

Preliminary Clinical and Radiographic Outcomes of Anterior Lumbar Interbody Fusion (ALIF) with stand alone PEEK cage and Anterior Plate Construct at the Bangkok Spine Academy



Buranakarl T, MD
email: tayard.bu@bgh.co.th

Tayard Buranakarl, MD¹
Kanoknard Jaisanuk, MD¹

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¹ Bangkok Spine Academy, Bangkok Hospital Medical Center, Bangkok Hospital Group, Bangkok, Thailand.

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*Address Correspondence to author:
Bangkok Spine Academy, Bangkok Hospital Medical Center,
2 Soi Soonyai 7, New Petchburi Road, Bangkapi, Huaykwang,
Bangkok 10310, Thailand.
E-mail: tayard.bu@bgh.co.th

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OBJECTIVE: To study the preliminary results of 20 patients who underwent Anterior Lumbar Interbody Fusion (ALIF) and were followed up for more than 6 months at the Bangkok Spine Academy.

MATERIAL AND METHODS: Study of the preliminary results and retrospective chart review of collected clinical and radiographic outcomes in 20 patients who underwent ALIF L1-L5 at Bangkok Hospital from April 2011 to April 2013 as a treatment for degenerative disc disease, spondylolisthesis, recurrent disc herniation and failed back surgery syndrome. Treatment involved using a stand-alone polyetheretherketone (PEEK) cage and an anterior plate construct (Synfix®, Synthes spine, PA, USA).

RESULTS: Of 22 patients who underwent ALIF surgery between April 2011 and April 2013 two were excluded from this series. The remaining 20 cases were followed up regularly until the fusion was complete.

Indications for surgery were degenerative disc disease, spondylolisthesis, pseudarthrosis from previous surgery, and recurrent disc herniation. Most cases experienced both back pain and leg pain from spinal instability and nerve root compression. Five cases underwent surgery because of back pain without any leg pain. The majority of patients (nine cases, 45% of total) were spondylolisthesis, including both degenerative and lytic types. Seven cases (35%) were diagnosed as degenerative disc disease. One case (5%) was treated because of the recurrence of disc herniation. One case (5%) was treated for pseudarthrosis and an implant breakage from previous fusion surgery.

In a total of 20 cases we operated on 23 levels of problematic discs. The mean operative time for each level was 156 (± 35.5) minutes (mean \pm standard deviation (SD)). The shortest operative time was 115 minutes for each level and the longest was 240 minutes. The intraoperative blood loss averaged at 315.2 (± 225) ml.

The initial pain score in self-reported questionnaires (visual analog scale (VAS) back, VAS legs) showed fast and lasting pain relief. The mean VAS preoperative back score was 5.7 (± 2.0), which at the two-week visit reduced to 0.6 (± 1.1). The mean VAS leg score was 3.55 (± 2.8), which reduced to 0.1 (± 0.2).

The Oswestry Disability Index (ODI) questionnaire was used to evaluate the improvement of the overall disability status and was found to decrease from 42.0 (± 28.2) to 13.9 (± 14.3) at the six-week follow up visit. It continued to decrease to 4.3 (± 6.4) at the three-month visit and 0.4 (± 1.0) at the six-month visit. There was a mean correction of segmental lordosis at an instrumented level from an initial 18.6 (± 8.8) to 21.2 (± 8.7) after surgery. There was a significant improvement in the mean coronal angle from 4.1 (± 4.5)

to 1.6 (± 2.0) postoperatively. The increase in mean disc height at the middle column was from 8.8 (± 3.2)mm to 14.4 (± 2.1)mm after surgery. The degree of slip changed from a mean of 16.7 (± 5.6)% to 8.4 (± 5.9)%, and the average slip improvement was 49.7 (± 27.9)% using the stand-alone ALIF technique.

One of the most challenging aspects of this surgery is the difficulty of an anterior retroperitoneal approach. The large venous and arterial channels obstruct exposure of the lumbar intervertebral disc. Of the 22 cases, one had inadvertent intraoperative venous bleeding from an old adhesion from a previous surgery but this was controlled by a vascular surgeon. There were no cases with an abdominal ileus after surgery. One case had retrograde ejaculation that was resolved during the second year follow up visit. There were no cases of neurological problems as this surgery went in from the front of the spine. Because the ALIF implant is large it carries the human body very well, so there were no cases of subsidence, implant breakage or loosening. The fusion was well established because of a big area of fusion on the vertebral end plate. The nature of this surgical technique ensures the patient experiences less back pain after surgery which in turn improves their ability to recover faster and to return to their full activity.

CONCLUSION: This preliminary mid-term report of the stand-alone ALIF procedure at the Bangkok Spine Academy shows satisfactory and consistent results. The benefits of this procedure include: reduction in back and leg pain, minimization of soft tissue injuries especially of uninjured back muscle, and lower likelihood of nerve root injuries. The only disadvantage of this procedure is that the technically demanding anterior approach needs prompt management for any vascular issues. These surgical techniques show fast and long-lasting, satisfactory results with less likelihood of long-term complications.

Spinal fusion is one of the major goals of spinal surgery especially in the case of spinal instability, infection, tumor and traumatic conditions. The history of spinal fusion began in the early 19th century with Russell Hibbs and Fred Albee, who applied an autologous bone graft on the dorsal surface of the spine to treat spinal tuberculosis. The success of this surgical technique is unacceptable because of the high rate of pseudarthrosis.^{1,2} After Denis classified the spinal column, minor spinal instability showed that posterior spinal fusion is not enough to maintain the whole vertebral column. Some may need anterior vertebral column support and fusion anteriorly. The advantage of anterior spinal fusion is the ability to provide a better biomechanical support, and it can achieve a solid fusion that leads to a more stable fusion than posteriorly.³ The surgical technique was changed from a transperitoneal approach to a retroperitoneal approach in order to reduce intra-abdominal complications. The implant design was developed from a simple metal cylindrical cage that needs posterior fixation to the well-

shaped PEEK cage with an anterior plate constructed in the same shape for stand-alone surgery. The advantage of stand-alone anterior fusion is to avoid complications of posterior fusion disease.² The modern anterior inter-body cage device was designed to have a bigger and larger area able to carry the human body weight, and placed around the area of the apophyseal ring of the vertebral end plate which is the strongest bone with the least likelihood of implant subsidence. In conjunction with the mini-plate screws device attached to the front, it improved the anterior-posterior stability of the implanted levels with a lower likelihood of loosening or dislodgement from its position. Due to the big area of graft material in contact with the patient's own bone, there was a high success of bone formation in between the vertebral end plate to produce a solid fusion. This is the key to success in solving spinal instability that can cause chronic back pain.¹ With this well-designed intervertebral cage in full anterior-posterior diameter, there is also the strongest likelihood of opening the intervertebral foramen and neural canal that has collapsed due to spondylolisthesis or degenerative disc disease. As a result this eliminates leg pain from nerve root compression. Due to the nature of a big-round cage to withstand the load when a patient is standing or walking, there is less likelihood of a neural canal collapsing. This makes this technique of surgery appropriate for the patient who wants to have vigorous activity after surgery. The indirect decompression effect from the inserted large cage into the intervertebral space has an advantage over the direct decompression in terms of elimination of the incidence of nerve root injuries and eliminates the chance of post-operative pain from epidural scarring.

One of the major disadvantages of this surgery is the risk of vascular injuries during the anterior retroperitoneal approach: the great venous and the arterial blood vessels lie in front of the vertebral body of L4-5 and L5-S1. The surgeon should be familiar with the possibility of anatomical variation of all blood vessels in order to get an adequate exposure. Some good candidates for ALIF cannot be operated on because of a pathological level of vascular anatomical variation. The technical team must be prepared for any inadvertent condition arising during surgery. These conditions might include vascular leakage or difficulty to mobilize a great vessel due to adhesion. A back-up vascular surgeon should be ready to help the spine surgeon promptly when necessary.

ALIF surgery using this technique (stand-alone PEEK cage with anterior plate construct, Synfix®, Synthes, USA) has been available in Thailand since early 2011 and continues to be performed to the present day. For the purpose of this article, we will discuss the indications and candidates for this operation, the surgical steps, and will include the preliminary results of 20 cases (23 levels) performed between April 2011 and April 2013 with details of blood loss, operative time, radiographic evaluation, and the mid-term clinical outcomes.



Figure 1: Stand alone ALIF PEEK cage with anterior plate construct (Synfix®) available in Thailand.

Figure 2: Synfix®, stand alone PEEK cage with anterior plate construct was filled with bone graft substitute, Bone Morphogenetic Protein (white).

Figure 3: Mini-opened surgery on the front by retroperitoneal approach can expose the entire anterior surface of the pathological disc.

Material and Methods

Indications and surgical candidates

ALIF is surgically indicated for posterior lumbar decompression or spinal fusion in patients who have axial back pain and or radicular leg pain. Patients with axial back pain from degenerative disc disease, or recurrent disc herniation requiring total removal of the disc material to achieve solid fusion are good candidates for ALIF. The ability to achieve this goal without disturbing soft tissue on the back side makes this procedure ideal for patients who have chronic back pain with a tendency of chronic back pain syndrome in the case of soft tissue scarring from conventional surgery. The advantages of the possibility of achieving solid fusion in ALIF means there is a lower likelihood of back pain remaining from pseudarthrosis, which is generally more prevalent in posterior spinal fusion surgery. The ability to open the disc space height and to reduce the slippage of vertebrae using a big cage is appropriate for spinal stenosis from neural foramina narrowing from collapsing or bulging discs in spondylolisthesis grade 1 and 2 (both degenerative or lytic in origin). The large ALIF cage will result in an automatic reduction in the slipped vertebra into a normal sagittal alignment and also an indirect decompression of the nerve root within the spinal canal. Due to a high success rate in solid fusion with a larger bony contact area around the vertebral end plate, and a greater variety of good graft material, we can choose such an autogenous bone graft, demineralized bone matrix and bone morphogenetic protein compared to posterior surgery. This surgical technique is considered best for patients with failed lumbar fusion surgery.

ALIF is contraindicated for cases of abnormal variation of the great vessel laying in front of the pathological disc level which is an obstacle for adequate exposure. Because of the big intervertebral cage diameter, this procedure requires almost the entire anterior exposure

of the desired disc space. At present, the recommended equipment of use includes the abdominal ring retractor, as well as the designed disc Rongeur. These tools make surgery easier and more minimally invasive. That said, this procedure cannot be undertaken if the surgeon cannot mobilize the entire vessel out of the area of the surgical site. Some patients are not eligible for surgery because of adhesion round the affected level from previous abdominal or spinal surgery. There is a risk of massive bleeding from even a small leakage of the great vessel, especially from the venous structure that is easily torn. Also contraindicated are cases of highly collapsed disc space, as there is a chance of auto fusion between both levels. This is because of a tendency of failure in the elevation of the disc space height before the insertion of the cage. Despite this procedure having a low likelihood of cage subsidence in the vertebral body, any patient who suffers from a very severe osteoporotic bone condition is also contraindicated for the ALIF procedure.

Patient selection

The patients included in this study had an indication for spinal fusion and/or spinal decompression. All of them had lesions from L4 to S1, which is the most common pathological level in degenerative spine disease.

Indications

1. Degenerative disc disease (back pain / leg pain).
2. Spondylolisthesis grade 1 and 2 (degenerative / Lytic).
3. Recurrent disc herniation.
4. Pseudarthrosis from previous back surgery.

Contraindications

1. Variation in the great vessels that prevent adequate exposure.
2. Adhesion in the retroperitoneal space from either a previous surgery or infection.
3. Severe osteoporosis.
4. Severely collapsed disc where the disc space height cannot be expanded.

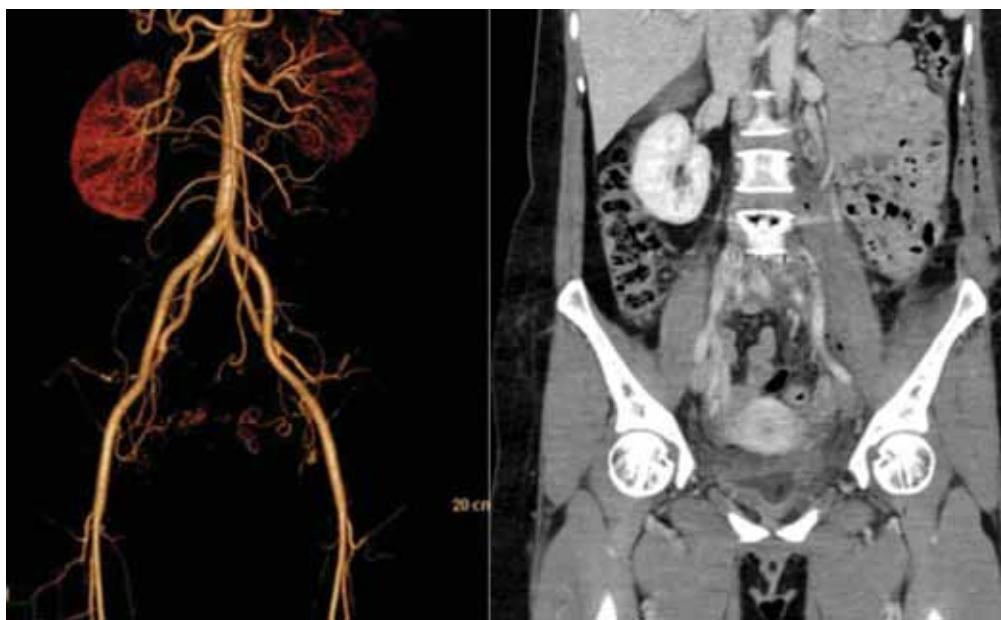


Figure 4: In a case of suspected variation of the great vessel on the front of the spine, the magnetic resonance angiography is considered.

Each patient receives comprehensive counseling and advice before the operation is undertaken. The surgeon informs the patients of any inadvertent problems that may arise intraoperatively and postoperatively. Any male patients who wish to undergo this surgery receive counseling about the risk of retrograde ejaculation that can lead to infertility. Men who are planning on having children are advised to do sperm banking. All our cases had back up from a vascular surgeon at our hospital during surgery for prompt management in case of any vascular injuries during the operation.

Study design

Data for this study was obtained through retrospective chart reviews and concurrent follow-up of patients who received ALIF surgery performed by the same spine surgeon (Buranakarl T) at the Bangkok Spine Academy. The outcome data was obtained prospectively preoperatively and at each postoperative visit through self-administered questionnaires. The roentgenographic data was obtained and calculated by another orthopedic doctor (Jaisanuk K) and the medical research department.

The patients' hospital and clinical charts were reviewed to identify any complications and the patient outcomes. The chart review included a compilation of demographics (age, gender), symptoms and diagnosis, surgical details (levels treated, instrumentation use, blood loss, operative time, complications), duration of hospital stay, any additional procedures, results of physical exams, late-occurring complications and patient complaints, prospective collected back and leg pain scores (visual analog scale, VAS), and a disability index. Radiographic measurements were

taken before and after surgery to assess any change in the sagittal and coronal plane alignment of the individual operated disc levels, the overall lumbar spine, and the lumbar scoliosis curves. The radiographs were also analyzed for vertebral abnormalities such as fractures or collapses, correction of the sagittal and coronal plane, and vertebral slip correction in the sagittal and coronal plane in each level. At the follow up visits (at six weeks, three months, six months, and twelve months) all patients were re-evaluated using the VAS pain scale and the Oswestry Disability Index (ODI), and for nerve root injury, sexual function, wounds and other complications.

Surgical technique

Under general anesthesia, the patient is prepared in the same manner as normal spine surgery. The intravenous (IV) line and urinary catheter are placed. The patient is transferred to the operating table and placed in a supine Fowler position with a roll of towel underneath the operated lumbar level in order to maintain an extension of the lumbar spine. Both legs are placed on the lithotomy table and attached with anti-thrombotic calf pump. Both legs are spread out for the first surgeon standing in front of the abdomen and the hip flexor to relax the abdominal muscle. The fluoroscope c-arm is placed underneath the table to ensure it can move freely all the way down without any obstacle to evaluate the disc space and end plate laterally.

After aseptic treatment of the skin, lateral fluoroscopic images are used to identify the correct level of skin incision on an imaginary line from the disc to the abdominal wall. Through this mark, a seven- to nine-centimeter transverse incision is made on the front of the abdominal

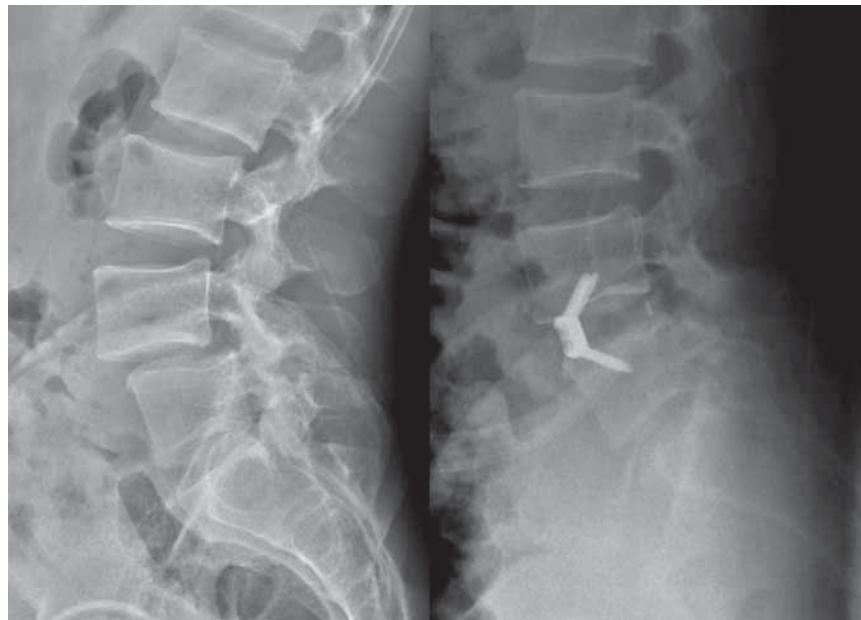


Figure 5: One of the good case for ALIF is lumbar spondylolisthesis grade 1 - 2 with or without radiculopathy. This surgery is able to reduce the slip level to normal alignment and also decompression the neural foramen.

wall, starting at the midline and proceeding towards the left. The rectus sheath is identified and split longitudinally. The median border of the rectus muscle is identified and separated. The rectus muscle is retracted laterally and bluntly to keep exposure of the sheath underneath the rectus until it reaches the most lateral aspect of the rectus sheath layer. At this area, the reflected arcuate line (linea arcuata), where the abdominal sheath is attached is identified. The reflected arcuate line is cut longitudinally to enter the retroperitoneal space.

A blunt dissection is carried out within the retroperitoneal space in order to expose the affected disc level. The abdominal content such as bowels and its peritoneum is retracted to the right of patient, and kept just in front of the psoas muscle and vertebra in order to expose the great vascular structure. The synframe® retractor system is applied to keep the peritoneal contents away from the operative field. The interval between the great vessels and the psoas is dissected to identify the vertebral bone. The level is confirmed by using fluoroscope. The dissection is undertaken by gently dissecting and mobilizing the great vessels until the annulus of the disc level is exposed. Four Steinmann pins are inserted into the upper and lower vertebral bodies in order to retract the vessels out of the anulotomy field.

The annulus is cut on the midline with two parallel incisions in order to make an opened door flap. Both left and right flap are sutured at the end and retracted to both sides to expose the inner annulus and its nucleus. The entire disc is removed and the end plate cleaned using a Cobb elevator without damaging the bone. We ensure there is no remaining disc material on the backside of the posterior longitudinal

ligament. Posterior osteophytes can be removed using a Kerrison's Rongeur if needed. The disc space is spread to the normal height using an interbody spreader. The cage size is determined by using the standard trial until it fits properly in the space. This is then rechecked by lateral and anteroposterior (AP) fluoroscope, to make sure it is not undersized or oversized when compared to the adjacent disc level.

The correctly sized Synfix® cage is then opened from its container and filled with the bone graft substitute (bone morphogenetic protein (BMP) or demineralized bone matrix graft (DBM)) and inserted into the selected disc space. The position of the ALIF cage is checked within the space by a lateral and anteroposterior (AP) fluoroscope again to make sure the posterior border of the cage is just a millimeter in front of the posterior border of the vertebrae. The roll of towel placed underneath the patient's body is then removed. The cage position is checked once more before the final fixing of the cage to the vertebral body. The synfix® cage, together with the titanium plate placed anteriorly is fixed by four cortical screws and positioned divergently into the upper and lower vertebral body. After the position of the cage is confirmed by fluoroscope, bleeding is stopped, a low pressure drain is put in place, and the abdominal sheath is securely sutured into position layer by layer.

All patients were transferred to the intermediate intensive care unit for close observation ready for treatment should there be any concealed bleeding after the surgery was finished. Most patients were transferred to the normal in-patient ward within 24 hours of surgery and started walking by day two after surgery.

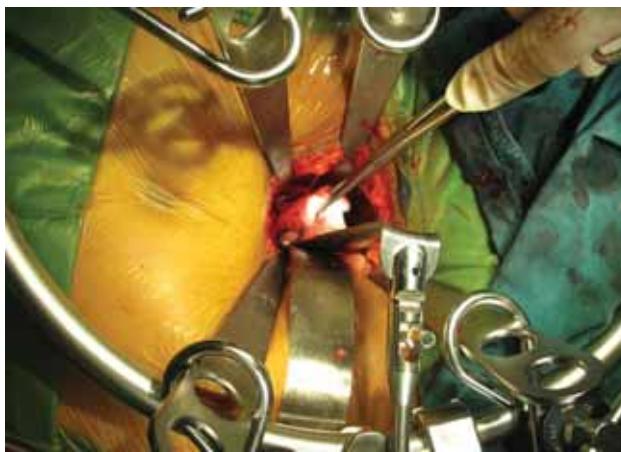


Figure 6: For the mini-opened anterior approach to the lumbar spine, the Synframe retractor is one of the instruments needed for good exposure.

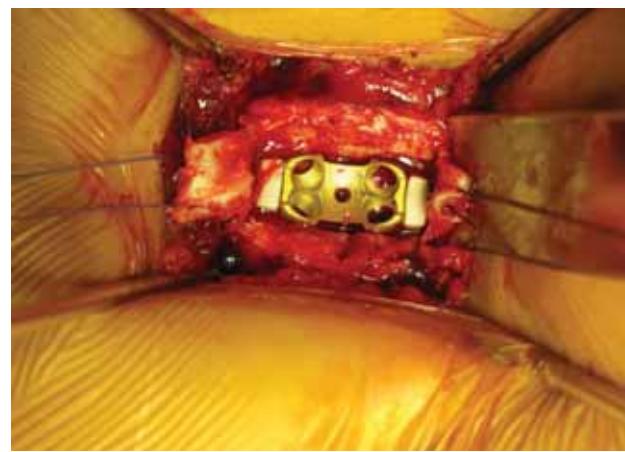


Figure 7: The proper size of PEEK cage with anterior plate construct (Synfix®) was inserted into the affected disc and fixed with screws.

Results

Demographic and Clinical Data

Of the 20 patients, 19 were male (95%) and one female (5%). The mean age is 41.2 years with 63 the oldest and 24 the youngest. Twenty-three levels were operated on, with the majority being at the L5-S1 in 15 levels (65.2%), and L4-L5 in eight levels (34.8%). It is not surprising that the distribution of the surgical levels falls mainly between L5-S1. This is because at the L4-5 we ask the patient to consider a more convenient fusion surgery option such as direct lateral interbody fusion (DLIF) or oblique lateral interbody fusion (OLIF). Both are available in our center. All patients chose the ALIF procedure for lumbar degenerative disc disease, spondylolisthesis from degeneration and developmental pars defect, recurrent disc herniation, or failed back surgery from pseudarthrosis. Most cases had indications of back pain with radiation to the leg due to nerve root compression. Five cases (25%) involved back pain only caused by degenerative disc disease also confirmed by provocative discography. There were seven cases (35%) with a diagnosis of degenerative disc disease. Nine cases (45%) were given a diagnosis of spondylolisthesis grade 1 or 2 with some being pars defect in origin. Only one case was given a diagnosis as a recurrent disc herniation and one other (5%) was pseudarthrosis with an implant breakage at L5-S1 from long posterior fusion surgery. Demographic and clinical data is shown in Table 1.

Table 1: Demographic and Clinical data.

Parameter	Mean	Min/Max
Patients (n)	20	
Male	19 (95%)	
Female	1 (5%)	
Age (years)	41.8 (10.7)	24 / 63
Pre-op VAS back	5.7 (± 2.0)	3 / 10
Pre-op VAS leg	3.6 (± 2.8)	0 / 9
Diagnosis		
Degenerative disc disease	7 (35%)	
Spondylolisthesis	9 (45%)	
Recurrent disc herniation	1 (5%)	
Failed back (Pseudarthrosis)	1 (5%)	
Spine level		
L4-5	8 (34.8%)	
L5-S1	15 (65.2%)	
Improved disc height (mm)	5.68 (± 3.0)	
Improvement in coronal angle (degree)	2.6 (± 3.8)	-0.8 / 16.9
Improvement in segmental lordosis (degree)	2.5 (± 6.3)	-7.4 / 12.9
Improvement slip (percent)	49.7 (± 27.9)	20.9 / 100

Operative and Clinical outcome

The duration of surgery was measured as skin-to-skin time. The mean operative time was 156.5 (± 35.5) minutes (mean \pm SD). The shortest duration of surgery was 105 minutes for each level and the longest surgery took 240 minutes. The operative time seemed to be affected by the time consuming task of establishing exposure, especially the time required for vessel mobilization. Intraoperative blood loss averaged 315.2 (± 225.5) milliliters. The lowest blood loss for each level was 50 milliliters and maximum blood loss was 800 milliliters. Blood loss mostly occurred during exposure of the intervertebral levels. One case, an overseas patient that was not therefore completely followed up, had inadvertent blood vessel injuries that caused massive bleeding. The cell server was attached and a vascular surgeon immediately scrubbed in and cleared this situation. This case demonstrates the need for special preparation with a back up vascular surgeon on standby whenever this operation is performed.

Nerve root injuries represent a potential complication, but this is less likely to happen compared to conventional posterior surgery. This is because the direct decompression of the bony canal near the compressed neural structure is not required. The intraoperative complications

that come from open surgery, such as the dura tear, do not exist. Injury to the superior hypogastric plexus (which lies beneath the peritoneum, courses to the aorta (anterior view) and crosses anterior to the left common iliac vein) can cause retrograde ejaculation. In the 20 cases reported we had only one case experiencing retrograde ejaculation after surgery and this was resolved within the second year. Other post-operative complications such as post-operative ileus, infection, cage subsidence or implant breakage, and lymphocele did not occur.

The mean back and leg pain measured by VAS before surgery was 5.7 (± 2.0) for back pain and 3.6 (± 2.8) for leg pain. Some patients had only one symptom, either back or leg pain. After the surgery at the two-week visit, back pain rapidly improved to 0.6 \pm 1.1 and leg pain improved to 0.1 (± 0.2). We observed that the rapid recovery in back and leg pain from ALIF is faster than posterior opened surgery, which may be because there is minimal soft tissue destruction and the effect of indirect decompression of nerve roots without direct contact that can cause inflammation in open surgery (Figure 8).

This is a preliminary report of ALIF operations at our center, the Oswestry Disability Score is collected before the operation and then compared with post operative status at six weeks, three months and six months and these are not yet all complete for all 20 cases. The 11 patients that completed the questionnaire at six months were examined. These show very satisfactory results with rapid improvement of physical function after surgery. The mean ODI pre-operative visit was 41.9 (± 28.2) and this reduced to 13.8 (± 14.3) at the six-week visit and continued to reduce to 4.3 (± 6.5) at the three-month visit and 0.35 (± 1.0) at the six-month visit (Figure 9).

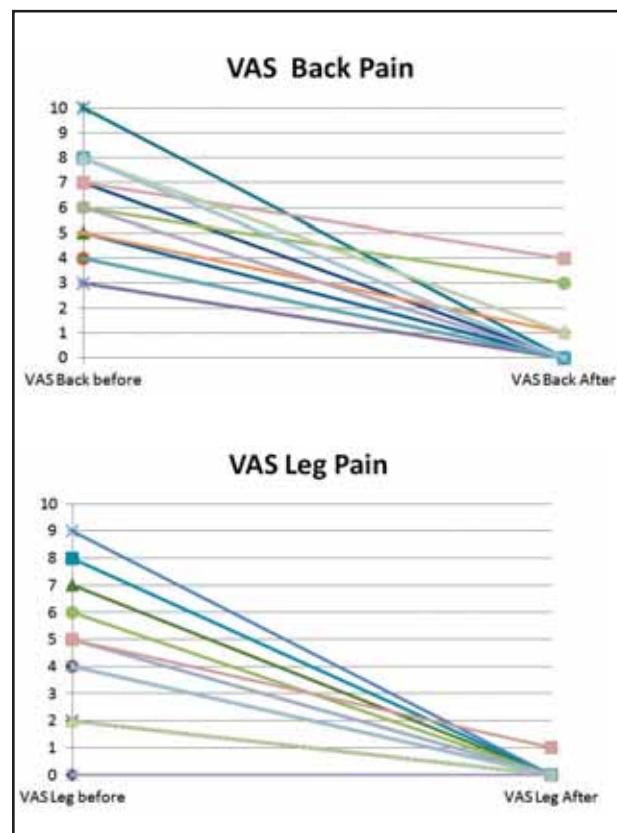


Figure 8

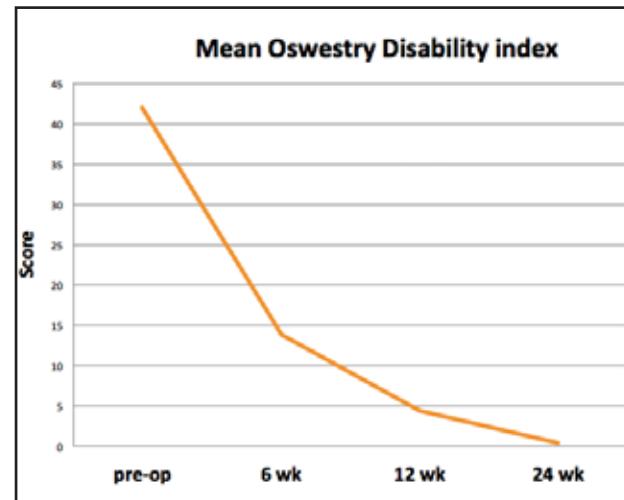


Figure 9

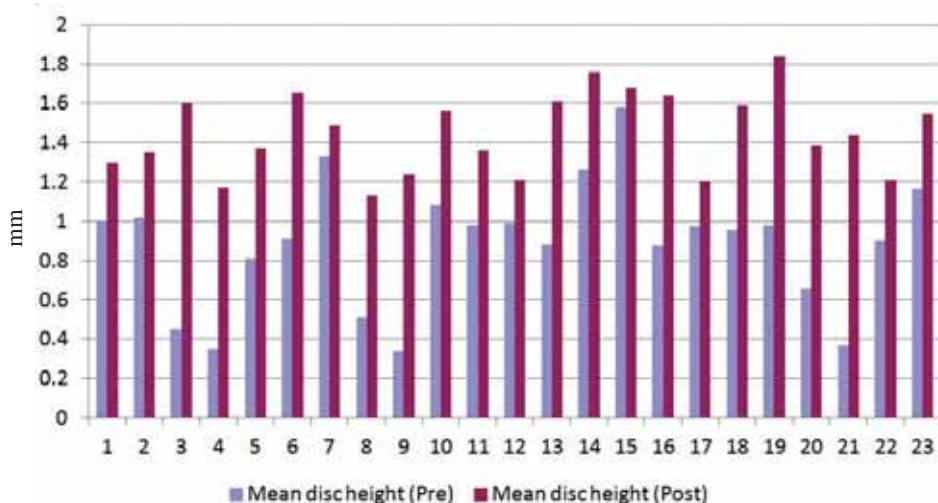


Figure 10

Radiographic outcome

One of the advantages of ALIF surgery is the ability to improve disc space height and the correction of coronal and sagittal alignment. In our study the same positive results as another previous report are shown. (Figure 10) The mean disc height before surgery is 8.8 (± 3.2)mm improving to 14.4 (± 2.1) after surgery. The mean segmental lumbar lordosis before surgery 18.6 (± 8.8) changed to 21.2 (± 8.7) after surgery. The coronal angle or scoliosis angle improved from 4.1 (± 4.5) to 1.6 \pm 2.0 degrees after surgery. Moreover, the degree of slip improved from a mean of 16.7 (± 5.6)% to 8.4 (± 5.9)%. The mean change of the percentage of slip when compared to before surgery is 49.7 (± 27.9)%.

Discussion

Spinal fusion is one of the major goals of spinal surgery especially in the case of spinal instability, infection, tumor and traumatic condition. Russell Hibbs and Fred Albee made the first steps in spinal fusion at the start of the 19th century for the treatment of spinal tuberculosis. They did this by applying the autologous bone graft on the dorsal surface of spine. This surgery became unacceptable because of the high rate of postoperative pseudarthrosis. After the spinal column was classified by Denis, it was demonstrated that posterior spinal fusion is not sufficient to maintain the vertebral column. After this, anterior fusion to address the degenerative condition of the spine was studied.⁴

A 1931 surgical publication reported treating patients with spondylolisthesis by inserting a bone spacer from the anterior body by Capener.⁵ Shortly after this, there were reports about success in curing spondylolisthesis using this procedure from many orthopedic surgeons such as Mercer,⁶ Friberg⁷ and Merled'Aubigne.⁸ This procedure

is used to undertake surgery on the transperitoneal space directly. Reports about using the technique of Anterior Interbody Fusion in patients who have problems from disc disease are reported for the first time by Lane and Moore⁴ in 1948. The retroperitoneum technique was proposed by a Japanese surgeon, Iwahara, in 1944.⁹ At that time, most indicators for undergoing the operation included detection of spine instability or moving by intervertebral discs of patients.

The posterior decompression is a key factor to mending pinched nerve or nerve compression resulting in sharp leg pain except in the case of foraminal stenosis, such as intervertebral disc collapse or severe listhesis. The surgery to widen the space for nerves from the posterior might not be enough. It is necessary to increase the height of the disc, which results in an indirect decompression and becomes a highly successful fusion, which is based on kinetics as well. The anterior interbody fusion has indications which can solve symptoms of pinched nerves from this cause very well.¹⁰

The lumbar cage device used in ALIF is a product designed to replace an intervertebral disc. At first, these were made of titanium because titanium can be moulded into many shapes, and can prevent disc space collapse during the healing process and can be fortified by titanium screws.^{2,11} The most important thing is to design the cage to provide high stability and load-sharing for the endplate. This is achieved by adapting the biomechanics of the vertebral end plate, by loading the weight, with the ring apophysis area being twice as strong as the central area.¹² Consequently, the shape of the cage plays an important role in the success of the surgery with this material. Obviously, it is not a surprise that at first the cage was not placed on the Apophyseal ring of spine, as this causes problems of subsidence such as we see with as the rectangular cage, Bagby and Kuslich (BAK) cage or LT-Cage[®].

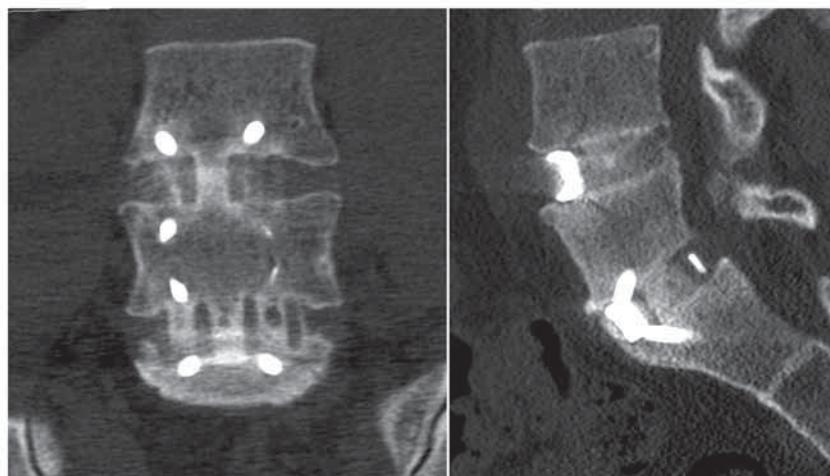


Figure 11: ALIF has advantages in term of solid fusion. This picture shows solid interbody fusion after 6 month stand alone ALIF with rh-BMP2.

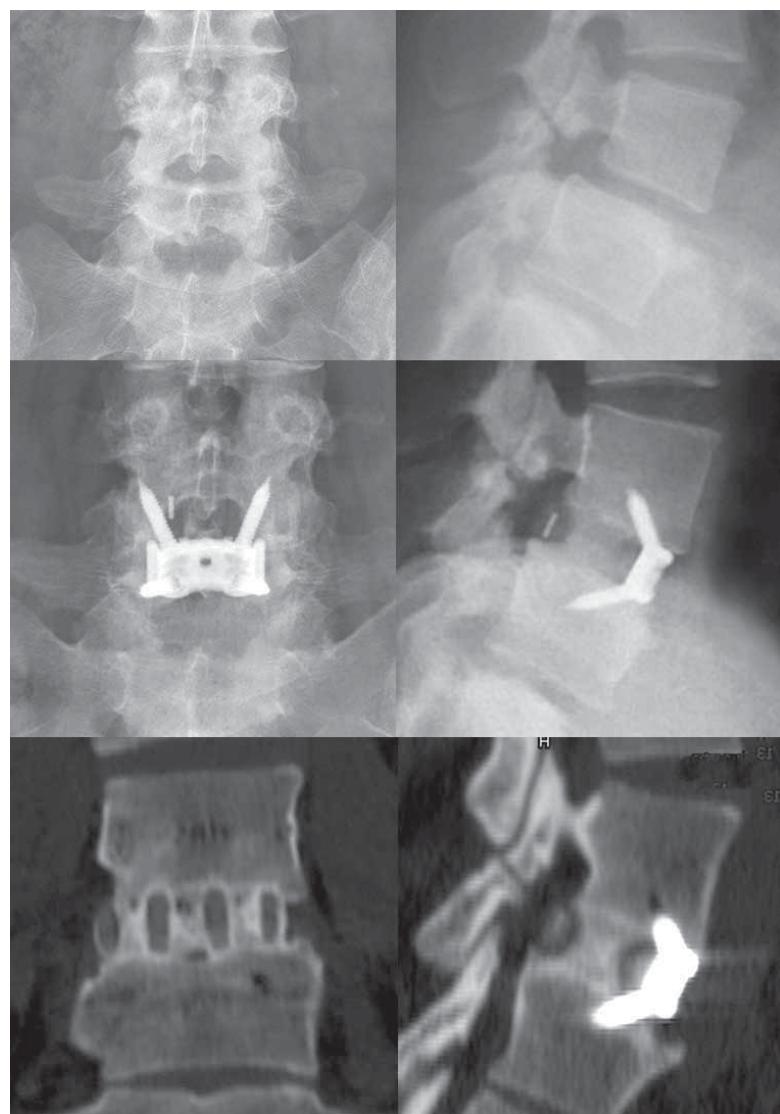


Figure 12: Stand alone ALIF is also suitable for lytic spondylolisthesis. The pictures show acceptable reduction of slip and solid fusion 6 months later.

Later the cage was designed with a very similar shape to an intervertebral disc, and often placed on the cortical ring of the spine. Stability was created by inserting a screw at the front like the Synfix® cage we used in this study.

There are many advantages of anterior interbody fusion compared to posterior interbody fusion. For example, interbody fusion has better back biomechanics because it supports the weight from the front side (anterior column support) and it balances the weight pressure (re-established load transmission).^{3,13} Moreover, the rate of spinal fusion is high because of the compression site so the growth of bone is excellent according to Wolff's rules (Juius Wolff 1836-1902). When the bone is completely joined, we achieve solid fusion, which is stronger than posterior interbody fusion.³ Moreover, the adjustment of Lordosis and disc height has an advantage over posterior fusion (TLIF)¹⁴ as it can avoid muscular damage from posterior surgery (preserved paraspinal musculature and tension band).^{15,16} Anterior lumbar spinal fusion also reduces the incidence of adjacent segment degeneration when compared to posterior open surgery.¹⁷

In our study, there is a range of age groups and indications for surgery. This illustrates the versatility of this operation to address several spinal conditions. ALIF is not only recommended for degenerative conditions of the spine: young patients who suffer from lytic spondylolisthesis in the early adult age group are also suitable candidates for this operation. The disc level considered common for this operation is L5-S1 and L4-L5 because, at these levels, vessels are easy to mobilize, there are fewer organs at risk of being damaged, and the wound is cosmetic.

One of the advantages of ALIF surgery is the factor of disc space correction, the restoration of foraminal height, local disc angle, lumbar lordosis, and sagittal balance when compared to open posterior instrumentation.¹⁸ In our study we showed positive improvements in disc height in all cases after surgery. The listhesis degree in all listhesis cases has an improvement average of 50% in our study. This corresponds to the outcome of leg pain improvement because it widens the nerve root foramen and the neural canal respectively. The nerve root decompression caused by the anterior widening of spinal foramen and canal without posterior surgical decompression is called the '**indirect decompression**' effect.¹⁰ Moreover, the improvement of segmental lordosis and coronal angle can also improve back pain caused by sagittal and coronal misalignment. In our study, all patients show significant and satisfactory improvement in both back pain and leg pain after surgery.

Anterior Interbody Fusion is highly suitable for curing chronic back pain originating in disc degeneration. This is because this surgery can take the pain generator (i.e. the disc) out completely and create a solid fusion

which results in a rigid and immovable column of bone even in micro motion, which otherwise could be a cause of back pain.¹⁹ This type of surgery incurs minimal damage of back muscles, which lessens the chance of pain from wounded muscles. In our study, patients were diagnosed as having degenerative disc disease through examinations using magnetic resonance imaging (MRI) and Discography.²⁰ The result of surgery shows marked rapid and sustained reduction of back and leg pain in just a few weeks after surgery. Also, the ODI score shows excellent improvement at the six-week, three-month, and six-month follow ups in all cases, with pain decreasing more than 25 points when compared to pain levels experienced before surgery. Moreover, as in other clinical studies,^{2,21} we observed that most of the patients returned to full activity and experienced perhaps even better results than expected from conventional posterior open surgery. This is confirmed with a much lower disability score at the six-month visit.

However, there are some disadvantages with this method. Despite it being an anterior surgery through the retroperitoneum, adjacent organs and blood vessels could be endangered.^{22,23} Therefore, professional experience is needed for operating the intervertebral disc area close to arteries and veins. Quraishi and his team studied 304 patients in England finding that there are 4.6% venous injuries that needed to be repaired and 1.6% arterial injuries.²² Brau and his team found in 1,315 patients 0.5% arterial injuries and 1.4% venous injuries. There are a lot more reports about this risk. That said, the average of arterial injuries is less than 1% and venous injuries account for about 1-3%.^{2,23,24} In our study, the mean intraoperative bleeding was around 300 milliliters and this is acceptable and seems close to levels seen in conventional posterior open surgery. The venous vessel was injured in only one case, and there was a blood loss of several thousand milliliters in the reservoir of the cell server. The patient recovered well without any post-operative complications.

A particular risk to be aware of is retrograde ejaculation. This is by sympathetic fibers of the hypogastric plexus, which lie behind the posterior surface of the peritoneum at the L5-S1 level. This event usually occurs in 2-4 % of cases, and 50% of these patients eventually recover fully.²⁴ Other complications such as abdominal ileus, lymphadenoma, injuries to the ureter, and abdominal hernias have been reported infrequently.

Conclusion

Anterior lumbar interbody fusion (ALIF) is a standard procedure for degenerative disc disease, lumbar spondylolisthesis, recurrent disc herniation and failed lumbar fusion surgery. The main reason is this procedure can provide good exposure for the surgeon to entirely remove the pain generator such as the disc. ALIF can offer a large

contact surface area for solid fusion and weight bearing procedures, and it has less likelihood of failure. It can increase disc space and create the optimal lumbar lordosis and coronal balance especially in L5-S1. The clinical outcomes show rapid and long lasting improvement in back pain, leg pain and quality of life.

However, there are some disadvantages of this method. Even though it is an anterior surgery through the retroperitoneum, adjacent organs and blood vessels could be

endangered. The incidence of retrograde ejaculation is not high, but it can be a serious problem in younger men who plan to have children. The incidence of blood vessel injuries can be lowered by a well-trained exposure surgeon with back-up support if necessary. The surgical team should be ready for immediate action if any inadvertent problem begins. Although this surgery has some disadvantages it remains one of the leading operations providing the most promising results.

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