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10 Anterior Lumbar Interbody Fusion

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■ Historical Background

Anterior lumbar interbody fusion (ALIF) was first used in the treatment of tuberculosis and lumbar spondylolisthesis.[1–3] Although described by Capener[4] in 1932 as the "ideal" operation for spondylolisthesis, he further elaborated that "the technical difficulties of such procedure, however, preclude their trial." This statement was soon to be proven wrong by numerous technical advances in ALIF. When initially developed, the transperitoneal approach for lumbar arthrodesis was the norm, but was later replaced by the retroperitoneal approach. The first description of the transperitoneal approach was published in 1906 by Muller,[5] and Iwahara[6] first reported the later approach in 1944. Further broadening the scope of ALIF, Lane and Moore[7] in 1948 reported ALIF as a treatment for lumbar degenerative disk disease. Here they used the transperitoneal approach with an allogenic bone graft in 97 patients, reporting a 54% fusion rate after 8 months and a clinical success rate of 94%.

Further developing Iwahara's retroperitoneal approach, Hodgson and Stock[8,9] established the foundation for the modern era of ALIF while treating Pott's disease with different bone grafting materials. Debridement of the necrotic tissue, followed by decompression of the spinal canal, allowed them to place corticocancellous blocks of autogenous bone into the defect to obtain arthrodesis. The dowel technique, developed by Ralph Cloward in 1953, involved the use of cylindrical shaped corticocancellous dowels. Although Cloward[10–12] used a posterior approach, his methods for disk removal, end-plate preparation, and grafting were widely used. Following Cloward's dowel technique, four individuals adapted this to make their own innovations in bone grafting methods. Two of them, Harmon[13] in 1963 and Sacks[14] in 1965, were the first to utilize the dowel technique for an anterior lumbar fusion. The third, Crock, developed a cylindrical allograft for the anterior approach to the lumbar spine. Finally, the fourth, O'Brien et al,[15] modified a technique of using trapezoidal bone blocks for the treatment of lumbar discogenic pain through ALIF. They later developed a hybrid interbody graft using a biologic fusion cage (femoral cortical allograft ring) packed with autogenous cancellous bone graft. By using autogenous iliac crest bone graft, rapid incorporation and vascularization of the graft are achieved, as well as and long-term stability.[16] Furthermore, the femoral allograft ring allows for acute stability of the construct and a compatible framework for host bone ingrowth.[15]

Despite the success in safely exposing the anterior lumbar spine, in the 1970s and 1980s stand-alone ALIF was not a reliable procedure due to low fusion rates. Early in the development of the procedure, there was great discrepancy among success rates. The reported numbers were incredibly inconsistent, with some reporting huge success and others complete failure. For example, Lane and Moore,[7] as stated previously, reported a 94% clinical success rate. In contrast, though, Adkins[17] in 1955 had a fusion rate of l%. Early reports encompassing numerous surgical techniques and a heterogeneous group of patients demonstrated a fusion rate of 95% by Harmon,[13] 70% by Hoover,[18] 90% by Crock,[19] and 96% by Fujimaki et al.[20] However, other reports cited fusion rates of 19%, 40%, 45%, and 56% by Calandruccio and Benton,[21] Nisbet and James,[22] Raney and Adams,[23] and Flynn and Hoque,[24] respectively. A 1972 study conducted from the Mayo Clinic and authored by Stauffer and Conventry[25] concluded definitively that the stand-alone ALIF had a low success rate. After reporting on 83 patients who underwent ALIF without instrumentation between 1959 and 1967, they found an extremely low success rate, with pseudarthrosis occurring in 44%. The Mayo Clinic study resulted in a review of the ALIF as a stand-alone procedure, and it soon after fell out of favor, particularly for the indication of lumbar degenerative disk disease and lumbar axial back pain.

In response to these low fusion rates, a technique combining an ALIF with posterior fusion became very common.[26] Although the anterior approach continued to be utilized for the diskectomy, lordosis restoration, and fusion block insertion, a posterior approach was used to access the posterior elements for instrumentation and stabilization **(Fig. 10.1)**. The addition of posterior instrumentation increases stability across the segment and decreases motion while the fusion solidifies. Despite having a very high fusion rate, the magnitude of the circumferential fusion increased morbidity. Although the ALIF usage had been revitalized with posterior instrumentation, the search for a better construct continued. **Fig. 10.1**

These new innovations included anterior lumbar instrumentation, first reported by Humphries et al[27] in 1961. They developed a slotted, contoured plate that was placed over the anterior lumbar spine in an attempt to enhance arthrodesis. Another advance in anterior hardware was the cylindrical cage. The first cylindrical cages were modified from a smooth, stainless steel, fenestrated cylinder (Bagby

Fig. 10.1 Lateral radiograph of circumferential fusion using a femoral ring allograft for the anterior lumbar interbody fusion (ALIF) and translaminar facet screws for posterior stability.

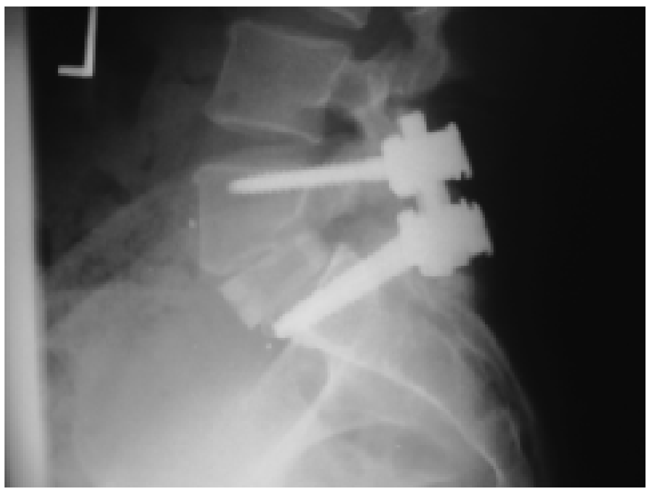

Fig. 10.2 Lateral radiograph of circumferential fusion using a femoral ring allograft for the ALIF and pedicle screws and rods for posterior stability.

basket) used by Bagby and colleagues in the mid-1970s and early 1980s to treat Wobbler syndrome, which is a chronic cervical instability causing myelopathy in thoroughbred horses.[28] In Bagby's procedure, he packed the cage with cancellous bone chips obtained from the reaming of the cervical decompression, thus eliminating the need for an autograft harvest. Further, the cage was developed with perforations in its walls to allow for bone ingrowth and to enhance fusion. This construct allowed for early stability and improved arthrodesis. Animals studies corroborated the success of this procedure with fusion rates as high as 88%.[28–31] Following the original cylindrical cage, more and more improvements in the design of the cages led to the Bagby and Kuslich design (BAK, Spine-Tech, Minneapolis, MN), which was first implanted in humans in 1992.[32] This BAK titanium cage was threaded and screwed into the end plates for stabilization and fusion of the segment. Another similar device developed by Ray[33] (Ray TFC, Surgical Dynamics, Norwalk, CT) was initially used in posterior lumbar interbody fusion (PLIF) but was later adapted to the ALIFs as well.

Although cylindrical cages were originally metal alloy, the development of machined bone dowels provided several advantages. Threaded bone dowels are similar in nature to a metal cage, but differ in that they are osteoconductive, incorporated over time, radiographically benign, and easier to revise.

Despite the rampant usage and initial success of the threaded cylindrical cage in the late 1990s, the next generation, the lumbar tapered (LT) cage, has several advantages over the cylindrical predecessor. It provides the same benefits of a cylindrical device, but allows the surgeon to symmetrically ream the end plate while restoring lordosis. Symmetric reaming prepares the end plate for fusion and preserves the strength.

In addition, LT cages packed with recombinant human bone morphogenetic protein (rhBMP-2) perform as well as those packed with autograft. **AQ2**

Other constructs include trapezoidal cages. Trapezoidal constructs can be made from various materials, but several features are shared, including a large footprint for maximum end-plate coverage and a large inner volume for bone graft and future fusion maturation.

Although cages continue to be widely used, femoral ring allografts (FRAs), as well as other trapezoidal implants are growing in popularity. The rhBMP-2 is also commonly used during all spinal fusions. Using rhBMP-2 decreases donor-site morbidity, as well as operating room time, and has proven to be as effective as autologous bone. Not surprisingly, the surgical approach has again been revisited, and recent research has shied away from laparoscopic approaches in favor of a retroperitoneal "mini" open approach. Although the ALIF was conceived over 100 years ago, it continues to be updated and improved with each new generation of implant and surgeon.

The ALIF has developed over decades, and specific attributes have been identified as primary contributors to a successful outcome. With the disk as the pain generator, removal of the pain source with a total diskectomy addresses the patient's presenting complaint. Also, restoration of disk height can alleviate foraminal stenosis. Re-creation of native lordosis may decrease juxtalevel stress. And lastly, posterior stabilization maximizes the likelihood of fusion **(Fig. 10.2).** **Fig. 10.2**

■ Biomechanics

The greatest strength of the vertebral body is present in the peripheral subchondral bone of the cortical end plate.

When threaded cages are used, the preparation process violates this peripheral ring of subchondral bone. Although this process compromises the strong ring of subchondral bone and theoretically raises the risk of subsidence, it also exposes vascular cancellous bone that may facilitate healing.

In contrast, to prepare the intervertebral space for a nonthreaded, trapezoidal implant, such as an FRA, the strong peripheral ring of subchondral bone is preserved and directly supports the graft while fusion occurs. In the past when FRAs were fashioned by the surgeon on the back table, the size and shape were difficult to match, and this strong ring of subchondral bone may not have been maximally utilized. Now, FRAs are more frequently manufactured, and thus size and shape are more predictable. This enables the surgeon to match the implant to the patient and build the most stable construct. In addition, manufactured FRAs have the benefit of insertion instruments that distract the adjacent vertebral bodies and ensure proper alignment and placement.

The spine endures a wide range of biomechanical forces, from 400 N while standing, to greater than 7000 N during heavy lifting,[34,35] with an maximum compression strength of 10,000 N.[36] The selected implant should not fail under these loads. When tested, modern-day implants usually sustain the maximum loads, with failure occurring at the end plate or the sacroiliac joint.[37] With implants infrequently failing, every effort must be made to utilize the intrinsic strength and healing potential of the end plate to promote rapid fusion. Considering that the implants usually do not fail, when constructs do fail, it generally results in subsidence of the implant into the vertebral body, or cavitation. As the end plate fails, either due to violation during preparation or after excessive loading, the implant migrates into the vertebral body and the segment collapses. Cavitation is addressed by choosing an implant with a large contact area, or footprint. A larger footprint provides a bigger foundation for the implant, decreasing the load per square inch **(Fig. 10.3).**

Fig. 10.3

Subsequently, a successful implant should be mechanically strong to withstand compressive loads while providing an osteogenic, osteoinductive, and osteoconductive matrix. Many metal alloy implants provide strength and stability but are unable to incorporate these other attributes. To compensate, metal implants provide an environment that allows the surgeon to place an autogenous cancellous bone graft, which does accomplish these later goals. Although metal implants can provide an environment that is fusion friendly, it is limited by the specific design and subsequent volume available for the fusion to traverse through the implant. To maximize the area available for fusion, the surgeon should expose the entire end plate with a total diskectomy,[38] as well as choose an implant that provides the most volume for the biologic substrate and future fusion block.

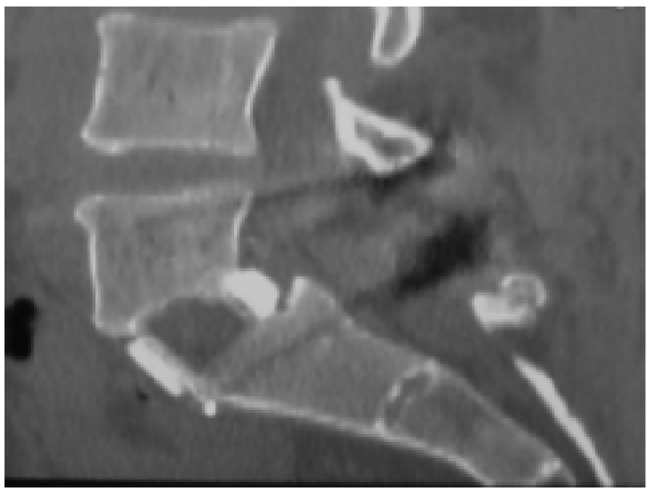

Fig. 10.3 Sagittal reconstruction of a computed tomography (CT) scan with a femoral allograft at L5-S1 demonstrating a large footprint and support on the peripheral endplate.

Implant design affects how the load is transmitted to the adjacent vertebra and may contribute to juxtalevel discogenic pain.[39] A recent biomechanical analysis revealed that greater implant contact area transmits loads to the adjacent segment in a more physiologic manner and could decrease adjacent level pain, as Kumar et al[39] found in 2005 that implants with smaller surface areas transmit loads in a similar manner to a degenerative disk that causes discogenic pain. In addition, physiologic stress patterns are better recreated when the patient's lordotic curve is restored. Consequently, when choosing a device, the largest appropriate implant should be carefully implanted after a total diskectomy. This would theoretically prepare the end plate in the correct fashion, load the adjacent vertebra more physiologically, and, when fused, minimize the risk of juxtalevel disease and pain.

Rh-BMP-2 is now routinely used for spinal fusions. The decrease in donor-site morbidity and operating room (OR) time are inviting; however, a recent study found a concerning trend. This prospective cohort study found a lower fusion rate with rhBMP in FRAs. Although, the ALIFs studied were stand-alone, the fusion rate was decreased with the use of rhBMP. The authors believe that the drop in fusion rate, although insignificant, may be secondary to rhBMP-induced resorption of the FRA **(Fig. 10.4).** If the ring is absorbed more quickly, the graft may weaken or fragment, which allows motion at the segment before fusion occurs, resulting in an unsatisfactory outcome.[40] This stand-alone study reinforces the significance of stabilizing the fusion segment. Although FRA implants are stable at the time of implantation, rhBMP may accelerate the resorption process and destabilize the segment before fusion can occur. Posterior stabilization with pedicle screws or translaminar facet screws provides the needed stability necessary for fusion.

Fig. 10.4

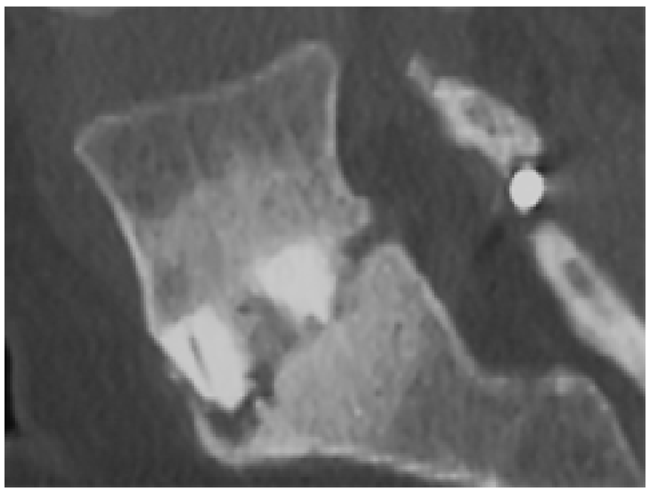

Fig. 10.4 Sagittal reconstruction of CT scan with a femoral allograft packed with recombinant human bone morphogenetic protein (rhBMP-2) demonstrating early resorption of bone at the caudal graft–host junction.

Although the ALIF was conceived as a stand-alone device, posterior instrumentation has proven to be optimal for reliable fusion. Even though the stand-alone ALIF does have intrinsic stability, posterior stabilization is recommended because posterior instrumentation provides stability in the range the cage does not.[41] Several implant options have been used, two of which are pedicle screws and translaminar facet screws. Ferrara et al[42] performed a biomechanical comparison of these two constructs and found both to be reliable constructs, with similar properties. After 180,000 cycles, both constructs were equivalent with regard to stiffness and motion. With similar biomechanical properties, implant choice can be determined by other factors, including surgeon preference, and patient-specific characteristics.

Although both constructs have similar integrity, multiple factors should be considered. Best and Sasso[43] recently reviewed 105 ALIF patients receiving translaminar screws or pedicle screws, and they found that the OR time was greatly reduced with translaminar screws, and the blood loss was significantly less.[43] Translaminar screw placement combines a midline incision and percutaneous screw placement, thus decreasing the overall incision length. To place translaminar facet screws, less muscle stripping is required, the cephalad facet joint is not disrupted, and instrumentation prominence is not an issue.[44] Despite the benefits of translaminar facet screws, patients with a prior complete laminectomy and removal of the spinous process or those with spondylolysis are not candidates.

Understanding the biomechanics of the spine is critical to interpreting the principles with the latest implants and techniques. Despite the ever-changing approach to lumbar disk disease, the ALIF relies on removal of the entire degenerative disk, preserving end-plate strength, re-creating physiologic lordosis, eliminating motion across the segment, and most importantly, achieving a stable fusion.

■ Patient Selection

Most low back pain is transient and self-limiting; however, 5% does not respond to nonoperative treatment.[45,46] Although this small percentage of patients does not improve with the most conservative measures, the surgeon must be confident that all conventional alternatives have been exhausted. Leaving options behind and moving ahead too quickly places risks on patients who would have improved without surgery and puts the surgeon at risk of an unacceptable outcome. Utilizing conservative methods and screening tests with high predictive value improves practice outcomes.

The ALIF is a commonly used surgical intervention to treat discogenic low back pain not controlled by nonoperative measures. Indications for an interbody fusion include degenerative disk disease of one or two adjacent levels of the lumbar spine, with severe, chronic, disabling, low back pain lasting longer than 6 months and unresponsive to adequate nonoperative therapy.[33,47] Less than three levels should be addressed at a time, as the risk of pseudarthrosis increases with each additional level fused and clinical success decreases.[48–50]

The pathophysiology of discogenic pain is poorly understood; however, we do know that other factors, such as compensation and pending litigation, affect outcomes.[51] These confounding variables must be accounted for prior to determination of the definitive therapy. The importance of the history and physical examination cannot be overstated; the interaction with the patient is an opportunity for the surgeon to assess the patient's expectations and determine if the patient is motivated by secondary gain.

Magnetic resonance imaging (MRI) is a sensitive and specific tool for diagnosing disk pathology[52]; however, asymptomatic disk pathology or herniation can be as high as 34%.[53] Boden et al[53] studied 20- to 39-year-olds, and found that more than one third had asymptomatic disk degeneration and more than one fifth had asymptomatic disk herniations. MRI should not be used as a screening tool and should be ordered only when clinical suspicion is high for spinal pathology.

Although controversial, diskography can provide the surgeon additional information prior to surgical intervention. Diskography is a diagnostic tool that many feel correlates pathoanatomy and symptomatology in patients with primary discogenic pain. Several studies suggest improved outcomes in interbody fusion patients after supportive preoperative diskography.[54–56] Re-creation of concordant pain with diskography especially under low pressures can verify the pain source or help rule out pathology at a specific level **(Fig. 10.5)**. Fig. 10.5

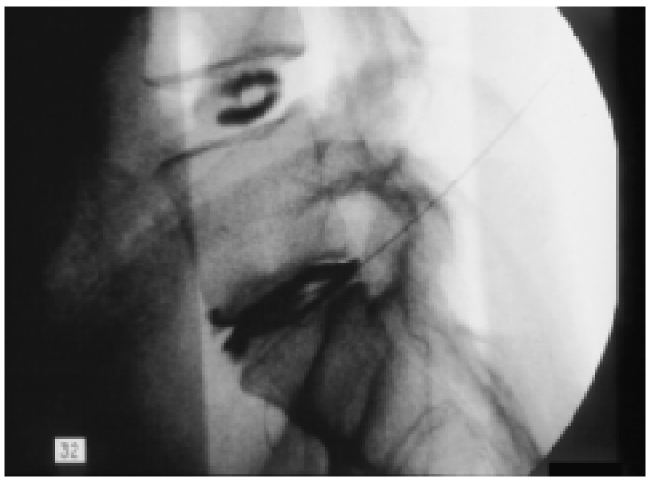

Fig. 10.5 Lateral radiograph during diskography with a morphologically abnormal L5-S1 disk and a normal L4-L5 disk.

Another provocative test with predictive value is the selective nerve root injection (SNRI), which can elucidate the pathophysiology of the pain generator in patients with complex disk disease or nontraditional radiculopathy. A positive result, meaning the patient has 100% relief of symptoms following the injection of anesthetic, correlates with the benefits achieved following surgical intervention of simply decompressing the offending nerve.[57] This procedure is easily performed by an experienced anesthesiologist and gives the surgeon an added layer of confidence before surgical intervention **(Fig. 10.6).** Fig.10.6

Operative intervention for spinal pathology places the patient at risk. Utilizing available diagnostic tools improves patient outcome and avoids low-yield surgical intervention. The least expensive and most easily used tools likely are the history and physical examination of the patient.

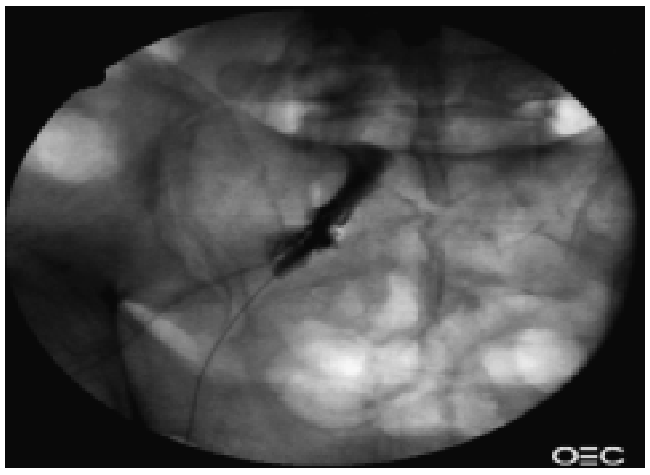

Fig. 10.6 Anteroposterior radiograph during selective nerve root injection (SNRI) of the left S1 nerve.

■ Clinical Studies

The ALIF has evolved over several decades through constant reevaluation and technique revision. To date, the most reliable constructs employ an anterior fusion that is stabilized posteriorly with instrumentation. Several attempts have been made to optimize an anterior-only, stand-alone technique; however, fusion rates have been less reliable. Posterior instrumentation provides the additional stability needed for rapid fusion, and now with the addition of rh-BMP, donor-site morbidity can be eliminated.

Despite the wide usage of cylindrical cages throughout the 1990s, no prospective fusion data was available until 2004. Starting in 2000, 140 patients were enrolled in a prospective, randomized, controlled, clinical trial comparing fusion rates of stand-alone threaded cages and stand-alone FRAs.[58] The 13 surgeons who took part in the trial implanted either a pair of cylindrical threaded titanium cages or an FRA. Both implants were packed with autograft, and fusion was evaluated at 6-month intervals by a board-certified radiologist. At 6 months, 95% of the threaded cages were fused as compared with only 10.9% of the FRAs, and the superior fusion rate remained in favor of threaded cages throughout the study. The highest fusion rate obtained by the FRA control group was 51.9% at 2 years, in contrast to the lowest fusion rate seen with the threaded cages was 95% at 6 months. Regardless of the outstanding fusion capacity of threaded cages, clinical outcomes remained equal between groups.[58] These surprising clinical findings may be explained by Fraser's[59] analysis in 1995, which attributes the clinical success of the ALIF to the surgical approach to the pathologic disk and not the fusion status.

The more recent emergence of LT cages enables surgeons to restore lumbar lordosis while achieving the similarly high fusion rates seen with cages. Burkus et al[60] compared LT cages implanted with rh-BMP-2 and FRA with autologous bone graft, and found no difference in outcomes, supporting the use of rh-BMP-2.[60] Having an off-the-shelf substitute for autologous bone graft allows surgeons to spare their patients the morbidity associated with donor sites, without sacrificing the osteoinductive properties needed for a fusion **(Fig. 10.7).** Fig. 10.7

Although donor-site morbidity has overshadowed autologous bone grafting, a prospective analysis was lacking. The senior author of this chapter participated in the first prospective analysis of over 200 spinal fusion patients randomized to an autologous donor arm and an rh-BMP arm comparing postoperative pain. Nearly one third of the autologous donors had persistent donor-site pain 2 years postoperatively compared with zero pain in the rh-BMP randomized group.[61] The ability to eliminate donor-site pain is an appealing option for the spine surgeon, despite appearing to be an added expense.

A comparison of an off-the-shelf osteoinductive growth factor reveals that they are in fact a cost-effective way of

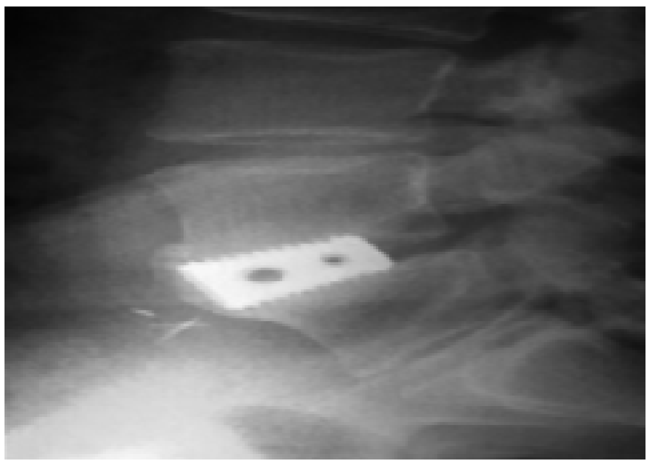

Fig. 10.7 Lateral radiograph of ALIF with an lumbar tapered (LT) cylindrical cage and BMP.

decreasing patient morbidity and maximizing patient outcomes. This 2003 evaluation found that the cost of BMP is offset by reductions in other care expenses. For example, valuable OR time is reduced with the use of a protein substitute, the postoperative period is less painful, and less nursing staff wound care is required for the patient.[62]

Reduction of OR time is beneficial for patients as well as for surgeons. Similar to using rhBMP, performing a 270-degree fusion (posterior instrumentation without fusion after an ALIF) versus a 360-degree fusion may be another effective way to trim OR time. A 2001 prospective randomized trial failed to reveal any clinical difference with the addition of the posterior instrumentation. The Oswestry Low Back Disability Index (ODI) and the Numerical Rating Scale (NRS) were used to evaluate outcomes following ALIF with or without posterior stabilization, and there were no statistical clinical differences.[63] Without clinical support of the posterior fusion, surgeons could choose to decrease operative supply cost (i.e., supplies needed for posterior fusion), shorten OR time, and decrease intra/postoperative complications.

Evaluation of patient success can be addressed from many perspectives. A clinical evaluation may reveal a pain-free patient with total resolution of symptoms despite a radiographic result that may be discordant, or vice versa. Using interval plain radiographs and computed tomography (CT) scans, a recent study shows that LT cages plus rhBMP compared favorably with LT cages plus autograft, and those supplemented with rhBMP achieved more bone formation outside of the cage. Both constructs formed bone similarly through the implant, but rhBMP improved bony fusion outside the cage. This confirms that rhBMP is not only comparable to autologous bone graft as an osteoinductive agent, but may be superior when specifically evaluating bone formation outside the stabilizing construct.[64]

Multiple papers support the stability of threaded cages and the clinical success[33,65,66]; however, a recent retrospective review revealed an increased complication rate with threaded devices compared with nonthreaded trapezoidal block-type constructs. This retrospective review identified a significantly higher number of intraoperative complications with threaded devices and the tools used to prepare the site and insert the devices. The study also found more postoperative complications; however, this was not statistically significant. The greatest numbers of complications seen were vascular in nature, including both intraoperative and postoperative. Most of these complications can be linked to the added steps required to prepare the level for the threaded device and the insertion instrumentation.[58]

The surgical techniques employed to expose the anterior lumbar spine focus on the preservation of adjacent structures to minimize long-term complications. The anterior lumbar spine can be approached via a transperitoneal or extraperitoneal approach using various incisions. As with other surgical disciplines, minimally invasive techniques have been pioneered with varying results. The laparoscopic anterior lumbar interbody fusion (LALIF) first appeared in the late 1990s,[67,68] with positive results presented by the early users. Initial LALIF reports indicated that the procedure was a safe, less invasive procedure, with less blood loss and faster patient recovery. However, follow-up reports found LALIF to be more time-consuming, and the touted benefits similar to those achieved with a "mini" open retroperitoneal approach.[69,70] In 2003, Chung et al[71] performed a 47-patient side-by-side comparison of the LALIF and the mini-ALIF and reported similar clinical and radiographic outcomes, with no identifiable advantages to the LALIF, despite the added technical challenge. Not only have the proclaimed benefits of the laparoscopic approach been challenged, but also specific complications are higher with the LALIF.

Two studies in 2003 reported a higher risk of retrograde ejaculation following a transperitoneal LALIF as compared with a mini-open retroperitoneal ALIF.[72,73] The delicate superior hypogastric plexus lies on top of the L4–S1 anterior spine and innervates the internal vesical sphincter. Damage to the plexus can cause retrograde ejaculation in men. The transperitoneal approach, either laparoscopic or open, dissects through this fragile web of nerves, whereas an open retroperitoneal approach, mini or traditional, sweeps the plexus from left to right. Retraction of the plexus as a whole versus dissection through it appears to decrease the risk of internal vesical sphincter denervation.

■ Imaging

Evaluation of interbody arthrodesis is difficult and controversial secondary to various fusion criteria.[50,59,74,75] Varying criteria include bridging bone and no motion on flexion and extension films, whereas others allow limited motion.

Radiographic assessment is also limited by the materials implanted.

Computed tomography and plain x-ray are traditionally used to assess fusion. Utilizing these tools, pseudarthrosis is identified by lucency around the cage, motion across the segment, or lack of bridging bone extending through the cage. Unfortunately, no study, other than histologic, is 100% reliable. Even with the improved quality of reconstructed, thin-segment, high-resolution CT, it is also unreliable in evaluation of fusion status.[38,74,76,77]

Post-ALIF pain is often attributed to pseudarthrosis. A follow-up study of patients with persistent back pain following ALIFs with radiographically confirmed fusions found a high rate of pseudarthrosis upon reoperation. Six of seven patients had pre-revision CT scans that failed to show peri-implant lucency. Seven of eight patients had pre-revision plain films showing no signs of loosening. The CT scan and plain films were both hindered with the use of a metal implant as compared with a bone allograft, making the predictive value of these screening tools low when metal implants were used.[74,77]

In addition, Cizek and Boyd[74] performed a cadaveric study on three different implant materials to determine the predictive value of CT scan versus plain radiographs for identification of a fusion. They compared bone cages, titanium cages, and carbon fiber cages, and found that neither CT scan nor plain radiograph was reliable. Fusions identified on CT were often refuted with plain films and vice versa.

Another study on pig-tailed macaques *(Macaca nemestrina)* reexamined this controversy, finding thin section helical CT better than plain films at identifying the presence of fusion; however, the extent of fusion was overestimated on CT when compared with histology. The predictive values of the CT results were greater in this nonhuman study with 83% concordance between the CT and the histology, versus 45% concordance with plain radiographs.

In summary, radiographic assessment of interbody fusions is suboptimal secondary to interpretation and implant artifact. Although these tools may be beneficial for identification of the grossly positive or negative result, the more difficult cases may require additional studies and possibly surgical exploration for definitive diagnosis.

■ Conclusion

Low back pain is generally treated with nonoperative measures, including nonsteroidal antiinflammatory drugs (NSAIDs), physical therapy, lifestyle modification, and time. Unfortunately, not all patients with discogenic pain respond to nonoperative treatment. A thorough preoperative evaluation should be able to determine patients with primary discogenic pain who may respond to operative arthrodesis.

The mini-open retroperitoneal ALIF approach allows the surgeon to maximize exposure without compromising the superior hypogastric plexus or the rectus muscles. The mini-ALIF approach is retroperitoneal and minimally invasive in nature with a low complication rate.

Choosing an implant is a personal decision and should be founded in clinical success. FRA has proven to be successful, especially with posterior instrumentation, and has unique benefits with regard to postoperative imaging. When an FRA is used in conjunction with posterior instrumentation and an off-the-shelf osteogenic biologic, an ideal construct for a 360-degree fusion has been created. Additionally, using translaminar facet screws to minimize soft tissue insult will optimize clinical success.

Our current assessment of spinal pathology will continue to change and our treatment options will too. Although spine surgery is an ever-changing world, the patient interactions and clinical success that motivate those involved is a constant.

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Queries to Author

AQ1: AU: chapter title has been changed to be consistent with the title in TOC OK?
AQ2: AU: most later chapters use theabbreviation style rhBMP-2. OK?
AQ3: AU: Please supply ref. 51.