

Progress, Challenges And Opportunities In Disc Space Preparation For Lumbar Interbody Fusion

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Citation

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Abstract

Lumbar interbody fusion from a posterior approach affords the advantage of adding interbody fusion to a posterolateral fusion while avoiding the added morbidity of an anterior approach to the spine. Transforaminal lumbar interbody fusion (TLIF) provides anterior column support through a single posterolateral approach to the disc space with minimal neural retraction and disruption of only one facet joint. While the cross-sectional area of bone required to obtain an adequate arthrodesis remains unclear, case series consistently report high fusion rates for TLIF. However, prior studies have demonstrated difficulty in removing sufficient disc material through a unilateral approach. It is believed that a larger area of bony contact between the grafts and the vertebral bodies heightens the chances of successful interbody fusion. However, specific regions of the disc space, such as the contralateral posterior quadrant, remain difficult to access with conventional instruments and techniques.

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INTRODUCTION

Posterior lumbar interbody fusion (PLIF) and its variations are gaining wide acceptance for the treatment of segmental instability, spondylolisthesis, and degenerative disc disease. There has been a renewed interest in posterior lumbar interbody fusion techniques because of the advantages of adding interbody fusion to the posterolateral fusion while avoiding the added morbidity of an anterior spinal approach.¹ Standard PLIF requires a wide laminectomy, partial or complete facet resection, and neural retraction.² PLIF is typically performed as a bilateral procedure. One of the concerns with the standard PLIF procedure is the amount of neural retraction required which could potentially lead to nerve root injury, dural laceration, and epidural fibrosis.³

Transforaminal lumbar interbody fusion (TLIF) was developed to address these issues. TLIF is a unilateral approach to provide anterior column support through a single posterolateral approach to the disc space.⁴ The disc space is accessed via a path that runs through the far lateral

portion of the intervertebral foramen, requiring minimal neural retraction and removal of only one facet joint.⁵ The advantage of the TLIF over PLIF is that it is usually performed unilaterally, thus, preserving the interlaminar surface on the contralateral side, which can be used as a site for additional fusion. In addition, it minimizes manipulation of neural structures, thus reducing the incidence of epidural fibrosis.

Comparison of posterior and transforaminal approaches to lumbar interbody fusion reveals no significant difference in terms of blood loss, operative time, or duration of hospital stay when a single level fusion is performed. However, fewer complications occur with the transforaminal approach compared to the multiple complications associated with the posterior approach.⁶ However, infections, dural lacerations, nerve root injuries, and pseudoarthroses are still reported.^{5, 7, 8}

DISCUSSION OF TECHNIQUES

For a solid fusion to occur it is essential that a thorough discectomy be performed, as well as, thorough removal of vertebral endplate cartilage. Failure to do so could result in nonunion and development of a pseudoarthrosis. While conventional TLIF has been shown to reduce complications, there is evidence that posterior unilateral techniques do not permit as thorough a discectomy and endplate preparation. Javernick, et al reported removal of 69% of total disc

volume using a unilateral surgical technique. In contrast, postoperative CT images confirmed more than 80% cross-sectional area of removed disc per level using a bilateral PLIF technique. A bilateral approach was recommended for some implants to avoid possible contralateral neural compromise by retropulsed disc material after graft or implant insertion.⁹

Cloward introduced the PLIF procedure in 1945. He advocated removal of almost the entire disc, leaving the adjacent surfaces of the vertebrae completely clean of all soft tissue (Figure 1). "As much of the disc as possible is taken out, extending removal to as near the anterior longitudinal ligament as possible."¹⁰ The early acceptance of PLIF was less than enthusiastic, perhaps due to the technically demanding nature of the procedure. By the late 70's, interest began to increase and the PLIF technique continued to evolve.

Figure 1

Figure 1



The attempted total discectomy, in reality, involves only the posterior 80% of the disc space.¹¹ In PLIF, 80% to 90% of the posterior disc material should be removed. A larger area of bony contact between the grafts and the vertebral bodies heightens the chances of successful interbody fusion.¹² The major criticism of the unilateral posterior lumbar interbody fusion procedures, such as TLIF, is that the use of a unilateral discectomy decreases the probability of fusion because it decreases the prepared surface area between graft and host. While most agree that it is necessary to graft at least 50% of the total disc area, computation on CT scans reveal that less than 50% of the disc area is actually grafted in many cases.¹³ While the minimal cross-sectional area of endplate required to achieve fusion has not been clearly

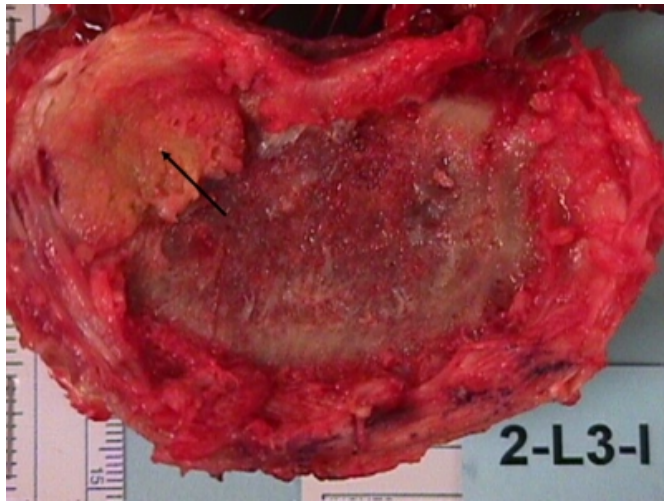
established, from a biologic and biomechanical standpoint, the greater the available surface area the better. One in vitro study revealed that 80% of the vertebral bodies with graft covering 25% of the total endplate area or less failed at loads less than 600 N, while 88% of the vertebral bodies with 30% or greater endplate area covered were able to carry a load greater than 600 N.¹⁴ However, 600 N is not an unexpected level of force to be exerted on the lumbar disc, so these results suggest that interbody graft area should be significantly greater than 30% of the total endplate area to provide a margin of safety. Reports of various studies have demonstrated fusion rates with TLIF similar to those expected using other interbody fusion techniques.^{5, 6, 7, 8}

Regardless of the technique used, the goal is to maximize the area of exposed vascular bone. In general, the larger the surface area decorticated for fusion, the greater the availability of potential osteogenic cells and the larger the contact area exposed to support a bony bridge large enough to carry a mechanical load. There is little data to study the effect of decreased fusion surface area, although clinical experience from repair of nonunions suggests that inadequate decortication, insufficient quantity of bone graft, and inadequate removal of interposing soft tissues can predispose to nonunion.¹⁵ Unless a massive graft is employed to replace the excised disc, a pseudoarthrosis is likely to occur because it is easier for fibrous tissue derived from the remnants of the disc to invade the graft than it is for bone to grow from one vertebral body to the other.¹⁶ The only tissue in the disc space should be bone graft. Loose or empty spaces will be invaded by fibrous tissue and thus delay osteosynthesis.¹⁷ When nucleus pulposus is mixed with the autogenous bone graft in an interbody fusion cage, it can delay or decrease the bone formation inside the cage, thus influencing the final fusion.¹⁸

Additionally, excessive tissue remaining in the disc space can be displaced by the implant, causing iatrogenic herniation. The region of the disc space most difficult to access through a unilateral annulotomy is the contralateral posterior quadrant (Figure 2). This is the disc material most at risk for herniation following displacement by a large implant.

Figure 2

Figure 2

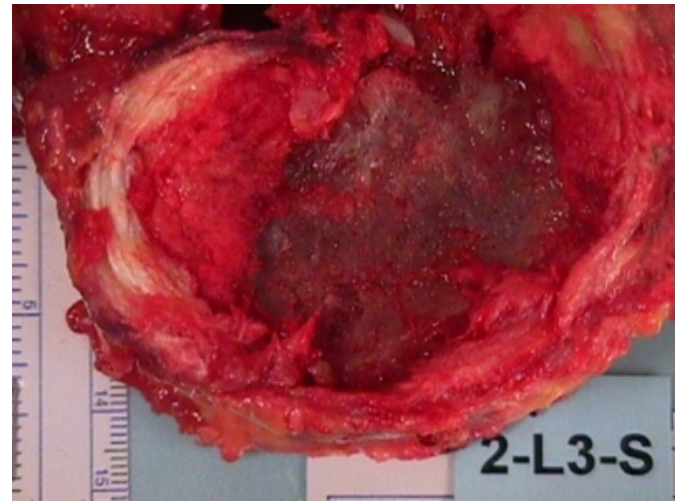


Host site and graft preparation are crucial, not only to ensure optimal conditions for fusion but also to guarantee a strong, stable construct. Adequate compressive strength can be attained with an interbody graft if the force is uniformly distributed across a large area of bone graft. In order to safely carry body weight without detectable crushing of the bone tissue, the graft must cover approximately two-thirds of the area of the endplate.¹⁰

To enable fusion, a sufficient amount of potentially osteogenic cells is necessary; therefore, bleeding bone must be present adjacent to the graft. Two techniques of endplate preparation can be distinguished. One includes deliberate endplate cavitation to provide a host bed of bleeding cancellous bone. The other technique involves excision of the cartilage endplate down to bleeding subchondral bone.²⁰ The decortication need not be total, nor should it extend deep into vascular soft cancellous bone. The endplate is a very thin shell of bone (usually < 0.5-mm thick); however, it may serve to distribute the load more evenly over the underlying strut-like trabecular bone to provide additional strength. An in vitro study demonstrated that the compressive strength and stiffness of the vertebral body are both reduced by 54% when the endplate is removed, increasing the risk of implant subsidence.²¹ The removal of only a very thin layer of cortical endplate, a mere change in color from white cortical endplate to a brownish subcortical cancellous bone, is sufficient to assure an adequate source of vascularization. Because the bony texture is more porous in the central portion of the vertebral body, thin decortication would prevent settlement of the graft due to softness of the cancellous bone.¹²

Figure 3

Figure 3



The thin layer of subchondral cortical bone is stronger than the underlying cancellous bone of the vertebral body. Subsidence of interbody fusion constructs in adjacent endplates is a frequent mode of failure.²⁰ Bone mineral density (BMD) of the vertebral endplate is higher at the periphery and lowest in the middle of the endplate. The endplates are thicker in the anterior and posterior regions as compared to the central region. These properties define the center of the endplate as being the weakest region. As such, interbody fusion constructs should rest on the anterior or posterior periphery of the vertebral endplate. While removal of the endplate subchondral cortical bone provides a bleeding interface for fusion; it may present an increased risk of graft or cage subsidence. Additionally, placement of implants in the weaker central region of the vertebral endplate could cause early failure.²⁰ Removal of the endplate has a negative effect on the vertebral bone strength and thus increases the risk of implant subsidence.²¹

Figure 4

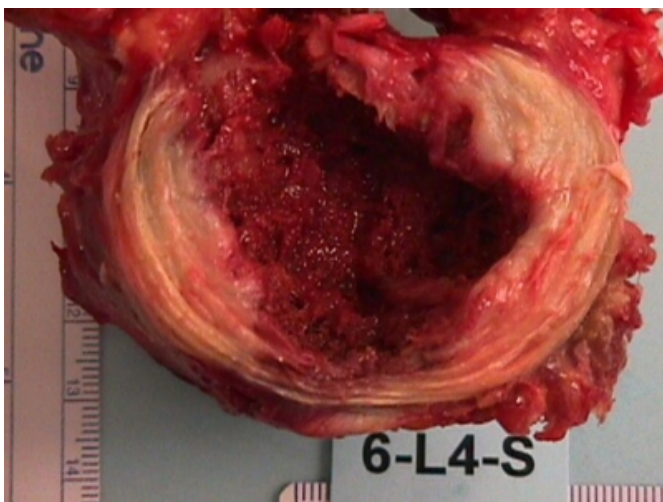
Figure 4



A lumbar interbody fusion implant with approximately 30% endplate surface contact through a rim resting on the peripheral endplate offers compressive strength similar to that of an implant with full surface area in contact with the endplate. It also appears that the more an implant rests on the periphery of the endplate, the better its compressive strength, regardless of implant surface area in contact with the endplate. The advantage of such an implant concept is that the graft material placed inside the implant can be in direct contact on a larger and non-interrupted surface with the host bone. Finally, removal of the central bony endplate in areas where the implant is not in direct contact with cortical bone does not reduce the compressive strength of the vertebra. However, it may improve the biologic potential of the host bed to incorporate the graft material.²²

Figure 5

Figure 5



CONCLUSION

In summary, advances in surgical technique have reduced complications in lumbar interbody fusion surgery, but unintended damage to neural structures still persists. The same advances that contribute to the prevention of these adverse events make preparation of the disc space more difficult, potentially causing problems with graft or cage placement, ingrowth of fibrous tissue, or insufficient host/implant contact leading to pseudoarthrosis. While future improvements in lumbar interbody fusion outcomes may result from further advances in implants and biologics, significant opportunities for improvement exist in the tools and methods employed. Tools designed for the transforaminal approach that allow preparation of a greater proportion of the disc space, and powered tools that reduce the time and manual insertions and withdrawals required to prepare the site, could provide tangible benefit. And as we have seen in other medical interventions, smaller more efficient devices could enable the adoption of more minimally invasive techniques. Table 1 below recapitulates these points.

Figure 6

Table 1

Challenge	Impact	Opportunity
Less traumatic disc preparation	Less damage to neural structures and fewer complications	Powered tools that reduce the manual insertions and withdrawals required to prepare the site
Faster disc space preparation	Shorter procedure and anesthesia time, and reduced risk of infection	Powered tools that reduce the time required to prepare the site
More complete removal of nucleus	Increased cross sectional area for fusion, reduced problems with graft or cage placement, ingrowth of fibrous tissue, or insufficient host/implant contact leading to pseudoarthrosis	Tools designed to provide improved access to the disc space in a TLIF approach
More precise endplate preparation	Reduced subsidence and pseudoarthrosis	Devices designed to remove endplate cartilage without damaging the thin bony endplate

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