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Surgical outcome of high grade spondylolisthesis following reduction, instrumentation, fusion through single stage posterior approach

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Abstract
Introduction: Literature evidence of outcome of reduction, spinal fusion through single stage posterior approach in patients of high-grade spondylolisthesis is lacking. Aim of the study, is to study the surgical outcome of High-grade spondylolisthesis patients, managed through single stage posterior approach.
Materials and Methods: We have retrospectively analysed high -grade spondylolisthesis adolescents and young adults of patients of age less than 30 years, who have undergone reduction and spinal fusion in our institute for the past 5 years with a follow-up of two years. 27 patients, who have undergone surgery in the time period between 2011 to 2016, were evaluated with preop standing lumbosacral radiograph for slip angle, L5 incidence angle, lumbar lordosis, slip percentage. Oswestry disability index [ODI] score for low back pain, neurological examination, sf-36 health survey questionnaire are the clinical parameters analysed. The patients who had undergone the surgery were followed up for 2 years and evaluated with standing radiographs for all the above radiological parameters, clinical parameters and assessment of spinal fusion by Bridwell criteria. Parameters were analysed statistically with SPSS software version 25.0. p less than 0.05 was considered statistically significant.
Results: The aim of the surgery is to reduce the L5-S1slip angle to less than 30 degrees, and not about the complete restoration of displacement of L5 over S1. Mean slip angle, L5 incidence angle, Lumbar lordosis, slip percentage changed from 41.57 to12.10 [$p<0.01$], 78.57 to 47.50[$p<0.05$], 81.40 to 55.5 degrees, 4.93 to 1.77 percent respectively. Change in slip angle, L5 incidence angle were statistically significant. ODI score improved from 71.17to 17.72. SF-36 health survey questionnaire showed superior results at follow-up and all the patients showed excellent fusion [Bridwell grade 1], no significant neurological complications were encountered at 2 years follow-up.
Conclusion: Surgical outcome of high-grade spondylolisthesis patients through single stage posterior approach produces superior results, at two years postoperatively, if intraoperatively slip angle is reduced to less than 30 degrees.

Keywords: spondylolisthesis, high grade spondylolisthesis, slip angle, l5 incidence angle

Introduction
Spondylolisthesis is the anterior displacement of one vertebrae over other. It has been divided into low and high grade, depending on the degree of displacement. The treatment option for low grade spondylolisthesis is realignment, decompression, posterior instrumentation, interbody fusion using cage has been the standard of treatment. The treatment options for high grade spondylolisthesis are 1.Insitu fusion, 2. Reduction, partial restoration of sagittal alignment, decompression, posterior instrumentation using interbody cage, 3. Posterior instrumentation, sacroplasty, decompression, transsacral fixation using dowel fibula graft, 4. Anterior vertebrectomy followed by posterior instrumentation and fusion, all with equivocal results.
The aim of the paper is to document the clinical, radiological, functional outcome of high grade spondylolisthesis patients treated with Reduction, decompression, posterior instrumentation and fusion using single posterior approach.

Materials and Methods
Study design: A single center retrospective review

Study centers: Apollo hospitals, Chennai.

Methodology
Retrospective review of all adolescent and young adult patients operated for high-grade (Meyerding 3-4-5) L5-S1 Dysplastic/Isthmic spondylolisthesis at the study center.

Inclusion criteria
1. Slip magnitude >50% (Grade 3, 4, 5)
2. Dysplastic/Isthmic types
3. Adolescent and Young adults of age less than 30 years.
4. Symptomatic

Patients treated at thecenters from 2010 to 2015 were enrolled into the study with follow-up of at least 2 years.

Exclusion criteria
1. Patient not willing for follow-up.
2. Patient not interested in the study.
3. Patients who were planning for pregnancy in near future.

Surgical technique
The technique consisted in reduction of lumbosacral kyphosis and posterior/posterolateral instrumented fusion done by single stage posterior approach. Reduction consisted of decompression, nerve root decompression, sacral dome resection, posterior translation L5, posterior fixation, optional S2 alar screw fixation, posterior spinal fusion.
After satisfactory induction of general endotracheal anesthesia, the patient was positioned prone on a four-poster frame and all pressure points well padded. The hips were placed into maximum extension to obtain positional reduction. Intraoperative radiographs were obtained after positioning to check the amount of reduction obtained. A standard posterior midline lumbosacral approach was used to expose the spine from L3–S2. Decompression was performed by removal of the loose arch of L5 and the scar tissue that had formed around the area of the pars inter articularis. The L5 and S1 nerve roots were completely decompressed bilaterally. If additional reduction in lumbosacral kyphosis is desired or deemed necessary, it was achieved by resection of the dome of the sacrum, which represented the posterior superior aspect of the central portion of the vertebrae. This then allowed access to the disc space, which was removed with rongeurs and disc shavers. Temporary distraction obtained by a rod anchored between L3 pedicle screw and S1 screw on one side. L5 and S1 pedicle screws were inserted on the other side of the temporary rod. Supplemental fixation with S2 alar screws were also placed and considered essential to reduce the stress on the S1 screws. Screw inserted in L5, and if purchase if found inadequate, L4 pedicle screw is also inserted. Persuader kept over the L5 screw and the top nut inserted after reduction of L5. Rods were prebent before using and connected to the L5, S1screws with top nuts. Autogenous bone graft for fusion was obtained from the iliac crest and along with excised bone debris packed in appropriate size PEEK cage and inserted at the L5-S1 disc space level and confirmed with image intensifier. Temporary distracting rod and L3 screw were removed. Opposite side L5, S1 screw were inserted. Compression was provided at the construct. Neuromonitoring was used throughout the procedure.

Clinical Outcome: Baseline and at two-year post-surgery follow-up. VAS [Visual analog scale], ODI [Oswestry Disability Index] and SF-36 questionnaire were documented.

Radiological outcome: Standard standing Lumbosacral spine radiograph for evaluation. Parameters evaluated include slip grade/magnitude, slip angle, L5 incidence angle[angle between two lines, one line drawn perpendicular to superior endplate of L5 from the midpoint of superior endplate of L5 and the other line drawn from the midpoint of superior endplate of L5 bisecting bicoxafemoral axis], Lumbar lordosis and Spino-pelvic parameters (PT, PI, SS). Dysplastic features [Sacral doming, Trapezoidal shape of L5 vertebral body, narrowed pedicles, S1 spina bifida, dysplastic posterior elements] were documented. All the parameters were tabulated preop and at two years of follow-up.

Fusion: Radiographic fusion was assessed using Bridwell criteria. Angular change of 3 degrees and or displacement of 3mm in standing radiograph was considered as pseudarthrosis.

Bridwell fusion gradingohd

Grade I	Fused with remodeling and trabeculae
Grade II	Graft intact, not fully remodeled or incorporated, though no lucencies
Grade III	Graft intact, but definite lucency at the top or bottom of the graft
Grade IV	Definitely not fused with resorption of the graft and with collapse

Statistical analysis was carried out using SPSS software 25.0

Results
Total number of patients studied were 27. Mean age of the patients was 18.85 years, Range 13 to 28 years. Male to Female ratio was 8:19. The total surgical time was mean 175 minutes. The mean blood loss was 935ml. [Range 750 to 1155ml]. There were 7 patients with grade 3 slip, 15 patients with grade 4 slip, 5 patients with spondyloptosis.

Table 1: Mean preop Slip angle, L5 incidence angle, Lumbar lordosis, Pelvic incidence, Pelvic tilt, Sacral slope were:

Parameters	Mean	Range
Slip angle	37.70	30 to 49
L5 incidence angle	64.81	56 to 78
Lumbar lordosis	72.92	64 to 80
Pelvic incidence	59.03	44 to 65
Pelvic tilt	18.14	14 to 25
Sacral slope	37.14	32 to 47

Table 2: Mean postop slip angle, L5 incidence angle, Lumbar lordosis, Pelvic incidence, Pelvic tilt, Sacral slope were:

Parameters	Mean	Range
Slip angle	5.7	4 to 9
L5 incidence angle	45.22	40 to 52
Lumbar lordosis	54.81	50 to 62
Pelvic incidence	50.85	40 to 55
Pelvic tilt	17.33	13 to 22
Sacral slope	31.88	22 to 38

Table 3: Mean preop, postop VAS, ODI, SF-36 score were:

Parameter	Preop	Postop	P
VAS	6.59	2.4	0.0001
ODI	67.74	18.51	0.0001
SF-36 SCORE	12.07	43.02	0.0001

Table 4: Mean percentage correction of the indices from baseline are:

Parameter	Percentage Change	p
Slip angle	84.90	0.0001
L5 incidence angle	30.22	0.0001
Lumbar lordosis	24.83	0.0001
VAS	63.42	0.0001
ODI	72.67	0.0001
SF-36 SCORE	64.17	0.0001

Only 11.11% patient's showed Bridwell fusion grade 2 at follow-up, all others showed Bridwell grade 1 at follow-up. No postop neurological complications, implant failure was encountered. Four patients [14.81% patients] had L5 root weakness, and one had ankle dorsiflexodr weakness. The neurology of the above patients improved with a mean period of 4.1months. Three patients, who had associated scoliosis along with high grade spondylolisthesis, were observed periodically every two months, and all the three patients scoliosis resolved at a mean period of 8.4 months.

Statistical analysis

All continuous variables were represented as mean ± SD. Categorical variables were expressed as percentage. Comparison of paired (Pre and Post surgery follow-up) continuous variables was done by Paired 't' test. Comparison of categorical variables was done by Chi-square test or Fisher's exact test based on the number of observations. Error bar charts were drawn to depict the differences in mean of various continuous parameters between pre and post follow up. Data entry was done in MS Excel spreadsheet. Data analysis was carried out by SPSS version 25.0. All 'p' values <0.05 was considered as statistically significant.

Mean pre-operative slip angle was 39.7 with SD of 5.4. During the follow-up period this has changed to mean of 5.7 degrees with SD of 1.7 which was statistically significant (p=0.0001). Mean L5 incidence angle preoperatively was about 64.8 ± 5.6 which changed to 45.2 ± 3.4 during the follow-up which was statistically significant (p=0.0001). Mean preoperative lumbar lordosis was 72.9 ± 3.7 and which changed to 54.8± 3.2 was statistically significant (p=0.0001).

Mean preoperative pelvic incidence was about 56.8±4.6 which changed to 47.3 ± 4.8 during the follow-up was statistically significant (p=0.0001). Preoperative mean pelvic tilt was 17.5±3.09 which changed to 17.3 ±2.3 was not statistically significant (p=0.745). Mean sacral slope preoperatively was about 38.1±3.6 which changed to 30.5±5.3 during the follow-up which was also statistically significant (p=0.0001).

Mean preoperative VAS score was 6.5± 1.1 which reduced to 2.3 ± 0.877 which was statistically significant (0.0001). Mean preoperative Oswestry disability index was 67.7 ± 5.2 which was reduced to 18.5 ± 3.3 during the follow-up had statistical significance (p=0.0001). Preoperative Mean SF-36 score was 120 ± 7.8 which was reduced to 44.11 ± 4.07 (p=0.0001).

Discussion

Smith and Bohlman [17] *et.al* used a single-stage decompression with in situ posterolateral and anterior column fusion to treat high-grade spondylolisthesis. The approach was an isolated posterior approach with anterior column support obtained by using a rib or fibular strut graft placed across the intervertebral disc through the lumbosacral junction. In their series of 11 patients, no neurologic complications or pseudarthrosis occurred. Their results, followed over an average of 64 months, did not appear to deteriorate with time. Roca *et al*. [18] in his 14 patients, treated in a similar way, arthrodesis was seen in 12 patients. The two had failure of fusion, due to graft issues – one had fibular strut graft fracture, and the other had resorption of fibular graft. Bradford *et al*. [19] evaluated 22 patients with high grade spondylolisthesis, treated by reduction and three column supports via a staged anteroposterior procedure, including a first-stage decompression and halo-skeletal traction for reduction, followed by a second-stage anterior arthrodesis. They reported 44% improvement in the slip angle with no significant change in the percentage slip. They concluded that it was more important to reduce the slip angle to obtain a good result and not necessarily reduction of the percentage slip. Molinarini *et al*. [20] evaluated 32 patients with high grade spondylolisthesis treated by three techniques: in situ posterior fusion without instrumentation (Group1); reduction, decompression, and posterior instrumented fusion (Group 2); and reduction, decompression with circumferential fusion by an anterior or posterior lumbar interbody technique (Group 3). Their rate of pseudarthrosis was 45% in Group 1, 29% in Group 2, and 0% in Group 3. Six reoperations were indicated in the seven pseudarthrosis, and five were performed. This include circumferential fusion. In this series four neurologic injuries also occurred. All four patients had slip reduction and fusion. There were four transient foot drops (15%), which took up to a year to resolve. One of the four continued to have a permanent toe extensor weakness at the final follow-up. Boachei [21] *et al*. in their study of 6 patients obtained fusion in all the 6 patients with a mean follow-up of 42 months. In high-grade spondylolisthesis, they proclaim, posterior approach is safe and effective in obtaining a solid arthrodesis, restoring sagittal balance, and improving function. They reinforce, that it is the partial reduction of the slip angle, not the percentage slip, in high-grade spondylolisthesis that is important in obtaining optimal results. Dormans [22] *et al*. in his paper of twenty year experience of treating high grade spondylolisthesis, has divided patients into three groups, *viz* insitu arthrodesis [A], partial reduction, posterior instrumentation, fusion [B], and reduction, sacroplasty, posterior instrumentation, fusion, wide nerve root decompression, with anterior column support [C]. He proclaims the third [C] group gives the best results with 92% fusion, lesser complications, with greater correction of slip angle, slip percentage, and sagittal pelvic balance. Rajasekharan [23] et.al in his paper of reduction vs in situ fusion in patients with high grade spondylolisthesis, suggests the superior end plate of L5 is to be considered for assessing pelvic parameters after fusion and superior endplate of S1 is to be considered preoperatively in assessing the same parameters. Three parameters changed significantly post-operatively in both procedures and showed comparable changes – PT, SFD and LSK. Pelvic incidence, sacral slope, lumbar lordosis does not show significant change. This suggests that the improved clinical outcomes for both treatment strategy may co-relate to changes in PT, SFD and LSK and the author call for re-evaluating the need for risky reduction procedures to establish normal pelvic parameters. Kan-min [24] *et al*. concludes that sacral dome resection from posterior approach in high-grade spondylolisthesis is a shortening osteotomy of the lumbosacral junction. It is very useful for single-stage posterior reduction of L5–S1 with the use of pedicle screws avoiding lengthening of lumbosacral junction and avoiding additional anterior surgery. This procedure followed by the instrumented fusion of L4–S1

produces a good multidimensional deformity correction with a minimal risk of neurological injury and a satisfactory clinical outcome. This is a safe surgical procedure to restore spino-pelvic alignment and the sagittal profile of the spine in the treatment of high-grade high dysplastic spondylolisthesis. In their study, L5 incidence improved from 74 to 56 degrees, the lumbosacral angle improved from 15 kyphosis to 6-degree lordosis, lumbar lordosis decreased from 69 to 53 degrees from preoperative to the last follow-up. While pelvic incidence of 77 degree remained unchanged, sacral slope decreased from 51 to 46 degrees and pelvic tilt increased from 25 to 30degrees. Clinical outcome was subjectively rated to be much better than before surgery by 14 out of 15 patients. Four out of 15 patients had temporary sensory impairment of the L5 nerve root which resolved completely within 12 weeks. There were no permanent neurological complications or no pseudarthrosis. In our study, slip angle changed from 37.7 to 5.7 degrees, L5 incidence improved from 64.81 to 45.22 degrees, lumbar lordosis decreased from 72.92 to 54.81 degrees from preoperative to the last follow-up. While pelvic incidence of 59.03 degree changed to 50.85, sacral slope decreased from 37.14 to 31.88 degrees and pelvic tilt decreased from 18.14 to 17. 33degrees.All the change in parameters were statistically significant, except the change in pelvic tilt.

Case 1

Fig 1: preop Clinical photo

Fig 2: preop xray

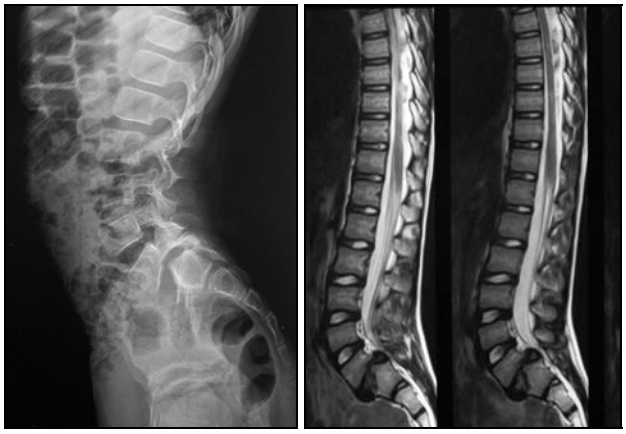

Fig 3: preop mri

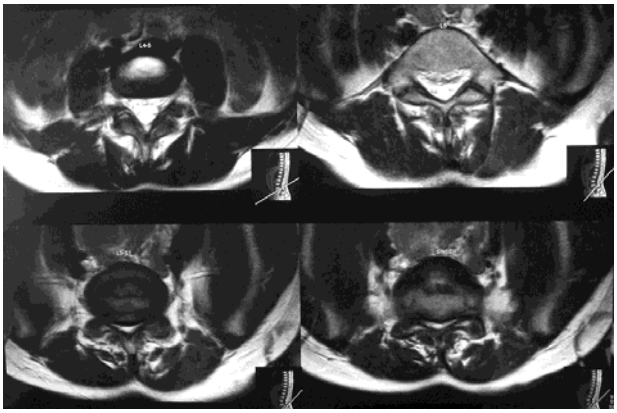

Fig 4: preop mri

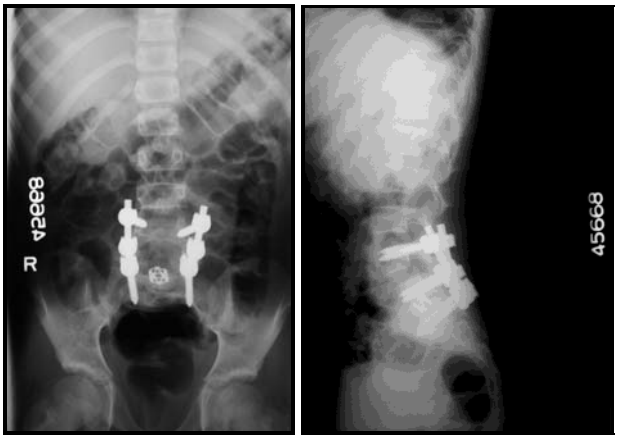

Fig 5: postop xray

Fig 6: 2 years followup

Fig 7: preop clinical photo

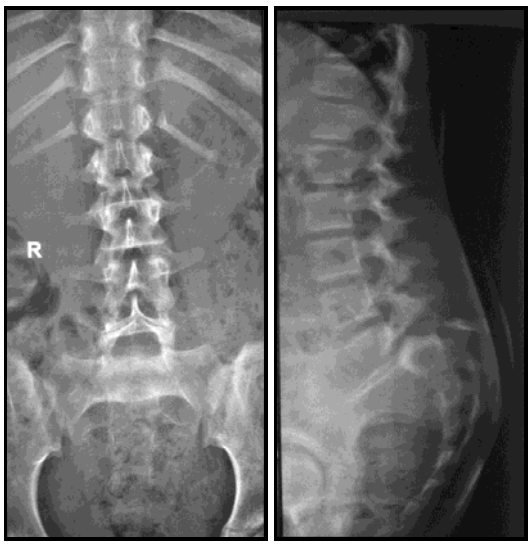

Fig 8: preop xray

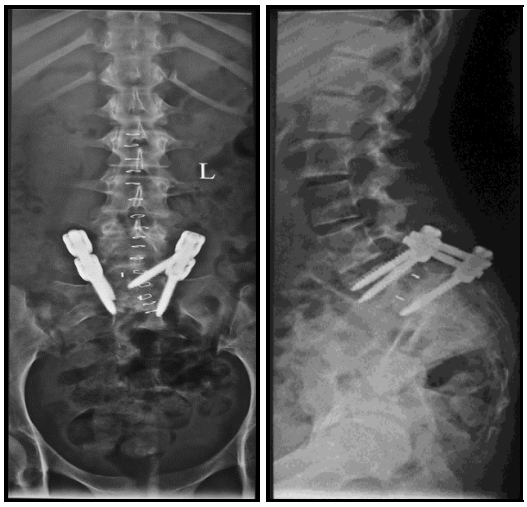

Fig 9: postop xray

Fig 10: postop clinical photo

Conclusion

The study supports that single stage posterior approach, with posterior decompression, instrumentation, sacroplasty is trustworthy procedure in managing high grade spondylolisthesis patients. Reduction in slip angle is of paramount importance, rather than considering reduction in percentage of reduction slip. Surgery should be focussed in restoring slip angle, L5 incidence angle, Lumbosacral joint angle to be less than 30, 80, 30 degrees to provide better quality of postoperative life in patients with high grade spondylolisthesis.

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