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REVIEW

Stand-Alone Anterior Lumbar Interbody Fusion: Indications, Techniques, Surgical Outcome and Complications

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Abstract

Introduction: Anterior lumbar interbody fusion (ALIF) is a well-established technique to achieve lumbar spine fusion with various indications including degenerative disc disease, spondylolisthesis, recurrent disc herniation, adjacent level disease, pseudoarthrosis, as well as being used as part of the overall strategy to restore sagittal balance. ALIF can be an extremely useful tool in any spine surgeon's armamentarium. However, like any surgical procedure, proper patient selection is key to success. A solid understanding of the biomechanics, careful surgical planning, along with clear knowledge of the advantages and disadvantages of stand-alone ALIF will ensure optimal clinical outcome. Stand-alone ALIF may be a suitable surgical option in carefully selected patients that can provide good clinical results and adequate fusion rates without the need for posterior instrumentation

Areas Covered: A brief overview of the indications, techniques, biomechanics, surgical outcome and complications of stand-alone ALIF is provided in this article with a review of the pertinent literature.

Expert Commentary: In this review we discuss the clinical evidence of using a stand-alone ALIF compared to other fusion techniques of the lumbar spine. The development of interbody cages with integrated screws has increased the arthrodesis rate and improved clinical outcomes while decreasing morbidity and operative time.

1.0 Introduction

Each year, lumbar disc disease results in over 13 million visits to physicians in the United States affecting men and women of the age 20 to 50.[16,27,43] An estimated 26 billion dollars is spent in the United States each year to treat lower back pain. With the continued advancement of surgical instrumentation and techniques, the options for treating lumbar degenerative disease continue to grow. The indications for lumbar fusion includes spondylolisthesis, degenerative disc disease, recurrent lumbar disc herniation, post-discectomy collapse and neural foraminal stenosis with radiculopathy, pseudoarthrosis, iatrogenic kyphosis, or the treatment of sagittal and/or coronal deformity. However, there are various factors including age, gender, specific pathology, potential complications and anatomical restrictions that clinicians must consider when selecting an appropriate fusion technique.[45,46]

The anterior lumbar interbody fusion (ALIF) procedure is a valuable tool for the treatment of a number of lumbar pathologies and it has been proven as an effective method to achieve interbody fusion.[19] The anterior and middle column provides 80% of the weight bearing load of the spinal column.[46,67] An anterior approach to the lumbar spine offers the opportunity for complete disc removal and placement of a larger interbody graft that can encompass over 90% of the osseous surface area to increase the potential for fusion.[46] Additionally, an ALIF can eliminate discogenic back pain by performing a complete discectomy, provide indirect decompression of the neural foramina by restoring disc height, allow for direct visualization of the vertebral bodies and maximize lumbar lordosis in the setting of restoring sagittal balance.[10,17,48,59]

Historically, the initial stand-alone ALIF surgery with threaded cages and femoral ring allografts only yielded adequate results. Clinical failure and radiographic pseudoarthrosis were not uncommon. The failures of the ALIF surgery led to the use of posterior instrumentation in addition to the ALIF surgery. The 360-degree fusion, which included a separate anterior and posterior approach, became increasingly common. However, disadvantages of a 360-degree fusion included increased hospitalization stay, longer intraoperative time, and an increased estimated blood loss (EBL).[32,56] The morbidity and scope of the 360-degree fusion led to the adoption of the posterior lumbar interbody fusion (PLIF) and transforaminal lumbar interbody fusion (TLIF) techniques which provided interbody placement and posterior instrumentation in one step. Hence, the stand-alone ALIF and 360-degree procedure became less common.

The growth of technology in medical spine devices has provided the opportunity for the ALIF surgery to be performed with new anterior interbody fixation devices. The idea was that stronger anterior fixation would result in higher fusion rates and negate the need for posterior instrumentation. Therefore, surgeons could still utilize the several advantages of performing an ALIF surgery including a large surface area for arthrodesis, the indirect decompression of the neural structures, and the ability to restore sagittal alignment without the morbidity and surgical time needed for posterior instrumentation or a 360-degree fusion.

2.0 Preoperative evaluation

Successful outcomes in any surgical procedure depends on appropriate patient selection. Patients that often benefit from spinal fusion includes those with lower back pain secondary to degenerative disk disease, pain with axial loading, segmental instability or sagittal deformity on plain radiography, or positive findings on discography. (Figure 1 and 2)[10,14,46] Other indications of ALIF may include spondylolisthesis, recurrent disc herniation, adjacent level disease, pseudoarthrosis, and sagittal imbalance There is no single test that will be a definitive indication for surgery, but rather clinical suspicion with supporting radiographic imaging and testing will point the clinician toward an appropriate candidate for surgery. Additionally, discography may be beneficial in the setting of multiple levels of disc degeneration; however, some believe that undergoing discography in of in itself can accelerate disc degeneration and iatrogenic injury. [13] While back pain complaints are common in the population, most patients are not candidates for surgery. Patients with diffuse degenerative changes at multiple levels with back pain are often poor candidates for surgery. In our clinical practice, we generally limit ALIF surgery to one level in cases of degenerative disk disease.

Preoperative MRI must be carefully reviewed to assess the extent of disc degeneration, the degree of central and foraminal stenosis, the vascular anatomy including the aortic bifurcation and sacral slope. A computed tomography (CT) myelogram can be used in patients with prior surgical hardware or have a contraindication to MRI. Plain radiographs including scoliosis films, if possible, should also be obtained to evaluate segmental lordosis and sagittal alignment. Flexion/extension lumbar x-rays may be beneficial, as patients with mobile spondylolisthesis should avoid ALIF surgery. Additionally, plain radiographs may reveal calcifications that may suggest undiagnosed vascular disease that may limit mobilization of vascular structures during the ALIF exposure.

3.0 Surgical Techniques

The patient is placed supine on a radiolucent operating room table and undergoes general endotracheal intubation. The arms are placed abducted on arm-holders with appropriate padding. Fluoroscopy is used to localize the intended discs level and adequate surgical corridor. The incision is marked slightly lateral to midline in line with the angle of the disk on the left side. We typically use a Pfannenstiel transverse incision.

After prepping and draping, the skin incision is made and subcutaneous tissue divided in a layered fashion. The anterior rectus sheath and the rectus muscles are retracted medially. Laterally, the abdominal wall is composed of three layers: the external and internal oblique muscles and the transversus abdominis. The fascial layer of each of these muscles form the anterior to posterior, and the recuts sheath encases the rectus muscle. The transversalis fascia is identified and stripped off its insertion into the abdominal wall. Next, the peritoneum is elevated off the psoas muscle posteriorly and medially using blunt dissection. The genitofemoral nerve and the ureter are then visualized coursing along the psoas muscle and gently retracted medially to avoid injury.

A critical step in the ALIF approach is negotiating the vasculature anterior to the lumbar vertebral body. At the L5/S1 disc space, the common iliac artery or vein and middle sacral vessels are often encountered. The middle sacral artery may obstruct the L5/S1 disc space and thus need to be ligated to obtain adequate exposure of the disc space. At the L4/5 level, the iliolumbar vein(s) must be ligated and cut to prevent stretch when retracted. The aorta typically bifurcates above the L4/5 disc space but can be located below the disc space. Bleeding should be controlled with pressure, Gelfoam, vascular clips or bipolar; monopolar cautery should be avoided since it may increase the risk of injury to the sympathetic plexus which is found on the lateral aspect of the vertebral bodies and forms the hypogastric plexus. After adequate surgical corridor is obtained, retractor blades are then inserted and secured in placed with a table-mounted holder.

The intended disc space is then identified and confirmed with fluoroscopy. The disc is opened using either a scalpel or a monopolar cautery with insulated tip. A Cobb retractor is used to develop a plane between the subchondral bone and cartilaginous end plate. Disc rongeurs and curettes are used to complete the discectomy. Paddle distractors are used to distract the disc in a progressive fashion to increase and maintain disc height. The posterior longitudinal ligament may be visible depending on the amount of osteophytes present in the posterior vertebral disc space. The endplates are prepared for arthrodesis by using curettes and rasps to obtain a bleeding surface. However, it is important to preserve the endplate to decrease the risk of implant subsidence. A trial implant is used to determine the size of the interbody. The interbody device is then packed with allograft and often with rhBMP. The implant must be aligned with the disc space to avoid breaking the endplates, which can lead to implant settling and loss of lordosis. Overly aggressive insertion or impaction of the implant can cause a fracture of the posterior vertebral body, compression of the thecal sac or nerve root impingement. Fluoroscopy should be used to ensure correct position of the implant.

In cases of stand-alone ALIF, the majority of anterior implants incorporate screw fixation into the implant itself, while others use an anterior plating system although this is used less frequently.[4,21,31,33,37,48,63] For screw insertion, a drill-guide is attached to the implant and screw holes are made. Fluoroscopy is used to guide insertion of the screws into the superior and inferior endplate of the adjacent levels. After interbody device is secured in place, the retractor blades are slowly removed while checking for any bleeding from surround tissues. The first retractor blade to be released should be the one retracting all the vasculature in case of vascular injury so that it may be addressed first. The right side retractor is removed last. The peritoneum and its contents are returned to its normal anatomic position and fascia closed. Subcutaneous tissue and skin are closed in layers.

4.0 Types of Implants

Anterior interbody constructs were developed based on the distraction-compression principles of Bagby.[3] Biomechanically, the anterior approach provides more stability to the anterior column compared to TLIF given the large surface area provided by the anteriorly inserted large graft. The interbody placed in the disc space also restores disc height, increases segmental lordosis, improves sagittal alignment and provides indirect decompression of the foraminal roots.[46,68]

Burns was the first to describe the ALIF procedure in 1933 for the treatment of spondylolisthesis.[4] Over the last several decades, the choice of interbody graft has increased over the last several decades and includes autograft iliac crest, cortical allograft or synthetic bone, threaded cylindrical titanium cages, impact titanium cages, carbon fiber reinforced or plain PEEK polymer, and impact carbon fiber reinforced PEEK wedges.[30,65,68] Osteoinductive materials such as bone morphogenetic protein (rhBMP-2) has been developed and remains the only approved indication for the use of rhBMP.[10]

Several biomechanical studies have evaluated the use range of motion (ROM) in the cadaver spine using graft only in neutral, lateral, flexion/extension, and axial rotation. ALIF provides a significant decrease in ROM during flexion, axial rotation and lateral bending when compared to the posterior fixation. Extension remains less stable compared to posterior fusion because of the disruption of anterior annulus or distraction of the facets; however, it is thought that it may be less disruptive than performing a partial facetectomy in posterior fusion.[52] Several different implant designs are currently widely used and briefly reviewed below.

4.1 Graft-only Stand-alone ALIF

In order to maintain disc height, an interbody is placed in the disc space with the primary goal being achieving solid arthrodesis at the index level. However, a graft-only construct in stand-alone ALIF has relative biomechanical strength. Nibu et al. evaluated the BAK interbody fusion device (Spine Tech Inc., Minneapolis, MN, U.S.A)which was composed of two titanium screw cages. Using an L5/S1 anterior interbody approach, they found that there was a significant increase in ROM during extension which is likely secondary to the disruption of the anterior annulus.[47] However, similar findings are noted during posterior approach interbody placement. Hence, it is thought that it may be the distraction of the facets that contributes to the increase motion during extension.[41,51,58] Glazer et al. evaluated three different anterior interbody fusion devices: a threaded cylindrical cage, a femoral ring allograft, and a corticonacncellous bone graft. They found that the femoral ring was stiffer than either the threaded interbody in flexion and corticocancellous bone graft in flexion and compression. The threaded cylindrical interbody fusion device was strongest in axial torsion. However, these constructs did not provide stability in extension.[24] Tsantrizos et al. compared the biomechanics of five different stand-alone ALIF cages (I/F, BAK, TIS, SynCage, and ScrewCage). ROM was found to be significantly reduced but there was still residual ROM that suggests micromotion with the graft-only construct. The difference in motion between each of the cages is due to the geometry mismatch between the endplate and cage. Additionally, cages with sharper teeth had higher pullout forces.[62]

Oxland et al. performed biomechanical study evaluation of two cages (BAK and SynCage) and assessed stability (ROM) without and with translaminar screw placement. In all areas of motion except for extension, the use of cages alone provided stabilization of the spine. The addition of translaminar fixation provided a stronger construct in extension.[51] Similar results by Rathonyi et al. using the BAK cage and found that in the cage only group, stability of the segment was significant in all motions except axial rotation and extension. The addition of translaminar fixation provided stability with these two movements and the strongest fixation.[58]

Attempts of evaluating stability under in vitro conditions were described by Phillips et al. by taking into account compressive forces. This biomechanical study involved using 2 BAK interbody grafts without and with transfacet posterior fixation under normal and high preloads. Significant stability of the region was noted in both groups except during normal preloads during extension in the cage only group. However, during higher preloads, the ROM during extension decreased. Interestingly, even with transfacet posterior fixation, the ROM during extension was not found to be significant compared to the cage-only group in the setting of higher preloads.[54] *In vivo*, the interbody spacer is placed in varying degrees of compression forces depending on the activity and is thought due to these findings that posterior instrumentation may help with stability and situations that the graft is most subject to movement.[53,54] Interestingly, Volkman et al. evaluated a similar construct but with only one BAK interbody graft and did find a significant increase in stiffness during extension between the cage-only group and the cage with transfacet posterior fixation.[54,66]

Some report using a “stop” or “blocking” screw (single screw in the adjacent superior vertebral body) to keep the interbody in place. However, this was used in the setting of posterior instrumentation as well. No biomechanical study was found evaluating the stability of using only the stop screw with an interbody.[5,6] Finally, Rao et al. found a significant changes in intradiscal pressures at adjacent levels following single level stand-alone ALIF procedure with paired LT cages.[57]

4.2 Stand-alone ALIF with integrated screws

Due to graft failure, decrease in stability without posterior fixation and lower arthrodesis rates, stand-alone interbody cages evolved to include integrated screws with the intention of preventing these complications. (Figure 3 and 4) However, there are relative contraindications for the use of stand-alone ALIF with integrated screws which includes spinal fractures, spinal tumor, osteoporosis, infection, spondylolisthesis and severe segmental instability.[60]

An early biomechanical study evaluating integrated screw fixation conducted by Kuzhupilly et al. who evaluated the stability of a femoral ring allografts (FRA)-only group compared to a group using a FRA interbody with integrated crossed screws. They found an overall increase in stiffness during extension using the FRA interbody with integrated crossed screw group but did not find a significant increase in stiffness in other motions when compared to the FRA-only group.[36]

Kornblum et al. performed in vitro biomechanical study using a lordotic PEEK interbody cage with integrated screws. They compared cage-only, cage with anterior plating, cage with integrated screws (three vs four screws), and cage with either pedicle screw or spinous process plate fixation. When using a cage with integrated screw, there between either group??? but there was more motion when only using three screws. Additionally, the cage with integrated screw group reduced ROM significantly in comparison to the cage-only group. In flexion-extension, a cage with spinous process plate or pedicle screw fixation was statistically stronger than the cage with integrated screws. The spinous process plate fixation and the cage with integrated screws provided the strongest construct in this motion. In lateral bending, there was no difference between the cage with anterior plating group and the cage with integrated screws group; however, the cage with bilateral pedicle screw group was the strongest. In axial rotation, there was not significant difference between the cage with integrated screws compared to those with supplemental fixation.[33]

Schleicher et al. evaluated the biomechanical aspects of two different anterior interbody stand-alone with integrated screw systems composed PEEK in flexion and extension at L4/5 and load bearing properties on each cage. They found that during flexion, the load bearing properties of the construct was primarily placed on the cage itself, while during extension, the load was primarily placed on the screw and plate junction. Additionally, the two interbody devices had different screw directions, one with integrated screws pointing toward the periphery of the vertebral body while the other with integrated screws pointed to the center of the vertebral body. The more stable segment in lateral bending, extension, and axial rotation had screw fixation pointed toward the periphery of the vertebral body.[60]

Cain et al. performed an *in vitro* biomechanical study evaluating stand-alone anterior interbody cage that had an incorporated an integrated but biomechanically separate anterior titanium plate and locking screw fixation similar to an integrated screw system. Results revealed stability of the stand-alone implant with equivalent if not superior stabilization compared to anterior cage with translaminar and pedicle screw fixation.[12]

Beaubien et al. also reports on a biomechanical study evaluating a PEEK interbody spacer with integrated screws and stand-alone threaded interbody and found that with integrated screws, there was a significant reduction in motion all directions with the most beneficial in torsional rigidity. Additionally, pullout strength was significantly higher when using an interbody with integrated screws.[5]

4.3 Stand-alone ALIF with Anterior Plating Systems

Humphries et al. was the first to describe using an anterior plate for stabilization of the ALIF technique. The loss of the anterior longitudinal band does remove some of the stability in the region. By using an anterior plate, this may restore the anterior tension band and provide stability similar to that of pedicle screws.[4,33] However, it was found out that the majority of the anterior plates were bulky, difficult to place given the major vessels with only a minor gain in stability limited its use.[12,28] This technique often carried the risk of longer dissection times in order to place the plate appropriately.[36]

Glazer et al. described a multilevel lumbar biomechanical study using an anterior construct composed of two hollow screws connected to a threaded cylindrical interbody device, attached to a rod, which provided the stability and stiffness to the lumbar region. The authors suggested that locking the system in extension may provide a more rigid construct.[23,36]

Beaubien et al. performed a biomechanical study using a thin anterior plate in addition to an anterior interbody device and found that the anterior plate significantly stabilized the fusion segment. Also there was a significant decrease in the ROM of that segment during flexion/extension and axial torsion. However, transfacet or transpedical screws stabilized the segment even further.[4] Tzermiadianos et al. reported similar results when evaluating an anterior graft using an anterior plate in comparison to an anteriorly placed graft with posterior transpedicular instrumentation at L5/S1. The anterior plate provided a significant decrease in the

ROM during flexion-extension but transpedicular instrumentation provided even more significant stability in flexion/extension and lateral bending.[63]

Nichols et al. evaluated the use of an anterior plate with a 6-degree lordotic polyvinylchloride ring. The anterior plate provided a significant decrease in ROM during flexion only. Additionally when using the lordotic cage they found an insignificant but notable decrease in stability in all motions besides lateral bending which they attribute to the lordosis of the cage.[48]

The shape of the anterior plate changed to accommodate the bifurcation of the vessels at L5/S1. Gerber et al. evaluated the biomechanics of two parallel cages without posterior instrumentation, a triangular plate with interbody and an anterior interbody with no pedicle screws with rods at L5/S1. Interestingly, there was no statistical difference between the anterior triangular screw-plate and the pedicle screw with rods in flexion, extension, and axial rotation. However during lateral bending, the anterior interbody and pedicle screws provided a more rigid construct.[21] A follow-up study at the same lab evaluated the biomechanics of an anterior plating system at L4/5 with and without the use of an interspinous fixation device or pedicle screw fixation. Karahalios et al. found that pedicle screws were superior except for axial torsion when compared to ALIF with anterior plating only. This was thought to be secondary to a different intervertebral disc level.[31]

5.0 Fusion and Clinical Outcomes

Arthrodesis is one of the main radiographic outcomes desired in the setting of improved functional mobility, quality of life, and decreased pain. It has been well-established that immobilization of the spine with instrumentation stabilizes and reduces motion which promotes arthrodesis and corrects deformity.[8,40] In order to promote arthrodesis, interbody spacers were developed to transmit the load without significant motion until arthrodesis could be achieved. Implants promoting arthrodesis can be composed of either autologous iliac crest graft, structural allograft, bone chips with metallic cages, titanium mesh cages, cylindrical threaded titanium cages, carbon fiber cages and poly-ether-ether-ketone (PEEK) cages.[68]

Fusion outcomes have varied in the stand-alone ALIF literature. McCarthy et al. evaluated the radiographic fusion of patients who had a stand-alone ALIF vs. an ALIF with posterior pedicle screw instrumentation. Of the 40 patients that underwent a stand-alone ALIF, only 65% had complete fusion at 19 months compared to 100% in those that underwent anterior and posterior fixation.[44] Ishihara et al. reported a 10-year follow-up study on patients undergoing ALIF. Of the 35 patients there was an 83% fusion rate but adjacent disc degeneration in up to 70% of patients.[29] Kumar et al found a 66% fusion rate and graft subsidence of 4mm in 84% of patients using a femoral strut allograft.

The first reports of both clinical and radiographic outcomes using an interbody only ALIF reported poor outcomes. Holte et al. reported on a series of 40 patients undergoing either an ALIF or ALIF with posterior fixation using femoral cortical allograft bone with iliac crest cancellous autograft bone. A fusion rate of 75% was noted in the ALIF only group and 98% in the combined group. These results are limited given that only 8 patients underwent ALIF only and 32 had an ALIF with posterior fixation.[26] Button et al. evaluated a series of 46 consecutive patients who underwent placement of an anterior BAK cage alone and found significantly worse clinical outcomes in which 22% of patients required revision surgery and 70% had fair or poor outcomes with a high rate of pseudoarthrosis.[11] In a multicenter FDA clinical trial measuring the safety and efficacy of ALIF with an I/F cage only, Li et al. found overall patient success was only 25% and a fusion rate of 57%. A total of 80 patients completed the two-year follow up. Clinical success was defined as a decrease in 15 points on ODI, successful radiographic fusion, no second surgery within two years and new neurologic abnormality.[38] However, in a large prospective multicenter trial of 947 patients, Kuslich et al. evaluated patients undergoing a BAK interbody placement with no supplementary fixation. They reported a 91% fusion rate, satisfactory reduction of pain in 84% and function improved in 91% of patients.[35] Similarly Kozak et al. reported a series of 45 patients undergoing a stand-alone ALIF and found successful arthrodesis in 97% of the patients. In this series, they used an anterior buttress screw plate to prevent the graft from dislodging from the vertebral disk space but it did not prevent motion of the graft within the disk space.[34,36] Choi et al. also evaluated a series of 90 patients who underwent a stand-alone ALIF with rectangular cages and found a 76% incidence of subsidence into the superior endplate of the vertebral body but there was no statistical clinical correlation with outcomes and concluded that subsidence was an expected finding in this group of patients.[15] Beutler et al. also found that subsidence was not correlated to clinical outcomes and would more often occur at L4/5 and with larger cages.

As newer interbody devices were developed, successful arthrodesis and better clinical outcomes were achieved. Strube et al. preformed a prospective study on 40 patients that either underwent a stand-alone ALIF with integrated screws using the SynFix LR system or an anterior posterior approach for a single level lumbar fusion. They found that VAS and ODI improved over time in both groups but significantly better in the stand-alone ALIF group. Patient satisfaction was significantly higher but there no significant difference in the fusion. They concluded that if there was no need for a posterior decompression, that a stand-alone ALIF could be successfully used in cases of single level DDD.[61] Allian et al. reported a prospective series of 65 patients who underwent ALIF with a PEEK cage with intracorporeal self-locking system and found a fusion rate of 96% and 2% subsidence. Significant clinical improvements in VAS, ODI, quality of life and decreased narcotic use were reported.[1]

Several studies have evaluated the use of posterior fixation with ALIF. Anjarwalla et al. reported a series of 81 patients who underwent ALIF, ALIF with translaminar screws, and ALIF with either unilateral or bilateral pedicle screw fixation. They found pedicle screw fixation provided a significant impact on fusion only but not on clinical outcomes when compared to the ALIF group. Translaminar fixation did not provide any significant differences in fusion or clinical outcomes.[2] Madan et al. performed a 2-year retrospective review on patients with stand-alone ALIF compared to PLIF. There was no significant difference in ODI scores between the ALIF and PLIF group. Improvement in working ability was 64% in the standalone ALIF group and 68.6% in the PLIF group. Complications included sciatica in the ALIF, which improved with repositioning of the instrumentation. [42] Udby et al. and Freudenberge et al. reported a series of patients undergoing stand-alone ALIF in comparison to TLIF and PLF respectively. The former study was limited to 9 patients in the standalone ALIF and 12 patients in the TLIF group. Both groups had significant improvement in pain scores and opioid medicine reduction at 6 months' post-op although the stand-alone ALIF group had better results. Operative time and EBL were significantly shorter in the stand-alone ALIF group compared to TLIF. There was no change in hospitalization stay between both groups. The latter series reported a retrospective series of 59 patients who underwent an ALIF with anterior plate or PLF. They found a significant decrease in mean surgical time in the ALIF group but EBL was not significant. There was no difference in

ODI scores or fusion. Complications were limited to two common iliac vein injuries and one postoperative thrombus in latter study. [18,64]

Glassman et al. performed a large retrospective review of 497 patients who either underwent a 1-2 stand-alone ALIF, ALIF with posterior fusion, PLIF, or TLIF. At one year follow up, the stand-alone ALIF group had better SF-36 improvement than the PLIF, PLIF/TLIF group and ALIF with posterior fusion. At 2-year follow-up, the stand-alone ALIF and PLF groups remained significantly better that the other surgical procedures. ODI was significantly better in the stand–alone ALIF group at both 1 and 2 year follow up.[22] Ohtoir et al. reported on a prospective 2 year follow up series of 46 patients with L4/5 spondylolisthesis corrected with either a non-instrumented ALIF or PLF and found that patients undergoing ALIF had significantly greater improvement in lower back pain but had longer hospitalization times.[49]

Using the Nationwide Inpatient Sample (NIS) database, Goz et al. evaluated 923,038 patients who underwent an ALIF, PLF/TLIF, and anterior/posterior lumbar interbody fusion. They found that ALIF and the anterior/posterior lumbar interbody fusion group both accounted for 10% of spinal procedure in 2001. However, by 2010 these operations accounted for 15% and 1% of all lumbar fusions respectively. Anterior/posterior lumbar interbody fusion accounted for a higher expenditure ($92,249) compared to ALIF only group ($75,872). Contrary to other case series', they found that the mortality rate was significantly higher in patients undergoing ALIF-only group (0.25%) vs the anterior/posterior lumbar interbody fusion group (0.18) and the complication rate was higher in the ALIF only-group after adjusting for age, gender, race and fusion length. The reason for the above remains unclear but the authors have attributed these findings to a more careful patient selection of patients for the anterior/posterior lumbar interbody fusion group that was not captured by the gross adjustment for comorbidity burden and differences in the perioperative management.[25]

The only FDA approved indication for rhBMP is during an ALIF. Lammli et al. published a series of 118 patients with degenerative disc disease that underwent either a 1 or 2 level stand-alone ALIF at L4-S1 using rhBMP in either an interbody alone, an interbody with integrated screws or an interbody with a anterior plating system. They found significant improvement in ODI and VAS scores, a significant increase in disc height, 93% fusion rate and no evidence of adjacent segment disease at 2-year follow-up. Additionally, there was a decrease in EBL, hospital stay and intraoperative time when compared to ALIF with posterior fixation. [37]

Burkus et al. demonstrated that the use of rhBMP-2 (Infuse, Medtronic Sofamor Danek, Memphis TN) during an ALIF in LT cages (Medtronic Sofamor Danek, Memphis TN) resulted in a fusion rate of over 94%.[10] However, in a comparison prospective study of patients undergoing FRA with autogenous iliac bone graft vs FRA with rhBMP2, Pradhan et al. found that the nonunion rate was higher in the rhBMP group and the study that study arm was terminated early. The authors contributed these findings to the aggressive resorptive phase of allograft incorporation prior to the osteoinduction phase.[55]

6.0 Complications

At any stage of the surgery, several anatomical structures are at risk during an ALIF including the abdominal viscera, great vessels, and the nerve roots. Because of the location of the disc, vessel mobilization is required. Vascular injury ranges from 1 to 24%.[20] Deep venous thrombosis ranges from 0.7 to 5%.[7]

Adequate access and maintenance of the disc space is essential for a straightforward surgical approach. Other vessels that may affect access include the common iliac vein, epigastric vessels and iliolumbar vein during L4/5 approaches. Early ligation of certain vessels may mitigate the risk of inadvertent tears which is more likely to occur in patients with vascular disease, retractor placement, and prior surgery.[50] Hemodynamic instability may occur due to blood loss, retroperitoneal hematoma, thromboembolic events from prolonged retractor use, pseudo aneurysms and arteriovenous fistulas can occur secondary to vascular injury.[20]

The lumbar prevertebral sympathetic plexus runs along the anterolateral edge of the vertebral bodies, adjacent to the psoas and traverses over the aortic bifurcation and common iliac vessels to form the hypogastric plexus. Injury to the sympathetic plexus can result in retrograde ejaculation. Retrograde ejaculation ranges from 0 to 50% and some have thought that it may be due to rhBMP although this does not seem to be a universal thought.[9,39] In a large series of 591 patients, Kuslich et al. reported a rate of 4% of retrograde ejaculation.[35] Minimizing electrocautery should decrease the risk of retrograde ejaculation.

Injury to the alimentary tract can be minimized by moving the peritoneum behind the retractors. Damage to the ureter is possible but more likely to occur in revision cases. Incidental nerve injury and durotomy are also possible. Finally implant failure including graft subsidence, extrusion, pseudoarthrosis is possible but minimized in the right patients and careful surgical technique. Failure of appropriate fascial closure can predispose to wound infection and incisional hernias.

7.0 Conclusion

ALIF is a valuable tool in a spine surgeon's armamentarium for the treatment of various lower lumbar pathologies including degenerative disc disease, spondylolisthesis, recurrent disc herniation, adjacent level disease, pseudoarthrosis, and sagittal imbalance. The initial stand-alone ALIF procedures using femoral ring allograft, autografts and threaded cages led to high rates of pseudoarthrosis and inconsistent clinical outcomes. Due to these results, the introduction of supplementary posterior instrumentation led to the 360 fusion. However, due to the longer operative times and morbidity associated with this procedure, the PLIF and TLIF techniques were developed.

As our knowledge grew and we recognized the importance of restoring sagittal balance, the ALIF procedure provided many advantages over posterior techniques. The development of new stand-alone interbody devices provided the stability and successful arthrodesis needed without the disruption of the posterior elements of the spine.

8.0 Expert Commentary:

Stand-alone ALIF provides the opportunity for adequate segmental stabilization of the intended fusion segment and potential arthrodesis similar to those undergoing posterior fixation. In our experience, patients tend to have faster recovery and shorter hospital stay after stand-alone ALIF compared to posterior transforaminal lumbar interbody fusion (TLIF) or 360-degree fusion. However, patient selection is key to ensure a good clinical outcome. Biomechanically, the arthrodesis rate of a stand-alone ALIF has changed with the development new interbody cages with integrated screws for stronger immediate fixation. The advantages of an ALIF include the ability to place a large interbody graft that maximizes the disc height and lumbar lordosis. However, in patients with severe central and foraminal stenosis, the indirect decompression provided by ALIF may not be adequate, and a posterior TLIF may be a better by offering direct decompression of neural elements. In addition, the complication profile for ALIF is different compared posterior approaches. Potential anterior approach-related complications such as vascular injuries and retrograde ejaculation must be discussed with patients pre-operatively. Spine surgeons must understand the limitations of ALIF and utilize this surgical technique appropriately to ensure optimal patient outcome.

9.0 Five-year review

Spinal fusion techniques have evolved rapidly and experienced significant advancement over the past two decades. ALIF is already becoming an important tool in the spine surgeons' armamentarium for treatment of various lumbar spine pathologies. Compared to the posterior techniques, ALIF offers various advantages including superior biomechanical properties and better ability in restoring lumbar lordosis. With the increased familiarity by both the access surgeons and spine surgeons, as well as the continued improvement and innovation in spinal implants, the complications associated with ALIF should continue to decline and the clinical outcome as such should continue to improve in the near future. In addition, with the increased understanding and awareness of the spinopelvic parameters and sagittal balance, ALIF will likely to play an increasingly important role as part of the overall strategy in spinal deformity correction, especially in conjunction with the transpsoas approach and posterior percutaneous instrumentation during minimally invasive spinal deformity correction. ALIF is a valuable tool for any spine surgeon and will play an increasingly important role in surgical management of various lumbar pathologies over the next five years.

10.0 Key Issues:

Stand-alone ALIF is a successful surgical option for arthrodesis of the lower lumbar levels without the need for posterior instrumentation.

Biomechanical properties of stand-alone ALIF constructs have evolved over the last two decades and increased the stability of a stand-alone ALIF.

Fusion rates with stand-alone ALIF are comparable to posterior fixation.

Careful patient selection including a solid understanding of the advantages and disadvantages of stand-alone ALIF will ensure optimal clinical outcome.

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Declaration of Interest

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A literature review of the clinical efficacy and biomechanical properties of interbody cages. Surgical approach and fusion rates are discussed.

Figure 1: A 45-year-old female with chronic disabling back pain. Sagittal T2 weighted MRI demonstrating loss of disc T2 signal at L5/S1

Figure 2: Left: Fluoroscopic radiographs of our patient undergoing discography at L2/3, L3/4, :4/5, L5/S1. Right: Axial computed tomography (CT) of injected fluorescence at L5/S1 which clinically correlated to the patient's pain during discography.

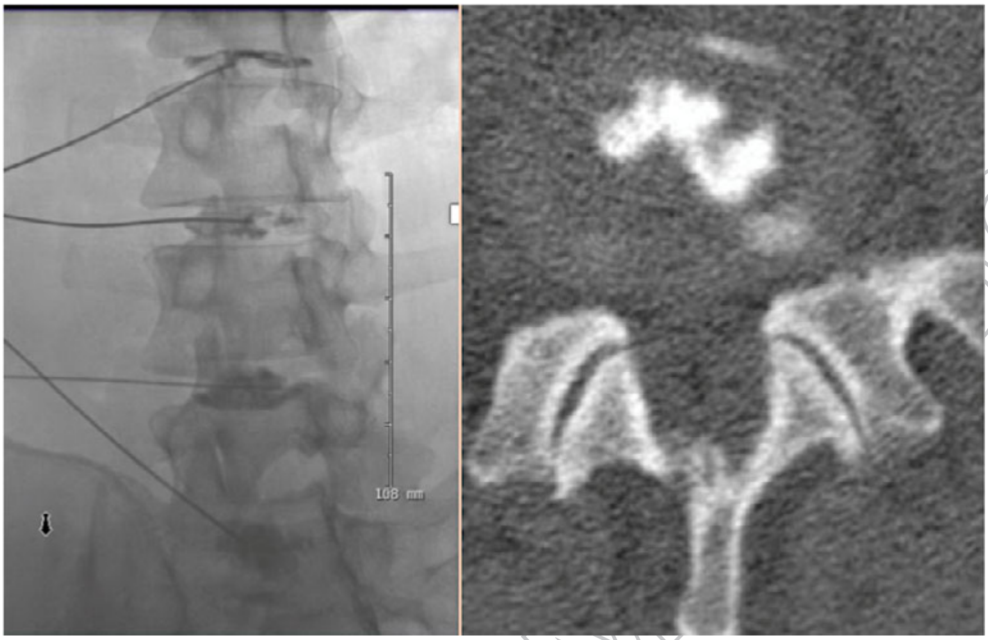

Figure 3: Immediate postoperative sagittal (left) and AP (right) of an L5/S1 ALIF with integrated screws.

Figure 4: One year sagittal (left) and coronal (right) postoperative fluoroscopic radiographs revealing successful arthrodesis of L5/S1.

Table 1: Advantages, indications, and relative contraindications of various stand-alone ALIF techniques

Advantages of Stand-alone ALIF	Indications	Relative Contraindications of Anterior Plating and Integrated Screw Techniques
Reduced blood loss	Spondylolisthesis	Grade II-IV spondylolisthesis
Large disc distraction	Neurologic deficit	Osteoporosis
Short operative time	Post-discectomy collapse	Irreducible pathology
Large interbody placement	Degenerative disc disease	Low vessel bifurcation
Restores lumbar lordosis	Pseudoarthrosis	
Reduces anterolisthesis	Adjacent level disc disease	
Restores coronal and sagittal balance	Recurrent lumbar disc herniation	
Direct visualization of vertebral disc	Neural foraminal stenosis with deformity	
Large increase in neuroforaminal volume	Chronic disabling back pain of discogenic origin for 1 or 2 levels	
No retraction on nerve roots which may decrease epidural scarring and fibrosis		