Abstract:
In high-grade spondylolisthesis the distorted anatomy due to forward slippage of L5 over S1, a high degree of sacral inclination, an unfavourable slip angle, and loss of normal lordosis make conventional approaches to 360 degree fusion difficult or hazardous. Traditional posterior instrumentation with posterolateral fusion is associated with a high rate of slip progression because the construct fails to provide anterior column axial load sharing and to restrict shear forces across the disc space. Interbody grafting is of marginal efficacy because of the limited endplate surface area available to create an interface with a graft. Several innovative techniques have been described to achieve successful arthrodesis in this setting. We present three cases of high grade, L5-S1 spondylolisthesis with sciatica and instability pain who were managed with three different techniques, namely, transsacral intervertebral pedicle screw fixation, transsacral intervertebral pedicle screw fixation and transvertebral fibular strut grafting, transsacral intervertebral pedicle screw fixation and transvertebral autograft filled cage. All three patients were operated by the same surgeon under intraoperative fluoroscopic guidance. Clinical and functional outcomes were analyzed using standard scores (ODI, SRS, VAS) preoperatively and during the recent follow up (26 months). Fusion was analyzed at the end of 14 months in all three patients. As fusion was unconvincing with conventional radiographs we analyzed fusion with a multislice helical topographic scan with multiplanar reconstruction with cage subtraction. Pain relief was good except with transvertebral fibular strut grafting. The ODI and SRS scores were significantly better with transvertebral cage fixation. 3D-CT films showed a fracture of the fibular autograft, whereas a solid anterior L5-S1 bridging fusion mass and...
intracage graft incorporation was evident with transvertebral cage. Transsacral intervertebral screw fixation with transvertebral cage provides a biomechanically stable construct capable of anterior column axial load sharing and resisting shear forces across the lumbosacral junction, given the anatomical constraints accompanying high-grade spondylolisthesis. The titanium cage will not be resorbed, as is the case with fibular allograft, and the autograft within it will enable an interbody fusion to occur.

**Keyword**: high grade, spondylolisthesis, interbody fusion, transvertebral cage

**Introduction**: Adult high-grade spondylolisthesis is extremely rare. It is characterised by a slippage of more than 50% (Meyerding grades III to V). It occurs most commonly at the L5-S1 level. In high-grade spondylolisthesis, the distorted anatomy due to forward slippage of L5 over S1, a high degree of sacral inclination, an unfavourable slip angle, and loss of normal lordosis make conventional approaches to 360 degree fusion difficult or hazardous (1). Traditional posterior instrumentation with posterolateral fusion is associated with a high rate of slip progression because the construct fails to provide anterior column axial load sharing and to restrict shear forces across the disc space. Interbody grafting is of marginal efficacy because of the limited endplate surface area available to create an interface with a graft. Several innovative techniques have been described to achieve successful arthrodesis in this setting. We present our experience with three cases of high grade L5-S1 spondylolisthesis who were managed with three different techniques.

**Materials and methods**: Three cases of adulthood high grade, L5-S1 spondylolisthesis presented to us with sciatica and instability pain.

**Case 1**: A 44 year old female patient presented with sciatica and instability pain of 12 months duration. Clinical examination revealed a decreased sensation in the L5 dermatome, EHL weakness and Straight leg raising up to 70 degrees. Plain anteroposterior and lateral radiographs of the lumbosacral junction revealed a Meyerding grade III (74% slip) L5-S1 spondylolisthesis. MRI and MR myelogram showed spinal canal narrowing (Figure 1.a). The patient was managed surgically by in-situ interbody stabilisation with transsacral transvertebral screws (Figure 1.b).

**Interbody stabilisation with transsacral screws**: Through a posterior midline approach, L4, L5, S1, S2 vertebrae were exposed. Decompressive L5 laminectomy was done to decompress both L5 nerve roots. Under image guidance, pedicle screws were inserted from S1 pedicles through the sacral body, the L5-S1 disc space into the L5 body bilaterally. Pedicle screws were inserted into the pedicles of L4 vertebra. Posterior instrumentation was applied from L4 to S1 vertebrae without any attempted reduction. Posterolateral bone grafting was done from L4 to S1. No intraoperative complications were encountered. Postoperative neurology was normal.
Fig. 1.a. Fig.1.b. Fig.1.a. Preoperative radiograph showing a Meyerding grade III L5-S1 spondylolisthesis with 74% slip. The spinopelvic parameters are shown in the table (inset). MRI and MR myelogram shows spinal canal narrowing. (b) Postoperative radiographs showing interbody stabilisation with trans sacral transvertebral screws from S1 to L5.

Case -2: 
A 20 year old male patient presented with sciatica and instability pain of 10 months duration. On clinical examination his neurology was unremarkable and the straight leg raising test was normal. Plain anteroposterior and lateral radiographs of the lumbosacral junction revealed a Meyerding grade IV (78% slip), L5-S1 spondylolisthesis. MRI and MR myelogram showed evidence of spinal canal narrowing (Figure 2.a). The patient was managed surgically by in-situ interbody stabilisation with trans sacral trans vertebral screws and interbody fusion with a transvertebral transsacral fibular strut graft (Figure 2.b). Interbody stabilisation with transsacral transvertebral screws and interbody fusion with a transsacral transvertebral fibular strut graft:

Through a posterior midline approach, L4, L5, S1, S2 vertebrae were exposed. Decompressive L5 laminectomy was done to decompress both L5 nerve roots. Under image guidance, pedicle screws were inserted from S1 pedicles through the sacral body, the L5-S1 disc space into the L5 body bilaterally. Pedicle screws were inserted into the pedicles of L4. Posterior instrumentation was applied from L4 to S1.

S1 laminectomy was done exposing the neural structures. After retracting the cauda equina and the S1 roots apart, under image guidance, a guide wire was passed in the midline from S1 to L5 followed by serial reaming. A 4 cm long fibular autograft was driven into position across the L5-S1 disc space. No reduction was attempted. Posterolateral bone grafting was done from L4 to S1. No intraoperative complications were encountered. Postoperative neurology was normal.

Fig.2.a. Fig.2.b. Fig.2.a. Preoperative radiograph showing a Meyerding grade IV L5-S1 spondylolisthesis with 78% slip. The spinopelvic parameters are shown in the table (inset). MRI and MR myelogram shows spinal canal narrowing, (b). Postoperative radiographs showing interbody stabilisation with transvertebral transsacral screws and interbody fusion with a transsacral transvertebral fibular strut graft.

Case -3: 
A 30 year old female patient presented with sciatica and instability pain of 6 months duration. Clinical examination revealed a decreased sensation in the L5 dermatome, EHL weakness and straight leg raising up to 60 degrees. Plain anteroposterior and lateral radiographs of the lumbosacral junction revealed a Meyerding grade III (68% slip) L5-S1 spondylolisthesis. MRI and MR myelogram showed spinal canal narrowing (Figure 3.a). The patient was managed surgically by in-situ interbody stabilisation with transsacral screws and interbody fusion with a transsacral transvertebral fibular strut graft.

Interbody stabilisation with transsacral transvertebral screws and interbody fusion with a transsacral transvertebral fibular strut graft:

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Through a posterior midline approach, L4, L5, S1, S2 vertebrae were exposed. Decompressive L5 laminectomy was done to decompress both L5 nerve roots. Under image guidance, pedicle screws were inserted through S1 pedicles, sacral body, the S1-L5 disc space into the L5 body bilaterally. Pedicle screws were also inserted into the pedicles of L4 vertebra. Posterior instrumentation was applied from L4 to S1. S1 laminectomy was done. After retracting the cauda equina and the roots apart, under image guidance, a guide wire was passed in the midline from S1 to L5 and serial reaming done. A titanium cage filled with autograft was driven into position across the L5-S1 disc space. No reduction was attempted. Posterolateral bone grafting was done from L4 to S1. No intraoperative complications were encountered. Postoperative neurology was normal. **Figure 3.a.** Preoperative radiograph showing a Meyerding grade III L5-S1 spondylolisthesis with 68% slip. The spinopelvic parameters are shown in the table (inset). MRI and MR myelogram shows mild spinal canal narrowing, **(b).** Postoperative radiographs showing interbody stabilisation with transsaccral screws and interbody fusion with a transsacral transvertebral autograft filled titanium cage.

**Results:**

**Analysis of radiological outcome:**

All three patients were operated by the same surgeon under intraoperative fluoroscopic guidance. They were followed up regularly. The average follow up period was 27 months.

Plain radiographs were taken at each follow up visit. (Figure 4.a,b,c,d,e,f). A comparative analysis of the preoperative radiographs and radiographs at latest follow-up showed a marginal reduction in slip angle and slip percentage. There was a reduction in the sacral slope and lumbar lordosis as compared to the preoperative values. The lumbar-sacral angle also showed improvement (Table 1).

**Figure 4 a,b,c,d,e,f.** Radiographs of all three patients taken during the last follow-up visit. In **Fig 4 e,f,** The transvertebral cage is well visualised and in **Fig. 4 c,d,** the transvertebral fibular graft is faintly seen.

**Table 1. Results from Radiographic Analysis.**
Analysis of interbody fusion:
Fusion was analyzed in all three patients at the last follow up visit. As fusion was inconvincing with conventional radiographs and conventional computerised tomographic films failed to show a convincing anterior intercorporeal fusion of the bone within the cage, we planned for fusion analysis with a multislice helical topographic scan with multiplanar(3D) image reconstruction with cage and screw subtraction. There was a pseudoarthrosis between L5 and S1 in the first case (Figure 5.a), while the CT films showed a fracture of the fibular strut in the second case (Figure 5.b), both indicative of a failure of fusion. In the third case the bone within the transvertebral cage had formed a solid bony trabecular mass bridging L5 and S1, indicating a bridging interbody fusion (Figure 6.a, b, c).

Analysis of Functional outcome:
Clinical and functional outcomes were analyzed using standard scores [Oswestry Disability Index (ODI) and Scoliosis Research Society(SRS) scores](2,3) preoperatively and postoperatively at 1, 6, 12 months and during the last follow up visit. The ODI scores were assessed at the final follow up visits using the ODI questionnaire (Figure 7). The patient treated with transvertebral screws alone showed some improvement in the ODI score from 37.7% (moderate disability) preoperatively to 20% (moderate disability) postoperatively, though he still remained in his preoperative functional state of moderate disability. There was no marked improvement in the ODI score from the preoperative state of severe disability, in the patient treated with transvertebral fibular strut graft. The patient complained of severe back pain during the follow up visits and failed to return to preoperative functional levels. The patient who was managed with a transvertebral cage showed a marked improvement in functional outcome from a preoperative state of severe disability to minimal disability at the final follow up.

![Fig. 5.a](image1.png) ![Fig. 5.b](image2.png)

**Fig. 5.a** Multislice helical CT with multiplanar reconstruction and screw subtraction showing a pseudoarthrosis between L5 and S1. **Fig. 5.b** Fracture of the fibular strut graft is seen in the multislice sagittal CT image of the second patient.

![Fig. 6.a](image3.png) ![Fig. 6.b](image4.png) ![Fig. 6.c](image5.png)

**Fig. 6.a** Multislice helical CT image showing the autograft within the cage has formed a solid trabeculation. **Fig. 6.b** Axial cuts showing the screw trajectories and the cage position. **Fig. 6.c** Sagittal multislice helical CT image showing solid trabecular bone bridging L5 and S1 after screw and cage subtraction.

![Oswestry Disability Index (ODI) Score](image6.png)
Interpretation of the ODI Score:
- 0-20% Minimal disability
- 21-40% Moderate disability
- 41-60% Severe disability
- 61-80% Crippled
- 81-100% Bed bound

**Figure 7.** Chart showing the ODI scores both pre-operatively and post-operatively during the final follow up visit. The patient’s functional outcomes with regard to pain, postoperative function, level of daily activity and social life were assessed at the final follow up visit using the SRS (Scoliosis Research Society) questionnaire (Figure 8). The SRS scores showed marked improvement in the patient treated with transvertebral cage as against the other two patients. There was a significant correlation between the SRS total score and the ODI score.

Interpretation of the SRS Score:
- Minimum score 20%
- Maximum score 100%

**Figure 8.** Chart showing the SRS scores both pre-operatively and post-operatively during the final follow-up visit.

**Discussion:**
Surgical management of high grade spondylolisthesis in still remains conflicting and controversial. It is logical that instrumented reduction will restore the normal sagittal profile and biomechanics of the lumbosacral region. Yet, the benefits of instrumented reduction still remain controversial (4). According to available literature instrumented reduction of L5–S1 high-grade spondylolisthesis is associated with an 8 to 30% rate of postoperative neurological compromise, mostly consisting of nerve root injuries or cauda equina syndrome. There is a relatively high incidence of well-documented complications associated with reduction, including instrumentation failure, loss of reduction and pseudarthrosis (3). Though reduction may reduce the slip, restore the sagittal plane balance and normal biomechanics, we believe that the risks of reduction in the setting of high-grade spondylolisthesis outweigh the benefits. In-situ fusion offers better long term clinical, radiologic and functional outcomes than instrumented reduction has in the same patient population despite no reduction in the translational deformity (5). In high-grade spondylolisthesis the distorted spinopelvic anatomy leads to altered lumbosacral biomechanics and global sagittal instability. Traditional posterolateral fusion with pedicle screw instrumentation for high-grade L5–S1 spondylolisthesis is associated with a high rate of slip progression because the construct does not provide anterior column axial load sharing and it is unable to restrict shear forces across the disc space. It is associated with a reported pseudarthrosis rate of 17% to 40% (6). Whereas traditional instrumented posterolateral fusion has proven to be reasonably effective in the treatment of high-grade spondylolisthesis, interbody arthrodesis significantly improves surgical outcomes (1). To provide anterior column load sharing and a larger surface area for fusion, ALIF is frequently used in addition to posterolateral fusion. This significantly improves the rate of fusion and reduces slip progression, but
adds the risk, increased operating time, and morbidity associated with an anterior procedure. Surgical management of high-grade spondylolisthesis requires constructs capable of anterior column axial load sharing and resisting shear forces across the lumbosacral junction, given the anatomical constraints accompanying high-grade spondylolisthesis (1). Interbody stabilisation with transsacral screws, transsacral screws with transvertebral fibular strut graft and transsacral screws with transvertebral cage are three different techniques which can achieve a successful arthrodesis in the setting of high-grade L5-S1 spondylolisthesis. The transsacral transvertebral screw construct weakens with time leading to a pseudoarthrosis. This correlated well with the poor functional outcomes in the ODI and SRS questionnaires in this study. Further pain relief was good except with transvertebral fibular strut grafting. This was due to the fibular graft resorption and fracture (as shown by the 3D CT films), which fails to resist the high axial loads at the lumbosacral junction in high grade L5-S1 spondylolisthesis as shown in previous studies (7). The 3D CT films showed a solid anterior L5-S1 bridging fusion mass and graft incorporation within the transvertebral cage. The titanium cage is a rigid modulus and will not be resorbed, as is the case with fibular allograft, and the autograft within it will enable an interbody fusion to occur. Despite no reduction in the translational deformity, this technique offers excellent fusion results, good clinical and functional outcomes, without neurological complications and prevents further progression of slip and lumbosacral kyphosis.

References:


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