

The Effect of Surgical Reduction of Isthmic Spondylolisthesis at the Lumbosacral Junction on Spinopelvic Morphology

Mrinal B Shetty¹, Vinayak Venugopal²

Abstract

Purpose: Spondylolisthesis, with abnormal sacro-pelvic morphology, tends to disturb the normal spino-pelvic sagittal balance and results in abnormal sacro-pelvic orientation. Publications have emphasized the techniques of reduction and associated complications, but there is little knowledge of the effect of the reduction of sagittal plane translation in spondylolisthesis on the sagittal balance of spine and pelvis in post-operative patients. Therefore, there is a need for more studies concerning the spinopelvic parameters in patients undergoing surgical reduction for isthmic spondylolisthesis.

Our aim through this study is to describe the clinical and radiological impact of the reduction of sagittal plane translation and rotation in isthmic spondylolisthesis at lumbosacral junction following reduction and interbody fusion transforaminal lumbar interbody fusion (TLIF) on pelvic and spinal parameters.

Materials and Methods: Adult patients undergoing surgical reduction and TLIF for isthmic spondylolisthesis at lumbosacral junction satisfying inclusion and exclusion criteria who have been admitted or treated under Unit of Spine Surgery, Department of Orthopaedics at Father Muller Medical College between August 1, 2016, and June 1, 2018. From the 18 patients included in the study, collected data were analyzed by frequency, percentage, mean, and standard deviation. Tests such as Friedman test were used to compare the parameters over different time point and posthoc analysis was carried out using Wilcoxon signed-rank test.

Results: Of the 18 patients included in the study followed up for a period of 1 year, 77.8% were female and 22.2% were male. Average lumbar lordosis (LL) improved from $46.17^\circ \pm 7.57^\circ$ to $57.87^\circ \pm 1.95^\circ$ at the end of 1 year ($P = 0.000$). Mean pelvic tilt (PT) preoperatively was $25^\circ \pm 8.95^\circ$, which reduced to $18.10^\circ \pm 2.29^\circ$ at the end of 1 year. Average pre-operative sacral slope (SS) was 32.33° which increased to 39.23° at the end of 1 year. Pelvic incidence remained a constant irrespective of the intervention. Preoperatively, the average sagittal vertical axis (SVA) was 4.03cm which indicates sagittal imbalance; at the end of 1 year, SVA was 2.40cm which indicates a well-balanced spine. The mean pre-operative Oswestry Disability Index (ODI) was 55.67 ± 9.46 which suggested moderate-to-severe disability as per the ODI scoring system, which improved to 12.00 ± 3.36 which indicates minimal disability. Preoperatively, average visual analog scale (VAS) score was 8 which reduced to 0.17 at the end of 1 year, which is a significant decline in the pain with minimal or no pain by the end of 12 months.

Conclusion: The procedure resulted in adequate reduction of listhesis, restoration of sagittal balance of spine, improvement of other spino-pelvic parameters (PT, SS and LL), adequate fusion of the lumbo-sacral junction, and less morbidity (indicated by VAS and ODI score). Hence, the measurement of spinopelvic parameters is of utmost importance in pre-operative planning, with the

aim of surgery then being to restore these deranged parameters to normal ranges. Reduction of translational as well as rotational component of spondylolisthesis with interbody fusion (TLIF) is an effective technique which restores the sagittal balance of spine, improves LL, improves fusion rate, and reduces the rate of adjacent segment disease as well as morbidity.

Keywords: Isthmic spondylolisthesis, reduction of listhesis, spinopelvic parameters.

¹Department of Orthopaedics, Division of Spine Surgery, Father Muller Medical College, Kankanady, Mangalore, Karnataka,

²Department of Orthopaedics, Father Muller Medical College, Kankanady, Mangalore, Karnataka, India.

Address of correspondence :

Dr. Vinayak Venugopal,
Department of Orthopaedics, Father Muller Medical College,
Kankanady, Mangalore, Karnataka, India.
E-mail: vinu.scorpio@gmail.com



Figure 1: Pre-operative and post-operative radiographic measurements

Introduction

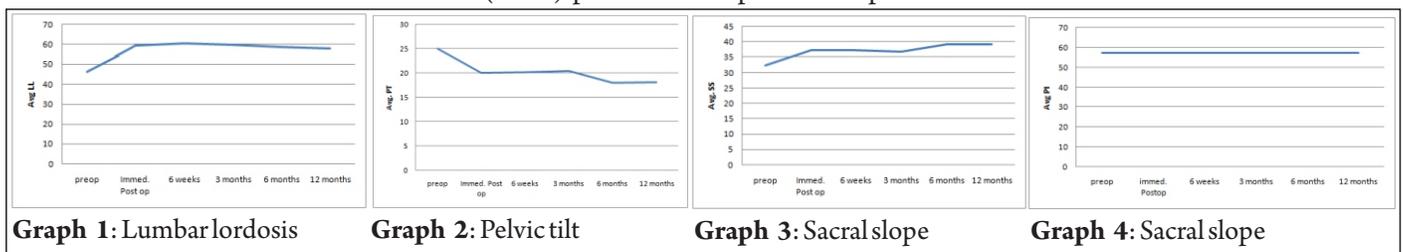
The importance of spino-pelvic sagittal balance has been proven by research in the past two decades. Normal sagittal alignment of the spine and pelvis helps in maintaining a stable posture and expends a minimum amount of energy. Spondylolisthesis, with abnormal sacro-pelvic morphology, tends to disturb the normal spino-pelvic sagittal balance and results in abnormal sacro-pelvic orientation [1]. In lumbar degenerative disease, loss of lordosis usually develops, with reversed ratio of extensors/flexors muscle power as compared with the normal controls [2,3]. It is accepted that restoring a normal sagittal contour is the main objective for a good functional outcome in spinal surgery [4]. Before any lumbosacral surgical treatment, parameters of sagittal balance should be analyzed, particularly if fusion is considered [5]. Biomechanical studies have shown that procedures that enhance disc height and lumbar lordosis (LL) increase tension in the anterior longitudinal ligament mediating better control of forces affecting the fused levels [6,7,8]. This is attained by accurately

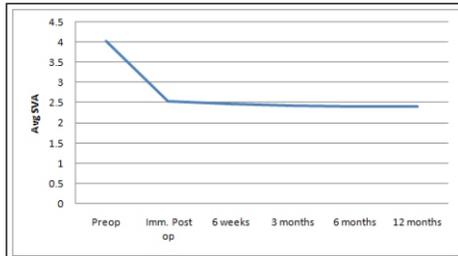
analyzing the sagittal balance using plain radiographs and calculating the different spinal and pelvic parameters, with the chief objective of surgery then being to obtain suitable values consistent with patient morphotype as defined by Roussouly et al. [9] During et al. [10], in 1985, defined the pelvic-sacral angle (PSA), Duval-Beaupere et al. [11] described the pelvic incidence (PI) angle 7 years later, and Jackson et al. [12] introduced the measurement of pelvic lordosis angle to assess the pelvic morphology. The most widely used parameter to evaluate the pelvic anatomy is PI. PI is an anatomical parameter that defines shape of the pelvis. It is a key factor in sagittal balance analysis and also in the occurrence and progression of spondylolisthesis. Treatment strategies have highlighted fusion of lumbosacral junction and restitution of sagittal balance is important after lumbar fusion, as it improves fusion rate and may reduce the rate of adjacent segment disease. Nevertheless, the role of the reduction of sagittal plane lumbosacral deformity remains controversial [13]. Even though many publications have emphasized the techniques of reduction and its associated complications, there is little knowledge of the effect of the reduction of spondylolisthesis on the sagittal balance of spine and pelvis in post-operative patients. Consequently, there is a need for more studies concerning the spinopelvic parameters in patients undergoing surgical reduction for isthmic spondylolisthesis. This prospective study aims at comparing the clinical and radiological impact of listhesis reduction and transforaminal lumbar interbody fusion (TLIF) procedures on pelvic and spinal

parameters in isthmic spondylolisthesis at immediate post-operative, 6 weeks, 3months, 6months, and 12months follow-up periods.

Materials and Methods

A prospective study of functional outcome and changes in spino-pelvic parameters in patients undergoing surgical reduction of isthmic spondylolisthesis at Father Muller Medical College Hospital. Patients aged above 18 years and treated surgically for isthmic spondylolisthesis between the periods 1st August 1, 2016, to and 1st June 1, 2018, are included in the study. Written informed consent were taken from each patient willing to be enrolled in the study. Patients will be evaluated clinically and radiologically preoperatively, immediate postoperatively, at 6 weeks, at 3months, 6months, and 12months. The aim of the surgery was to stabilize spondylolisthesis segment responsible for radicular and lumbar pain. In all cases, a posterior procedure involving transforaminal lumbar interbody fusion TLIF and pedicular fixation was performed with cage insertion. The goal was to restore a normal sagittal contour in relation to each patient’s lumbar morpho type. All surgeries were performed by a single trained spine surgeon. Full-length lateral spine radiographs in a standardized standing position with fingers of the upper arm overlying the ipsilateral clavicles were taken preoperatively, postoperatively, and at regular follow-up visits. The following radiographic parameters were measured.





Graph 5: Sagittal vertical axis

- Lumbar lordosis LL – Angle between the inferior end plate of T12 and the superior end plate of S1.
- Pelvic incidence PI- –Angle between a line joining the center of sacral end plate

to bicoxo-femoral axis and a line perpendicular to the sacral end plate

- Sacral slope (SS)- Angle formed by a line drawn along the sacral end plate and a horizontal reference line.
- Pelvic tilt (PT)- It is the angle subtended by a vertical line and a line connecting the centre center of the superior S1 end plate to a point that bisects the centre center of rotation of the hip joints.
- Sagittal vertical axis SVA–Measured as the offset between C7 plumb line and posterior superior corner of the sacrum.

A sagittal forward imbalance was defined as SVA >25mm.

The degree of slip was measured using Meyerding grade.

For all sagittal measurements, the angle was considered to be negative if the curve was lordotic and positive if it was kyphotic.

Radiographic measurements were done using Micro Diacom software by the same resident postgraduate in the department of orthopaedics for all the cases.

Functional outcome was assessed using Oswestry disability index(ODI) and visual analogue scale (VAS).

Results

Of the 18 patients included in the study, nine patients were aged 40 and below (50%) and nine patients were aged 40 and above (50%). About 77.8% of the study population were females and 22.2% were males. Average pre-operative lumbar lordosis LL was $46.17 \pm 7.57^\circ$, which improved to $59.30 \pm 2.47^\circ$ in the immediate post-operative period and at the end of 1 year follow-up, the average lumbar lordosis LL was $57.87 \pm 1.95^\circ$ which is highly significant statistically ($P = 0.000$).

The mean pelvic tilt PT preoperatively was $25 \pm 8.95^\circ$, which reduced to $20.00 \pm 8.65^\circ$ ($P = 0.000$) immediate postoperatively. The mean pelvic tilt PT at the end of 1 year follow-up was $18.10 \pm 2.29^\circ$. Average pre-operative SS was 32.33° which increased by 5° to 37.33° in the immediate post-operative period. The average SS at the end of 1 year follow-up was 39.23° .

There was no change in PI preoperatively and postoperatively, the mean PI preoperatively was 57.33° (range $54.65^\circ - 60.02^\circ$), postoperatively it was 57.33° , and on final follow-up at the end of 1 year, it is 56.38° , which is accordance with the fact that PI is a constant anatomical parameter.

The global sagittal balance of spine was quantified using the sagittal vertical axis

	n	Mean	Standard deviation	Repeated measures ANOVA F-value	P value
Pre-operative	18	46.17°	7.571	41.209	0
Immediate post-operative	18	59.30°	2.475		HS
6 weeks	18	60.47°	2.765		
3 months	18	59.67°	2.196		
6 months	18	58.70°	2.297		
1 year	18	57.87°	1.958		

	n	Mean	Standard deviation	Repeated measures ANOVA F-value	P value
Pre-operative	18	25.00°	8.951	40.592	0
Immediate post-operative	18	20.00°	8.65		HS
6 weeks	18	20.13°	8.343		
3 months	18	20.47°	8.375		
6 months	18	18.03°	6.283		
1 year	18	18.10°	2.297		

	n	Mean	Standard deviation	Repeated measures ANOVA F-value	P value
Pre-operative	18	32.33°	10.25	55.972	0
Immediate post-operative	18	37.33°	10.471		HS
6 weeks	18	37.27°	10.01		
3 months	18	36.87°	9.926		
6 months	18	39.13°	2.348		
1 year	18	39.23°	6.541		

	n	Mean	Standard deviation	Repeated measures ANOVA F-value	P value
Pre-operative	18	57.33°	5.402	8.004	
Immediate post-operative	18	57.33°	5.402		
6 weeks	18	57.33°	5.402		
3 months	18	57.33°	5.402		
6 months	18	57.33°	5.402		
1 year	18	57.33°	5.402		

(SVA) preoperatively, in the immediate post-operative period and on serial follow-ups at 6 weeks, 3 months, 6 months, and 1 year. Preoperatively, the average SVA was 4.03cm which indicates sagittal imbalance. Immediate post-operative assessment showed reduction of the sagittal imbalance to 2.52cm. On serial follow-ups, the average SVA was 2.47cm, 2.43cm, 2.40cm, and 2.40cm at 6 weeks, 3 months, 6 months, and 1 year, respectively, which indicates a well-balanced spine. Preoperatively, 9 patients (50%) had Grade 3 anterolisthesis, 6 patients (33.3%) had Grade 2 anterolisthesis, and 3 patients (16.7%) had Grade 1 anterolisthesis. In the immediate post-operative period, 9 patients (50%) had Grade 1 anterolisthesis, 6 patients (33.3%) had Grade 0, and 3 patients (16.7%) had Grade 2 anterolisthesis which was maintained at serial follow-up visits at 6 weeks, 3 months, 6 months, and 1 year, respectively. None of the patients had loss of reduction at the end of one 1 year follow-up.

The mean pre-operative ODI was 55.67 ± 9.46 which suggested moderate-to-severe disability as per the ODI scoring system, which improved to 28.67 ± 6.25 at 6 weeks postoperatively which suggested moderate to minimal disability. The average ODI at the end of 12-month follow-up is 12.00 ± 3.36 which indicates minimal disability. Visual analogue scale VAS was calculated based on severity of pain preoperatively and followed up to the end of one 1 year. Preoperatively, average VAS score was 8 for the 18 patients included in the study. On serial follow-ups, the average VAS

score at the end of 6 weeks, 3 months, 6 months, and 1 year were 1.50, 0.33, 0.17, and 0.17, respectively, which is a significant decline in the pain with minimal or no pain by the end of 12 months.

Discussion

All patients included in this cohort underwent surgical treatment of spondylolisthesis after failed conservative management for back pain with radiculopathy. Several studies have demonstrated the superiority of surgical management with better results regarding disability and pain relief. With growing knowledge and understanding of sagittal balance of spinopelvic unit, it is increasingly clear that adequate management of patients presenting with spondylolisthesis is not possible without accurately assessing sagittal balance and that clinical outcome is closely related to that latter. Analysis of spine and pelvic parameters should guide us in our treatment to insure post surgical achievement of suitable values for these parameters in concordance with the patient morpho type according to Labelle's classification. The aim of the surgery is thus to achieve the best spinopelvic sagittal alignment by fusing the level involved with or without reduction of spondylolisthesis. Good sagittal alignment is an economical standing position and should minimize muscle work during posture, therefore, diminishing pain directly due to excess muscle effort.

Lumbar lordosis (LL)

In a prospective study of sagittal spinopelvic parameters and deformity parameters in low-grade isthmic spondylolisthesis preoperatively and postoperatively by Feng et al. [1] (review this sentence) Of the 49 adult patients who underwent surgery for L5-S1 spondylolisthesis, average lumbar lordosis LL preoperatively was $58.08^\circ \pm 11.57^\circ$ and it increased by 5.7° to $-63.82^\circ \pm 11.13^\circ$ postoperatively. The increase in lumbar lordosis LL was beneficial to the realignment of spine and thus found to reduce the adjacent segment disease.

Bourghliet al. [14] in a prospective follow-up study on 30 subjects to assess the sagittal alignment of the spine and pelvis before and after surgical treatment of isthmic spondylolisthesis found that mean lumbar lordosis LL increased in a statistically significant fashion between the pre-operative and final follow-up measurements ($P = 0.025$): 47° preoperatively (range $19^\circ - 80^\circ$) and 61° at the final follow-up (range $32^\circ - 84^\circ$).

In our study with a sample size of 18, average pre-operative lumbar lordosis LL was $46.17^\circ \pm 7.57^\circ$, which improved to $59.30^\circ \pm 2.47^\circ$ in the immediate post-operative period and at the end of 1 year follow-up, the average lumbar lordosis LL is $57.87^\circ \pm 1.95^\circ$ which is highly significant statistically ($P = 0.000$).

Pelvic tilt (PT)

Bourghliet al. [14] in a prospective follow-up study on 30 subjects to assess the sagittal alignment of the spine and pelvis before and after surgical treatment of isthmic spondylolisthesis found that mean pelvic tilt PT decreased from 24.3° preoperatively (range $8^\circ - 50^\circ$) to 19.9° at the final follow-up (range $10^\circ - 39^\circ$) which showed significant improvement toward normal values for PT in relation to PI after surgery.

In our study, the mean pelvic tilt PT preoperatively is $25^\circ \pm 8.95^\circ$, which reduced to $20.00^\circ \pm 8.65^\circ$ ($P = 0.000$)

Table 5: Sagittal vertical axis

	n	Mean	Standard deviation	Repeated measures ANOVA F-value	P value
Pre-operative	18	4.03	2.056	11.697	0
Immediate post-operative	18	2.52	0.559		HS
6 weeks	18	2.47	0.566		
3 months	18	2.43	0.537		
6 months	18	2.4	0.518		
1 year	18	2.4	0.518		

immediate postoperatively. The mean pelvic tilt PT at the end of 1 year follow-up is $18.10^{\circ} \pm 2.29^{\circ}$.

Sacral slope (SS)

Ould-SlimaneSlimaneet al. [5] in a prospective follow-up study on 45 subjects to study the influence of TLIF on spinal and pelvic parameters of sagittal balance, the average SS preoperatively was 34.0° , which improved by 5.6° to -39.6° in the immediate post-operative period. Average SS at the end of 2-year follow-up was 40.8° .

Hreskoet al. [2315] in a retrospective study of 26 patients, evaluating the effect of reduction and instrumentation of spondylolisthesis on spinopelvic alignment noted an improvement in mean sacral slope SS by 11.4° .

In our study, the average pre-operative SS was 32.33° which increased by 5° to -37.33° in the immediate post-operative period. The average SS at the end of 1 year follow-up was 39.23° .

Pelvic incidence (PI)

Pelvic Incidence (PI) is the most widely used parameter to evaluate pelvic anatomy. In a prospective study by Feng, et al. [1] on 49 subjects on the study of sagittal spino-pelvic parameters and deformity parameters in low-grade isthmic spondylolisthesis preoperatively and postoperatively, PI of the patients before the operation was significantly higher than the normal volunteers and pelvic incidence PI was unaffected by the surgery. The mean PI preoperatively was $63.04^{\circ} \pm 11.88^{\circ}$ and postoperatively was $63.17^{\circ} \pm 11.88^{\circ}$.

In our study, there was no change in PI preoperatively and postoperatively, the mean PI preoperatively was 57.33° (range 54.65° – 60.02°), postoperatively it was 57.33° , and on final follow-up at the end of 1 year, it is 56.38° , which is accordance with the fact that PI is a constant anatomical parameter.

Sagittal vertical axis (SVA)

Ould-SlimaneSlimaneet al. [5] in a prospective follow-up study on 45 patients over 2 years to study the influence of TLIF procedures on spinal and pelvic parameters of sagittal balance, the mean SVA preoperatively was $5.2\text{cm} (\pm 1.71\text{cm})$, anterior translation reduced to $4.07\text{cm} (\pm 2.2\text{cm})$, and at the end of 2-year follow-up, it was $4.23\text{cm} (\pm 1.49\text{cm})$.

Bourghliet al. [2114] in a prospective study to assess the sagittal alignment of the spine and pelvis before and after surgical treatment of isthmic spondylolisthesis, the average SVA was 3.8cm preoperatively, which improved to 1.8cm in the final, follow-up.

In our study, the global sagittal balance of spine was quantified using the sagittal vertical axis SVA (SVA) preoperatively, in the immediate post-operative period, and on serial follow-ups at 6 weeks, 3 months, 6 months, and 1 year. Preoperatively, the average SVA of the 18 patients included in the study was 4.03cm . Immediate post-operative assessment showed reduction of the sagittal imbalance to 2.52cm . On serial follow-ups, the average SVA was 2.47cm , 2.43cm , 2.40cm , and 2.40cm at 6 weeks, 3 months, 6 months, and 1 year, respectively, which indicates a well-balanced spine.

Meyerding grade

Bourghliet al. [2114] in a prospective study of 30 subjects who underwent surgical treatment for isthmic spondylolisthesis, preoperatively, 1 one patient had Meyerding Grade 5, 4 four patients had Grade 3, 13 patients had Grade 2, and 12 patients had Grade 1; postoperatively, 1 one patient had Grade 3, 3 three patients had Grade 2, 11 patients had Grade 1, and in 15 patients, complete reduction was achieved (Grade 0) and none of the patients had loss of reduction in the follow-up periods.

In our study, preoperatively, 9 patients (50%) had Grade 3 anterolisthesis, 6

patients (33.3%) had Grade 2 anterolisthesis, and 3 patients (16.7%) had Grade 1 anterolisthesis. In the immediate post-operative period, 9 patients (50%) had Grade 1 anterolisthesis, 6 patients (33.3%) had Grade 0, and 3 patients (16.7%) had Grade 2 anterolisthesis which was maintained at serial follow-up visits at 6 weeks, 3 months, 6 months, and 1 year, respectively. None of the patients had loss of reduction in one 1 year follow-up.

Oswestry disability index (ODI)

In a prospective follow-up study done by Bourghliet al. [2114] to assess the sagittal alignment of the spine and pelvis before and after surgical treatment of isthmic spondylolisthesis, functional outcome was analysed analyzed and correlation examined. Functional evaluation was done using Oswestry disability index ODI. Mean ODI preoperatively was 43 (range 10–66), 20.3 immediate postoperatively (range 0–62), and 16.2 at final follow-up (range 0–58).

In our study of 18 subjects, the mean pre-operative ODI was 55.67 ± 9.46 which suggested moderate-to-severe disability as per the ODI scoring system, which improved to 28.67 ± 6.25 at 6 weeks postoperatively which suggested moderate to minimal disability. The average ODI at the end of 12-month follow-up is 12.00 ± 3.36 which indicates minimal disability.

VAS

In our study, the VAS was calculated based on severity of pain preoperatively and followed up to the end of 1 year. Preoperatively, average VAS score was 8 for the 18 patients included in the study. On serial follow-ups, the average VAS score at the end of 6 weeks, 3 months, 6 months, and 1 year was 1.50, 0.33, 0.17, and 0.17, respectively, which is a significant decline in the pain with minimal or no pain by the end of 12 months.

One patient at the end of 1 year follow-up

had persisting post-operative radiculitis that is secondary to stretching of the nerve roots following restoration of disc height post-surgery.

None of the patients had immediate post-operative surgical site infection, worsening of neurological status, implant failure, etc.

Summary

Surgical management of isthmic spondylolisthesis showed good clinical outcome with restoration of correct values for the pelvic position-dependent parameters, i.e., PT, SS, and SVA.

PI is an anatomic and constant parameter which remains unaffected by surgery. LL in accordance with PI is also important.

Pre-operative planning should include an accurate radiological study of the pelvis to assess the global sagittal balance. Pelvic parameters have an important role not only in defining patient spinopelvic morpho type but also with regard to control and regulation of global sagittal balance and post-operative alignment.

The surgical intervention resulted in restoration of sagittal balance of spine, which is of utmost importance with regard to the functional outcome post-procedure as well as for the success of fusion at the lumbosacral junction and for reducing the development of adjacent segment disease.

The final clinical outcome in terms of ODI and VAS showed a significant

improvement at the end of 1 year follow-up compared to the pre-operative status. Hence, measurement of spinopelvic parameters is of utmost importance in pre-operative planning, with the aim of surgery then being to restore these deranged parameters to normal ranges. Reduction of translational as well as rotational component of spondylolisthesis with interbody fusion (TLIF) is an effective technique which restores the sagittal balance of spine, improves LL, improves fusion rate, and reduces the rate of adjacent segment disease as well as morbidity.

References

- Feng Y, Chen L, Gu Y, Zhang ZM, Yang HL, Tang TS, et al. Influence of the posterior lumbar interbody fusion on the sagittal spino-pelvic parameters in isthmic L5-S1 spondylolisthesis. *J Spinal Disord Tech* 2014;27:E20-5.
- Jang JS, Lee SH, Min JH, Han KM. Lumbar degenerative kyphosis: Radiologic analysis and classifications. *Spine (Phila Pa 1976)* 2007;32:2694-9.
- Takemitsu Y, Harada Y, Iwahara T, Miyamoto M, Miyatake Y. Lumbar degenerative kyphosis. Clinical, radiological and epidemiological studies. *Spine (Phila Pa 1976)* 1988;13:1317-26.
- Barrey C, Jund J, Perrin G, Roussouly P. Spinopelvic alignment of patients with degenerative spondylolisthesis. *Neurosurgery* 2007;61:981-6.
- Ould-Slimane M, Lenoir T, Dauzac C, Rillardon L, Hoffmann E, Guigui P, et al. Influence of transforaminal lumbar interbody fusion procedures on spinal and pelvic parameters of sagittal balance. *Eur Spine J* 2012;21:1200-6.
- Cloward RB. The treatment of ruptured lumbar intervertebral discs by vertebral body fusion. I. Indications, operative technique, after care. *J Neurosurg* 1953;10:154-68.
- Drain O, Lenoir T, Dauzac C, Rillardon L, Guigui P. Influence de la hauteur discale sur le devenir d'une arthrodeseposterolaterale. *Rev Chir Orthop Traumatol* 2008;94:472-80. (provide it in English)
- Evans JH. Biomechanics of lumbar fusion. *Clin Orthop Relat Res* 1985;193:38-46.
- Roussouly P, Gollogly S, Berthonnaud E, Dimnet J. Classification of the normal variation in the sagittal alignment of the human lumbar spine and pelvis in the standing position. *Spine (Phila Pa 1976)* 2005;30:346-53.
- During J, Goudfrooij H, Keessen W, Beeker TW, Crowe A. Toward standards for posture. Postural characteristics of the lower back system in normal and pathologic conditions. *Spine (Phila Pa 1976)* 1985;10:83-7.
- Duval-Beaupère G, Schmidt C, Cosson P. A barycentremetric study of the sagittal shape of spine and pelvis: The conditions required for an economic standing position. *Ann Biomed Eng* 1992;20:451-62.
- Jackson RP, Peterson MD, McManus AC, Hales C. Compensatory spinopelvic balance over the hip axis and better reliability in measuring lordosis to the pelvic radius on standing lateral radiographs of adult volunteers and patients. *Spine (Phila Pa 1976)* 1998;23:1750-67.
- Helenius I, Lamberg T, Osterman K, Schlenzka D, Yrjönen T, Tervahartiala P, et al. Posterolateral, anterior, or circumferential fusion in situ for high-grade spondylolisthesis in young patients: A long-term evaluation using the scoliosis research society questionnaire. *Spine (Phila Pa 1976)* 2006;31:190-6.
- Bourghli A, Aunoble S, Reebye O, Le Huec JC. Correlation of clinical outcome and spinopelvic sagittal alignment after surgical treatment of low-grade isthmic spondylolisthesis. *Eur Spine J* 2011;20 Suppl 5:663-8.
- Hresko MT, Hirschfeld R, Buerk AA, Zurakowski D. The effect of reduction and instrumentation of spondylolisthesis on spinopelvic sagittal alignment. *J Pediatr Orthop* 2009;29:157-62.

Conflict of Interest: NIL
Source of Support: NIL

How to Cite this Article

Shetty MB, Venugopal V. The Effect of Surgical Reduction of Isthmic Spondylolisthesis at the Lumbosacral Junction on Spinopelvic Morphology. *Journal of Karnataka Orthopaedic Association* May-Aug 2019; 7(2):2-7.