

Posterior Lumbar Fixation Surgeries, Indications and Approaches (Posterolateral Fixation, PLIF and TLIF) Clinical Perspective

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Abstract: Background: Posterior lumbar fixation surgery is common procedure associated with lumbar fusion with different technique. The most frequent type of spine fusion is lumbar spine fusion, which can be done for a variety of reasons. There are two main techniques for lumbar spine fusion, posterolateral fusion and lumbar interbody fusion. This review aims to summarise, evaluate systematic reviews and analyze the therapeutic efficacy and outcome of posterior lumbar fixation surgeries and lumbar fusion including posterolateral fusion, PLIF and TLIF for most common diagnoses. In cases of recurrent lumbar disc herniation, there is no evidence that spine fusion has therapeutic advantage over repeated discectomy. There was no difference in the rates of re-operation between the two surgical procedures. According to lumbar fracture, we found no superiority in clinical benefit, system failure rate and other radiological parameters of arthrodesis over fixation only, in thoracolumbar burst fracture. The no-fusion group had much less surgical time and blood loss. Results of review for patients receiving fusion surgery for spondylolisthesis show that, In terms of attaining radiographic fusion, TLIF is superior to PLF without any observable increased risk for infection. However, There is very little evidence, that TLIF is better than PLF for attaining clinical improvement. If surgical intervention for spondylodiscitis is needed, less invasive surgical approaches (single-stage anterior or posterior fusion techniques) are strongly recommended, since they can have a better therapeutic outcome than more complex mixed anterior–posterior procedures. For more accurate evaluation of the efficacy of spinal fusion surgery on all indications, more evidence is required.

Keywords: Spine Fusion, Lumbar Fixation, Back Pain, Surgery

1. Introduction

The first posterior lumbar fusion was introduced by Cloward in 1953 for degenerative disc disease and spondylolisthesis. Pedicle screw instrumentation has since allowed a stiff construct to improve stability and fusion for a variety of spinal pathologies [1]. Lumbar fusion is a surgical treatment that is frequently performed procedure for the treatment of spondylosis, trauma, infection, neoplasm, and spinal instability [2]. Traditionally, a posterolateral fusion using autologous bone graft has yielded satisfactory clinical results; nevertheless, reported rates of fusion have been varied

[3]. Internal fixation using posterolateral transpedicular screw has greatly improved the fusion rate, particularly in situations of instability [2]. Interbody fusion may enhance clinical outcomes by removing the disc as a potential source of pain, increasing fusion rates, and restoring intervertebral height and lumbar lordosis [4]. Intervertebral fusion is accomplished using a posterior method in posterior lumbar interbody fusion (PLIF) and transforaminal lumbar interbody fusion (TLIF). Both procedures are used to treat degenerative disc disease, severe instability, spondylolisthesis, deformity, and

pseudoarthrosis [4]. Allograft, different cages (for interbody support), autograft, and recombinant human bone morphogenetic protein-2 have all yielded positive outcomes. These techniques for interbody fusion can help with spine reduction and fusion. PLIF and TLIF have a good biomechanical basis. The clinical results of various anterior and posterior spinal arthrodesis operations, on the other hand, are mostly identical [4]. PLIF is associated with higher rate of complications (dural tear ranged from 5.4 to 10 percent while neurologic injuries were 9 to 16 percent) [4].

In this review we tried to evaluate the review and analyze the therapeutic efficacy and outcome of posterior lumbar fixation surgeries with posterolateral fusion, posterior lumbar interbody fusion (PLIF) and transforaminal lumbar interbody fusion (TLIF) in different indications. We choose reviews with comparative studies between two different surgical procedures in same pathology. So we can compare the effect and result of posterolateral fusion or interbody fusion (TLIF, PLIF) with each other or both together or compare fusion with its relevant comparative group if present in some case like repeated discectomy in recurrent lumbar disc prolapse.

We conducted this review on reviews with comparative studies and randomised controlled trials (RCTs) wherever appropriate, and we compiled a list of the most recent and high-quality reviews. All papers with the medical topic heading (MeSH) of lumbar fixation and spinal fusion were found in Medline using Pubmed. Only published Literature in English language was included in the study. Limiting this search to reviews yielded 866 results. These 866 titles and abstracts were reviewed. Finally, 28 reviews were included following a double-blind analysis of potential papers to include. The data from these reviews has been broken down into parts based on the surgical indication: recurrent lumbar disc herniation, trauma, spondylolisthesis, and spondylodiscitis.

2. Recurrent Lumbar Disc Herniation

Recurrent lumbar disc herniation (RLDH) is the most common unfavourable consequence of initial lumbar discectomy. The prevalence of RLDH varies between 5% and 15% of the population [5]. In a Fragment-Defect group with extruded fragment and significant posterior annular loss of disc herniation, the RLDH rate was observed to be as high as 27% [6]. The best appropriate management for RLDH is still up for debate. Repeat discectomy (RD), both minimally invasive and traditional, are successful in relieving symptoms and decompressing the nerve root. There are considerable worries about iatrogenic instability and recurrence following RD. A recent retrospective analysis found that 38.4 percent of patients who got RD within two years went on to do SF within four years [7]. As a result, some surgeons choose spinal fusion (SF) as the conventional procedure for RLDH [8, 9]. Nonetheless, The main disadvantages of SF are instrumentation complications and the potential of adjacent segment degeneration.

Only comparative trials comparing RD and SF in the treatment of RLDH were included in this review [10]. There

are four comparative studies only one prospective and tree retrospective. All studies had at least a one-year follow-up period. The major goal of this review is to examine the revision rates of RD and SF in the treatment of RLDH. Operative duration, dural tear, postoperative hospital stay, clinical improvement, satisfactory rate and total cost are the secondary objectives. The RD group's revision rates appeared to be greater (9.09%) than the SF group's (2.0%). However, the difference was not statistically significant. Results showed a comparable percentage of patients (37.5%) receiving SF following RD as another study [7]. According to the meta-analysis, the RD group had much less operative duration and blood loss than the SF group, whereas the SF group had a higher overall cost. Both groups had similar rates of dural tear (0.136 percent in the RD group and 0.11 percent in the SF group). A separate measurement system was used to report the clinical outcomes. Original data in each study, however, revealed clinical improvement without statistical significance. In terms of ODI score, both groups improved equally, although the SF group's JOA score was slightly higher. Because back pain is considered more than leg pain in the JOA score, the SF group receives a higher JOA score.

3. Lumbar Fracture

The term "spine trauma" refers to a wide range of injuries, including highly unstable fractures and dislocations that are uncommon but extremely dangerous. Fractures are commonly given degrees of stability, and surgical intervention may be needed depending on the severity of probable instability and neurological involvement.

Only reports on burst fractures were found, which often occur near the thoracolumbar joint as a result of strong energy impacts [11]. 90 percent of spinal fractures are thoracolumbar fractures, with the burst subtype accounting for 20% of the total [12]. The surgical solution has been used as a viable treatment alternative since the 1990s [13]. Arthrodesis has been used to enhance biological stabilisation of the fracture and to protect the fixation system from material fatigue failure caused by spinal column movement at the fractured site. Without the safety of arthrodesis, the failure of the fixation mechanism will theoretically be a matter of time. Recent research has called into question the necessity of fusion with internal fixation [14].

The aim of this study was to compare the effects of fusion versus fixation without fusion on surgically treated thoracolumbar burst fractures [14]. There are five studies in the literature that attempt to address this issue. Four of them were randomised, while one was quasi-randomized. There were 220 patients in total who were examined, with an average follow-up time of 69.1 months. The clinical outcome outcomes in this study were not different between the groups, using VAS for pain or LBOS instruments to measure functional differences. Another clinical benefit of posterior instrumentation without fusion may be the prevention of complications at the autogenous bone graft donor site. The majority of fusion surgery patients reported postoperative

pain that restricted their mobility. In terms of surgical procedure outcomes, the no-fusion group saw significant reductions in both operative duration and blood loss ($p = 0.01$). There was no difference in time of postoperative stay ($p = 0.186$). Fixation system failures, such as fracturing, dislocation, and screw loosening, did not vary between two groups. If a long fixation is used instead of a short fixation, the failure rate is significantly lower. Implant removals that occurred as a result of device failure were assessed. The odds ratio for removing a fixation device was 4.09 higher in the no-fusion group than in the fusion group; however, this variable's assessment was limited since part of the system removal indicated in the trials was discovered to be related to cultural factors rather than system failure alone. In terms of radiological outcomes, segmental motion was assessed at the fracture level, and it was found that even after 10 years of follow-up, the no fusion group's mobility remained intact, with no signs of instability. The fusion group had a better outcome with the loss of kyphosis correction, but the difference was not statistically important, and the size of the effect indicates that it is clinically insignificant. The degree of kyphosis correction and the final kyphotic angle did not vary significantly, though the degree of kyphosis correction favoured the no fusion community. Evidence that fusion with internal fixation in the treatment of burst fractures provides no clinical or radiological benefit shows the possibility of treating these injuries with less invasive procedures. Percutaneous pedicle screws are becoming more common as a therapeutic option in this context. If trauma patients were treated with percutaneous pedicle screws instead of open surgery, there would be less morbidity and the outcomes would be the same. Some authors have reported positive results with percutaneous pedicle screws [15].

4. Spondylolisthesis

Spondylolisthesis is the forward movement of one vertebra over another, most often in the lumbar spine, which is sometimes asymptomatic. Degenerative and isthmic Spondylolisthesis forms are the most common in clinical practise. Degenerative cases are caused by the lack of facet joint integrity which manifest as back pain, radiculopathy, or neurogenic claudication because of the concomitant spinal canal stenosis in middle age and older people. In isthmic cases, the root issue is a non-healing stress fracture of the pars interarticularis caused by foraminal stenosis in lumbar radiculopathy [11].

Lumbar fusion for symptomatic spondylolisthesis is one of the most prevalent operations and as indication for lumbar fusion [16]. Interbody fusion has attracted attention recently as a viable method of performing 360-degree arthrodesis, with the claimed benefits of anterior column protection, indirect foraminal decompression, and improved lumbar lordosis [17]. Regardless, the best surgical procedure for spondylolisthesis depends on the patient and physician, there is also a need to figure out the best fusion therapy for these cases. The most widely used interbody fusion

procedure, TLIF, is of special concern. There is currently no data to justify the use of TLIF instead of standard PLF.

This review compares the fusion rate, clinical outcomes, surgical duration, blood loss, and infection rates of PLF vs TLIF for patients with spondylolisthesis (degenerative & isthmic) using data from retrospective studies and prospective RCTs [18]. Two randomized controlled trials were considered, as well as five retrospective cohort studies. In all seven investigations, the TLIF group had a posterolateral fusion in addition to their TLIF. In total, PLF was used on 324 patients, whereas TLIF was used on 329 patients. The findings of one trial were reported after a year, while the findings of the other six trials were released after two-year follow up.

Results showed that both intervention groups exhibited a reduction in back and leg pain. There was no significant difference in back pain and leg pain between surgical procedures according to VAS score, while in ODI shows difference in favour of TLIF group in observational studied and no difference in RCT studies. PLF group shows shorter operative times than TLIF group with no difference in blood loss and infection rate between two groups. Results of our study reported fusion rates between 24-month and 36-month follow-up. TLIF patients had a much better chance of attaining arthrodesis than PLF patients. With present data, this evaluation suggests that TLIF is superior to PLF in attaining solid fusion without any obvious higher risk of infection and scant support from clinical evidence. To corroborate previous findings, larger-scale randomised controlled studies should be done in the future.

5. Spondylodiscitis

Spinal infections are a rare but serious medical condition that typically necessitates extensive medical and surgical treatment. Discitis, osteomyelitis, epidural abscess, meningitis, subdural empyema, and spinal cord abscess are all examples of spinal infections. Only discitis and osteomyelitis, which are generally present in tandem and are referred to as spondylodiscitis. Spondylodiscitis is divided into three types: pyogenic, granulomatous (tuberculous, brucellar, aspergillar, and fungal), and parasitic [19].

This review contain 25 studies to evaluate Outcome of conservative and surgical treatment of pyogenic spondylodiscitis [20]. Studies reported conservative treatment or studies compare antibiotic treatment versus surgical treatment and, were excluded. While, include comparative studies reported surgical treatment with different approaches in pyogenic spondylodiscitis patients which need surgical interventions (7 studies). The seven studies containing only a minority of tuberculosis (negatively influenced the clinical outcome). All studies are comparative studies, 5 retrospective comparative studies (RCoS), 1 prospective comparative study (PCoS) and 1 randomized controlled trial (RCT). A total of 244 people were included in the sample. Of the 244 patients, 141 were male 93 were female we exclude 10 with TB spondylodiscitis. All trials

had a minimum follow-up period of one year. Over-all, the mean follow-up time is 24 months. average age was 58 years.

Anterior and/or posterior approaches were compared in four studies. Linhardt et al RCT's and Si et al PCoS's both compared a combined anterior and posterior stabilisation to single-stage anterior stabilization [21, 22]. In the anterior only party, they registered less pain and statistically important improved clinical outcomes. Vcelak et al. used the RCoS to compare the effects of a mixed anterior and posterior procedure with an independent posterior procedure using dorsal instrumentation and limited TLIF [23]. The rate of reoperation, relapse, medication failure, or mortality didn't meet statistical significant. There was a statistically important higher lack of sagittal balance in the isolated posterior approach group; however, this had no clinical implications [23]. In a retrospective study, Lee et al. compared the results of transpedicular curettage and drainage with posterior stabilization versus hybrid anterior/posterior stabilization [24]. There was no significant difference in clinical outcomes, and transpedicular curettage and drainage with posterior stabilization were recommended as a good therapy for patients with extreme co-morbidities [24]. In a hybrid anterior and posterior technique, Lin et al. analyzed the variations between an open and a percutaneous approach [25]. They discovered no significant differences in results between the open and percutaneous groups [25]. Two retrospective investigations [26, 27] examined the efficiency of anterior fusion with various types of cages and cage versus strut graft. Polyetheretherketone (PEEK) cages were compared to titanium (TTN) cages by Schomacher et al. [26]. The two cage types had no discernible differences [26]. Yong et al. investigated the distinctions between iliac bone struts and titanium mesh cages. While there was little disparity in health results, the strut group had a higher subsidence risk [27].

Currently, for the treatment of pyogenic spondylodiscitis, a variety of surgical therapeutic techniques are used. Historically, the best surgical procedure for treating spondylodiscitis has been anterior debridement paired with posterior stabilisation. However, because this is a complex surgery, it may be unsuitable for severely ill patients. less invasive surgical techniques have strong level of recommendation in comparison to more complex more extensive combined anterior-posterior surgeries, this may result in a better clinical outcome. Among these less invasive techniques are Single anterior or posterior operations, as well as combination anterior and posterior operations with percutaneous posterior stabilisation.

In the treatment of lumbar spondylodiscitis single-stage posterior fusion, transpedicular instrumentation restricted facet joint excision with removal of the infected focus of the intervertebral disc space and part of the end plate with supporting anterior column by TLIF, autogenous bone grafting and bone substitute is effective and with good results in patients had relatively minor bony destruction and little to no deformity. Isolated anterior approach is indicated in cases with extensive vertebral body osteolysis involving more than one third of vertebral body, pathologic fracturing, development of

segmental kyphosis, and radiographic signs of recurrent instability. Debridement of the anterior retroperitoneum and defect replacement using a titanium implant. In order to collect more evidence, newly emerging less invasive surgical procedures should be analyzed more thoroughly.

6. Conclusion

Overall, the findings show that for patients undergoing lumbar fusion for different indications, Posterolateral fusion, PLIF and TLIF represent usual and easy approach for most of spine surgeons.

In cases of recurrent lumbar disc herniation, there is no evidence that spine fusion has therapeutic advantage over repeated discectomy. There was no difference in re-operation rates between the two surgical treatments was found based on the results of the study. There was no difference in the rates of re-operation between the two surgical procedures. According to lumbar fracture, there was found no superiority in clinical benefit, system failure rate and other radiological parameters of arthrodesis over fixation only, in thoracolumbar burst fracture. The no-fusion group had much less surgical time and blood loss. These findings raise doubts regarding whether fusion is truly necessary in the treatment of thoracolumbar rupture fractures. Results of review for patients receiving fusion surgery for spondylolisthesis show that, In terms of attaining radiographic fusion, TLIF is superior to PLF without any observable increased risk for infection. However, There is very little evidence, that TLIF is better than PLF for attaining clinical improvement. If surgical intervention for spondylodiscitis is needed, less invasive surgical approaches (single-stage anterior or posterior fusion techniques) are strongly recommended, since they can have a better therapeutic outcome than more complex mixed anterior-posterior procedures.

Spine fusion for spondylolisthesis, burst fractures, spondylodiscitis, or degenerative diseases (recurrent disc herniation, degenerative scoliosis, spinal stenosis, or instability) should ideally only be done in high-quality clinical trials until the genuine value for each treatment of these disorders is proven. Treatment modalities will have to be driven by expert scientific judgment based on data with a high risk of bias before higher quality evidence becomes available. Patients considering spinal fusion should be well-versed on available evidence for their specific condition, as well as the relative advantages and risks of fusion versus non-operative therapies. It's also obvious that further study is needed to provide more solid evidence, we recommend follow-up or future work on this topic should be made.

References

- [1] Harris, E. B., Massey, P., Lawrence, J., Rihn, J., Vaccaro, A., & Anderson, D. G. (2008). Percutaneous techniques for minimally invasive posterior lumbar fusion. *Neurosurgical focus*, 25 (2), E12.

- [2] Brantigan, J. W., Neidre, A., & Toohey, J. S. (2004). The Lumbar I/F Cage for posterior lumbar interbody fusion with the variable screw placement system: 10-year results of a Food and Drug Administration clinical trial. *The Spine Journal*, 4 (6), 681-688.
- [3] Tajima, N., Kawano, K., Sera, K., Taguchi, A., Torigoshi, T., & Konishi, H. (1989). Posterolateral fusion of the lumbar and lumbosacral spine--a review of long term results. *Nihon Seikeigeka Gakkai Zasshi*, 63 (4), 262-268.
- [4] DiPaola, C. P., & Molinari, R. W. (2008). Posterior lumbar interbody fusion. *JAAOS-Journal of the American Academy of Orthopaedic Surgeons*, 16 (3), 130-139.
- [5] Barth M, Weiss C, Thome C. Two-year outcome after lumbar microdiscectomy versus microscopic sequestrectomy: Part 1: Evaluation of clinical outcome. *Spine (Phila Pa 1976)* 2008 (33): 265-72. <https://doi.org/10.1097/BRS.0b013e318162018c>.
- [6] Carragee EJ, Han MY, Suen PW, Kim D. Clinical outcomes after lumbar discectomy for sciatica: the effects of fragment type and anular competence. *J Bone Joint Surg Am Vol* 2003; 85-A: 102-8.
- [7] Heindel P, Tuchman A, Hsieh PC, Pham MH, D'Oro A, Patel NN, et al. Reoperation rates after single-level lumbar discectomy. *Spine (Phila Pa 1976)* 2017; 42: E496-501. <https://doi.org/10.1097/BRS.0000000000001855>.
- [8] Chitnavis B, Barbagallo G, Selway R, Dardis R, Hussain A, Gullan R. Posterior lumbar interbody fusion for revision disc surgery: review of 50 cases in which carbon fiber cages were implanted. *J Neurosurg* 2001; 95: 190-5.
- [9] Chen Z, Zhao J, Liu A, Yuan J, Li Z. Surgical treatment of recurrent lumbar disc herniation by transforaminal lumbar interbody fusion. *Int Orthop* 2009; 33: 197-201. <https://doi.org/10.1007/s00264-008-0531-1>.
- [10] Tanavalee, C., Limthongkul, W., Yingsakmongkol, W., Luksanapruksa, P., & Singhatanadgige, W. (2019). A comparison between repeat discectomy versus fusion for the treatment of recurrent lumbar disc herniation: systematic review and meta-analysis. *Journal of Clinical Neuroscience*, 66, 202-208.
- [11] Harris, I. A., Traeger, A., Stanford, R., Maher, C. G., & Buchbinder, R. (2018). Lumbar spine fusion: what is the evidence?. *Internal medicine journal*, 48 (12), 1430-1434.
- [12] Avanzi O, Landim E, Meves R, Caffaro MF, de Albuquerque Araujo Luyten F, Faria AA: Thoracolumbar burst fracture: load sharing classification and posterior instrumentation failure. *Rev Bras Ortop* 45: 236-240, 2010.
- [13] Kumar A, Aujla R, Lee C: The management of thoracolumbar burst fractures: a prospective study between conservative management, traditional open spinal surgery and minimally interventional spinal surgery. *SpringerPlus* 4: 204, 2015.
- [14] Diniz, J. M., & Botelho, R. V. (2017). Is fusion necessary for thoracolumbar burst fracture treated with spinal fixation? A systematic review and meta-analysis. *Journal of Neurosurgery: Spine*, 27 (5), 584-592.
- [15] Palmisani M, Gasbarrini A, Brodano GB, De Iure F, Cappuccio M, Boriani L, et al: Minimally invasive percutaneous fixation in the treatment of thoracic and lumbar spine fractures. *Eur Spine J* 18 (Suppl 1): 71-74, 2009.
- [16] Rajaei SS, Bae HW, Kanim LEA, Delamarter RB. Spinal fusion in the United States: analysis 31 of trends from 1998 to 2008. *Spine* 2012; 37: 67-76. doi: 10.1097/BRS.0b013e31820cccfb.
- [17] Sudo H, Oda I, Abumi K, Ito M, Kotani Y, Minami A. Biomechanical study on the effect of 16 five different lumbar reconstruction techniques on adjacent-level intradiscal pressure and 17 lamina strain. *J Neurosurg Spine* 2006; 5: 150-5. doi: 10.3171/spi.2006.5.2.150.
- [18] Levin, J. M., Tanenbaum, J. E., Steinmetz, M. P., Mroz, T. E., & Overley, S. C. (2018). Posterolateral fusion (PLF) versus transforaminal lumbar interbody fusion (TLIF) for spondylolisthesis: a systematic review and meta-analysis. *The Spine Journal*, 18 (6), 1088-1098.
- [19] Skaf, G. S., Domloj, N. T., Fehlings, M. G., Bouclaus, C. H., Sabbagh, A. S., Kanafani, Z. A., & Kanj, S. S. (2010). Pyogenic spondylodiscitis: an overview. *Journal of infection and public health*, 3 (1), 5-16.
- [20] Rutges, J. P. H. J., Kempen, D. H., Van Dijk, M., & Oner, F. C. (2016). Outcome of conservative and surgical treatment of pyogenic spondylodiscitis: a systematic literature review. *European Spine Journal*, 25 (4), 983-999.
- [21] Linhardt O, Matussek J, Refior HJ, Krodell A (2007) Long-term results of ventro-dorsal versus ventral instrumentation fusion in the treatment of spondylitis. *Int Orthop* 31 (1): 113-119. doi: 10.1007/s00264-006-0140-9.
- [22] Si M, Yang ZP, Li ZF, Yang Q, Li JM (2013) Anterior versus posterior fixation for the treatment of lumbar pyogenic vertebral osteomyelitis. *Orthopedics* 36 (6): 831-836.
- [23] Vcelak J, Chomiak J, Toth L (2014) Surgical treatment of lumbar spondylodiscitis: a comparison of two methods. *Int Orthop* 38 (7): 1425-1434. doi: 10.1007/s00264-014-2360-8.
- [24] Lee BH, Park JO, Kim HS, Lee HM, Cho BW, Moon SH (2014) Transpedicular curettage and drainage versus combined anterior and posterior surgery in infectious spondylodiscitis. *Indian J Orthop* 48 (1): 74-80. doi: 10.4103/0019-5413.125508.
- [25] Lin TY, Tsai TT, Lu ML, Niu CC, Hsieh MK, Fu TS, Lai PL, Chen LH, Chen WJ (2014) Comparison of two-stage open versus percutaneous pedicle screw fixation in treating pyogenic spondylodiscitis. *BMC Musculoskelet Disord* 15 (1): 443. doi: 10.1186/1471-2474-15-443.
- [26] Schomacher M, Finger T, Koeppen D, Suss O, Vajkoczy P, Kroppenstedt S, Cabraja M (2014) Application of titanium and polyetheretherketone cages in the treatment of pyogenic spondylodiscitis. *Clin Neurol Neurosurg* 127: 65-70. pii: S0303-8467(14)00389-8 42.
- [27] Yong HP, Jong DP, Choi YG, Lee SH (2008) Anterior debridement and fusion followed by posterior pedicle screw fixation in pyogenic spondylodiscitis: autologous iliac bone strut versus cage. *J Neurosurg Spine* 8 (5): 405-412.