect to the vertical line distally, whereas a negative PFA indicates a posterior tilt. The PFA value averaged between the right and left proximal femurs was considered in this study. A PFA $\geq +10^{\circ}$ was set as abnormal according to a previous study of the normal pediatric population [14].

The following radiographic parameters of sagittal spinopelvic balance were also assessed by a single observer from the lateral standing radiograph of the full spine and pelvis:

- Pelvic incidence (PI): Angle subtended by the line drawn from the hip axis (midpoint of the line connecting the centers of the femoral heads) to the midpoint of the sacral endplate, and a line perpendicular to the sacral endplate
- Sacral slope (SS): Angle subtended by the horizontal line and the sacral endplate line
- Pelvic tilt (PT): Angle subtended by the vertical line and the line drawn from the hip axis to the midpoint of the sacral endplate. It is positive when midpoint of sacral endplate is behind hip axis, and negative when midpoint of sacral endplate is in front of hip axis.
- Slip percentage (SLIP%): The percentage of translation of L5 with respect to S1 over the length of the sacral endplate as measured by Bourassa et al. [15], using a line perpendicular to the upper sacral endplate and transecting the posteroinferior corner of L5 vertebral body as the reference to determine the translation of L5 over S1.
- LSA: Angle subtended by a tangent to the posterior aspect of S1 and the L5 superior endplate line as described by Dubousset et al. [16]. This angle was found best to evaluate lumbosacral kyphosis for spondylolisthesis when to compared with five other methods [17] and in a recently published level III review by the SRS [18].
- Sagittal C7 plumbline: Vertical line drawn from the center of the vertebral body of C7.

Sagittal balance was characterized from the PI, SS and PT values, as well as from the spondylolisthesis type based on the SDSG classification [4,5]. In consequence, patients with HGS were categorized as follows:

- Type IV spondylolisthesis: high-grade slip with balanced pelvis
- Type V spondylolisthesis: high-grade slip with unbalanced pelvis and balanced spine
  - VA: with LSA $\geq 80^{\circ}$
  - VB: with LSA $< 80^{\circ}$ indicating severe kyphosis
- Type VI spondylolisthesis: high-grade slip with unbalanced pelvis and unbalanced spine

In order to determine pelvic balance from SS and PT values, the nomogram provided by Hresko et al. [6] is used.

Spinal balance is determined from the position of the C7 plumbline with respect to the hip axis. A C7 plumbline falling over or behind the hip axis refers to a balanced spine, whereas a C7 plumbline falling in front of the hip axis refers to an unbalanced spine.

Statistical analyses

In addition to descriptive statistics for the cohort group, direct comparisons using nonparametric Mann-Whitney *U* and Wilcoxon Signed Rank tests were performed, for paired and independent subgroups, respectively. Chi-square tests were used to compare proportions. Spearman's coefficients were used for bivariate correlations. In accordance to Cohen [19], statistically significant correlations were considered clinically strong if $r > 0.5$, moderate if $0.3 < r < 0.5$, and small if $r < 0.3$. Statistical analysis was executed using SPSS 24 software. A level of significance of 0.05 was used for all tests.

Results

Preoperative results

The average preoperative PFA in all HGS patients was 8.2° ± 6.0 (range −5° to 22°); it was 7.6° ± 6.5 (range −5° to 19°) for the reduction group, and 9.0° ± 5.5 (range 2° −22°) for the in situ fusion group. Using PFA ≥ +10° as a cut-off for defining abnormally increased PFA, 21 patients had normal PFA and 12 had abnormal PFA) preoperatively.

According to the SDSG classification, HGS was graded preoperatively as type VI in 15 patients, type V in 13 patients, and type VI in 5 patients. All 5 patients with type VI had concomitantly an abnormal PFA (Table 1).

The average preoperative PI, PT, SS, LSA and %SLIP in all HGS patients were 73.7° ± 11.4, 28.5° ± 11.5, 45.2° ± 11.6, 77.3° ± 19.5, and 80% ± 16, respectively. Interestingly, lower PFA correlated strongly with better self-image ($r = -0.56$, $p = .001$) and pain score ($r = -0.50$, $p = .003$) and moderately with higher total SRS-30 score ($r = -0.45$, $p = .009$).

Postoperative results

Reduction group

After reduction, there was a mean decrease in PFA by 5.1° ($p = .002$) (Table 2). The percentage of patients with normal PFA was significantly increased to 95% (19 of 20) postoperatively compared with 60% (12 of 20) preoperatively ($p = .008$). In parallel, there was an increase in SS (44.5° ± 10.2 to 49.5° ± 8.9, $p = .026$) and LSA (78.8° ± 21.3 to 96.2° ± 14.4, $p < 10^{-3}$), and a decrease in %SLIP (77% ± 17 to 29% ± 19, $p < 10^{-3}$). A tendency toward decreasing PT after surgery was also noted without reaching statistical significance (Table 3). The change in PFA correlated positively with the change in PT (r =0.52, $p = .020$) and negatively with the change in SS (r=−0.48, $p = .032$). In parallel, the change in PFA correlated strongly with a decrease in pain score (r=−0.56, $p = .010$), and furthermore a postoperative PFA correlated strongly with improved function (r=−0.51, $p = .022$) and moderately with a better self-image (r=-0.46, $p = .044$).

In situ fusion group

In contrast, there was no significant change in mean PFA after in situ fusion (Table 2). The proportion of patients with normal PFA remained stable after surgery (9 of 13 preoperatively vs. 10 of 13 postoperatively, $p = .658$). Similarly, PI, PT, SS, and %SLIP remained unchanged. Only LSA showed significant improvement after in situ fusion (75.1° ± 16.9 to 91.1° ± 19.3, $p = .005$). PFA correlated strongly with the change in PT ($r = 0.59$, $p = .035$) and the change in SS (r=-0.51, $p = .078$) but not with postoperative QoL.

The impact of reduction on QoL according to preoperative PFA

The 21 patients with normal preoperative PFA had similar postoperative QoL regardless of the type of surgery (reduction vs. in situ fusion), except for a better self-image, which was significantly higher after reduction (4.26 ± 0.58 vs. 3.73 ± 0.49, $p = .015$). When looking at the QoL preoperatively, both groups had similar scores except for a slightly better mental health and total score in the group undergoing reduction (Table 4).

For the 12 patients with abnormal preoperative PFA, the reduction group tended to have higher postoperative QoL scores in all domains when compared with the in situ group but the difference did not reach statistical significance. Those patients had similar preoperative QoL (Table 5).

Table 1
Distribution of patients according to preoperative PFA and SDSG grading in the HGS cohort (n = 33)

Preoperative PFA	Preoperative HGS according to SDSG Grading			Total
	Type 4	Type 5	Type 6	
Normal PFA	11	10	0	21
Abnormal PFA	4	3	5	12
Total	15	13	5	33

PFA, proximal femoral angle; HGS, high-grade spondylolisthesis; SDSG, Spine Deformity Study Group.

Table 2
Change in proximal femoral angle (PFA) after reduction versus in situ fusion

Type of surgery	n	PFA	Mean (°)	Standard deviation	*(°)	p Value
Reduction	20	Preoperative	7.6	6.5	−5.1	0.002†
		Postoperative	2.5	4.5		
In situ fusion	13	Preoperative	9.0	5.5	−2.4	0.119
		Postoperative	6.7	3.5		

PFA, proximal femoral angle.
* = Postoperative PFA - preoperative PFA.
† Statistical significance < 0.05.

Discussion

The proximal femoral angle is a newly reported lower extremity parameter, which is clinically relevant to the spinopelvic balance [14]. Moreover, this parameter can be easily assessed from standard long cassette radiographs showing the entire spine, pelvis, and proximal femurs. No previous studies have looked into PFA postoperatively. To our knowledge, this study is the first to identify the relationship between PFA and postoperative QoL. The results confirm our working hypotheses that normal PFA correlates with better QoL in patients with HGS undergoing surgery and that reduction to low grade is more likely to normalize the PFA when compared with in situ fusion.

When compared with normal population, HGS patients are found to have higher PI and distorted spinopelvic parameters [20]. Comparisons of the preoperative PFA and sagittal balance parameters confirm that PFA is an additional radiographic tool that should be considered in patients with HGS undergoing surgery. Recently, Mac-Thiong et al demonstrated in a preoperative study that increasing PFA correlates with increasing PT and decreasing SS, and is related to QoL [14]. The current study supports those findings in HGS and further demonstrates that lower preoperative PFA correlates with better self-image, less pain and higher total SRS-30 score.

The abnormal PFA found in all 5 patients with the most severe form of HGS (SDSG type VI) suggests that an abnormal femoral flexion (PFA ≥ + 10), is an expected late compensatory mechanism of sagittal balance related to a decompensated spine with the C7 plumb line falling in front of the hip axis.

The PFA changes after surgery

After reduction, PFA decreased by 5.1° on average (p = .002). This decrease was enough to result in PFA < 10° in most of the patients in this study (19 of 20). The significant decrease in PFA and %SLIP, along with the significant increase in SS and LSA demonstrate that reduction of HGS can successfully restore the global spinopelvic and lower extremity sagittal balance in a majority of patients for a minimum of 2-year follow-up. A tendency toward decreasing PT was noted, in agreement with the findings of Hresko et al. following reduction and posterior L4-S1 instrumentation [21].

Table 3
Sagittal parameters the high-grade spondylolisthesis patients undergoing reduction versus in situ fusion

		PI	PT	SS	LSA	%SLIP	PFA
Reduction group (n = 20)	Preoperative	Mean ± Std [Range] (°)	73.2 ± 11.7 [42-91]	28.9 ± 10.6 [2-50]	44.5 ± 10.2 [28-68]	78.8 ± 21.3 [42-129]	77.3 ± 16.7 [54-100]	7.6 ± 6.5 [(−5)−19]
	Postoperative		75.9 ± 11.1 [51-94]	26.4 ± 9.8 [11-43]	49.5 ± 8.9 [24-64]	96.2 ± 14.4 [69-124]	24.5 ± 13.4 [8-46]	2.5 ± 4.5 [(-6)−10]
	p value		0.052	0.176	0.026*	$< 10^{-3}$*	$< 10^{-3}$*	0.002*
In situ fusion group (n = 13)	Preoperative	Mean ± Std [Range] (°)	74.6 ± 10.8 [56-89]	28.2 ± 13.0 [14-60]	46.4 ± 13.9 [14-64]	75.1 ± 16.9 [58-102]	84.2 ± 15.5 [54-100]	9.0 ± 5.5 [2-22]
	Postoperative		77.9 ± 14.2 [55-105]	27.1 ± 6.5 [17-39]	50.8 ± 14.3 [29-72]	91.1 ± 19.3 [55-116]	78.9 ± 20.6 [55-100]	6.7 ± 3.5 [1-13]
	p value		0.239	0.894	0.455	0.005*	0.161	0.119

PI, pelvic incidence; PT, pelvic tilt; SS, sacral slope; LSA, lumbosacral angle; %SLIP, percentage slip; PFA, proximal femoral angle; Std, standard deviation.
* Statistical significance < 0.05.

Table 4
Quality of life pre- and postoperatively in patients with high-grade spondylolisthesis and normal preoperative proximal femoral angle

Quality of life	Type of surgery	n	Preoperative score (Mean ± Std)	p Value	Postoperative score (Mean ± Std)	p Value	QoL score (Mean ± Std)	p Value
Total Score	Reduction	12	3.65 ± 0.39	0.034*	4.19 ± 0.39	0.148	0.54 ± 0.58	0.808
	In situ fusion	9	3.26 ± 0.32		3.88 ± 0.54		0.62 ± 0.53	
Pain	Reduction	12	3.53 ± 0.69	0.193	4.45 ± 0.44	0.345	0.92 ± 0.85	1.000
	In situ fusion	9	3.11 ± 0.60		4.12 ± 0.76		1.01 ± 0.85	
Mental Health	Reduction	12	4.07 ± 0.56	0.023*	4.18 ± 0.62	0.754	0.12 ± 0.57	0.069
	In situ fusion	9	3.44 ± 0.58		4.09 ± 0.54		0.64 ± 0.68	
Self-image	Reduction	12	3.73 ± 0.53	0.193	4.26 ± 0.58	0.015*	0.53 ± 0.76	0.554
	In situ fusion	9	3.40 ± 0.63		3.73 ± 0.49		0.33 ± 0.64	
Function	Reduction	12	3.77 ± 0.67	0.219	4.34 ± 0.42	0.310	0.58 ± 0.77	0.972
	In situ fusion	9	3.49 ± 0.38		4.10 ± 0.64		0.61 ± 0.76	

Std, standard deviation.
QoL= Postoperative quality of life - preoperative quality of life.
* Statistical significance < 0.05.

In contrast, in situ fusion did not significantly alter PFA. The ratio of normal to abnormal PFA remained stable pre- and postoperatively. Likewise, different other sagittal parameters (PT, SS, %SLIP) remained unchanged. The significant improvement seen in LSA was most likely due to the postural reduction obtained once the patient is placed in ventral decubitus position with hip extension on the surgical table. The decreased low back pain postoperatively, may have also enhanced the overall posture in this setting.

Although the relationship between PFA and other parameters of spinopelvic balance is statistically significant, detailed alignment of the lower extremities (apart from the proximal femurs) was not measured in this study. For instance, it is expected that knee flexion would correlate with PFA, similar to the interdependence observed between the different anatomical segments of the spinopelvis in both normal subjects and patients with spondylolisthesis [1]. Knee contractures as a factor contributing to increased femoral flexion would be particularly important to assess in HGS since it has been well documented to occur independently in some patients secondary to tight hamstrings [7,8]. Therefore, future studies should ideally include the assessment of knee flexion from full body radiographs.

The QoL changes in relation to PFA

Decreasing PFA after reduction of HGS had a positive impact on the QoL. Normal PFA was associated with better QoL preoperatively in patients with HGS. Postoperatively, the current study revealed a significant improvement in pain, function and self-image scores with lower PFA post-reduction. Whether higher PFA contributes to pain in HGS or is a compensatory mechanism adopted to partly relieve the pain and/or radiculopathy associated with HGS remains uncertain, but the results showed that an improvement in PFA due to surgery is strongly related to a decrease in pain. It is also presumed that decreasing back pain and improving pelvic balance and hip contractures would explain the noted improved function and perhaps the range of motion at the lumbopelvic-hip axis. A future detailed gait and posture analysis would be interesting to do in this setting and validate our findings.

Given a normal preoperative PFA, the similar improvement in function, pain, and mean SRS-30 score after either in situ or reduction surgery, suggests that in situ fusion may be an adequate surgical option in some patients. However, reduction should be given consideration for patients with

Table 5
Quality of life pre- and postoperatively in patients with high-grade spondylolisthesis and abnormal preoperative proximal femoral angle

Quality of life	Type of surgery	N	Preoperative score (Mean ± Std)	p Value	Postoperative score (Mean ± Std)	p Value	QoL score (Mean ± Std)	p Value
Total Score	Reduction	8	3.21 ± 0.48	0.214	3.98 ± 0.61	0.933	0.76 ± 0.66	0.683
	In situ fusion	4	2.85 ± 0.54		3.68 ± 1.27		0.83 ± 0.76	
Pain	Reduction	8	2.85 ± 0.88	1.000	4.28 ± 0.91	0.283	1.43 ± 1.39	0.214
	In situ fusion	4	2.55 ± 0.50		3.48 ± 1.21		0.93 ± 0.73	
Mental Health	Reduction	8	3.83 ± 0.64	0.808	4.13 ± 0.88	1.000	0.30 ± 0.89	0.808
	In situ fusion	4	3.40 ± 1.59		3.90 ± 1.10		0.50 ± 0.93	
Self-image	Reduction	8	2.95 ± 0.49	0.283	3.89 ± 0.54	0.933	0.94 ± 0.46	0.570
	In situ fusion	4	2.70 ± 0.26		3.60 ± 1.33		0.90 ± 1.19	
Function	Reduction	8	3.60 ± 0.79	0.154	4.08 ± 0.77	1.000	0.48 ± 0.95	0.461
	In situ fusion	4	3.10 ± 0.35		3.70 ± 1.74		0.60 ± 1.83	

Std, Standard deviation.
QoL= Postoperative quality of life - preoperative quality of life.
Statistical significance < 0.05.

abnormal self-image, considering that self-image is significantly improved after reduction. This latter finding is in accordance with recent data showing that self-image was significantly better with decreasing PFA in patients with HGS [14]. Therefore, reduction remains a viable option for HGS even with a normal preoperative PFA, especially when patients have serious concerns about their posture and self-image. Altered self-image can be particularly seen in patients with hyperlordosis, heart-shaped buttocks, prominent abdomen, short trunk, pelvic retroversion, and/or hip flexion contractures.

Patients with abnormal preoperative PFA showed a tendency toward better QoL in all domains after reduction of HGS when compared with in situ fusion, suggesting that reduction should be given strong consideration in these patients. With the lack of significance most likely due to the small number of patients, a future study with a larger number of patients should be performed to validate the impact of reduction on postoperative QoL within this subset of patients. In addition, determination of the minimum clinical important difference in QoL in pediatric patients with lumbosacral spondylolisthesis should also be addressed in the future, in order to better identify patients achieving significant clinical improvement due to reduction.

Conclusions

This study demonstrates that reduction of HGS can significantly improve PFA. Decreased PFA correlates with less pain, improved function, and better self-image. When preoperative PFA is normal, in situ fusion is equivalent to reduction except for self-image, which is further improved with reduction. When preoperative PFA is abnormal, postoperative QOL tended to be improved with reduction, although the changes were not significant.

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