A New Paradigm in Cage Design to Promote Lateral Bridging Bone Formation during Trans-Psoas Intervertebral Fusion*

Kingsley R. Chin, M.D., *Charles E. Schmidt College of Medicine at Florida Atlantic University*
Institute for Modern and Innovative Surgery (iMIS), 1100 W. Oakland Park Blvd. Suite #3, Fort Lauderdale, FL, 33311

Jason Seale, M.B. B.S., *Institute for Modern and Innovative Surgery (iMIS), 1100 W. Oakland Park Blvd. Suite #3, Fort Lauderdale, FL, 33311*

Vanessa Cumming, M.B. B.S., *LES Society, 300 E. Oakland Park Blvd. Suite 502, Fort Lauderdale, FL, 33334*

Institute for Modern & Innovative Surgery
IMIS Orthopedic & Spine Disorders

Les Society
The Less Exposure Surgery Society

Corresponding Author: **Kingsley R. Chin, M.D.**
Affiliate Associate Professor of Clinical Biomedical Sciences, Charles E. Schmidt College of Medicine at Florida Atlantic University
Attending Spine Surgeon, Institute for Modern & Innovative Surgery (iMIS), 1100 W. Oakland Park Blvd. Suite #3, Fort Lauderdale, FL, 33311.
Tel: 617-697-5442 Fax: 877-647-7874 Email: kingsleychin@gmail.com


Figure 1A Figure 1B

Case 1: *Anteroposterior (A) and Lateral (B) plain radiographs show a grade 2 L4-5 degenerative spondylolisthesis with an attempted fusion with left unilateral pedicle screws.*


Figure 2A Figure 2B

Case 1: *Computed tomogram (CT) myelography sagittal view (A) shows L4-5 spondylolisthesis, residual stenosis and advanced degenerative disc and facet disease involving L3-4 and L4-5. Axial view (B) showing left L3-4 facet impingement by pedicle screw.*


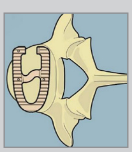

Figure 3A Figure 3B

Case 1: *Photo (A) and illustration (B) of SLIFT cage.*

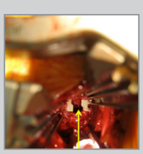


Figure 4A Figure 4B

Case 1: *Photo illustration of SLIFT open back design in-situ before (A) and after (B) packing with bone graft.*

Introduction

Since the advent of the Bagby and Kuslich (BAK) cage[1], there have been many new technologies and biologics developed to improve our ability to fuse the intervertebral space[2-6]. However, there is little attention to achieving fusion along the periphery of the vertebral bodies. When we look at naturally occurring fusions we see conditions where the body tries to bridge near or along the lateral margins such as ankylosing spondylitis (marginal bridging) or DISH (nonmarginal bridging) respectively. In the natural process of aging, the intervertebral disc degenerates leading to anterior and lateral "bridging" osteophyte formation[7-15]. The adaptive nature of bone formation under mechanical loading is well described in animal models[16-21]; and, it is presumed that vertebral osteophyte formation is stimulated by the same mechanisms as in these models because they grow out of compressed bone in the intervertebral disc spaces.

In this report we describe a novel intervertebral cage design for lateral access fusion (sagittal lumbar interbody fusion technology (S-LIFT), SpineFrontier Inc. Beverly, MA) that was developed to promote intervertebral bone formation as well as to replicate the natural tendency of lateral bridging bone[22]. We aim to illustrate how S-LIFT technology uses the rich blood supply of the psoas muscle to promote lateral fusion in two patients.

Case Report 1

A 71 year old male patient with a smoking history was referred with intractable back pain, neurogenic claudication, sciatica, and difficulty walking. He had a history of L4-5 unilateral pedicle screw attempted fusion for grade 2 degenerative spondylothisthesis with hemilaminectomies. Our patient reported continuous 8/10 pain scored using a visual analogue scale (VAS). Significant examination findings included painful and decreased range of motion in all planes; 5-/5 strength in all groups except left hip flexion, quadriceps, hamstrings, hallucis longus, and bilateral anterior tibialis (4+/5). X-ray and computed tomography (CT) myelogram of the lumbar spine illustrated stenosis at L3-5, pseudoarthrosis (L4-5), a loose pedicle screw (L4-5), degenerative spondylolisthesis, facet disease (L3-4 and L4-5), L3-4 facet impingement by instrumentation and a vacuum disc at L4-5 ***(Figure 1A-B and Figure 2A-B)***.

The patient consented to revision L3-5 decompression and instrumented fusion. A lateral-retroperitoneal trans-psoas approach[22] to fuse the discs at L3-4 and L4-5 was deemed best to use the virgin, more vascular psoas muscle overlying the disc spaces laterally and to avoid the devascularized scar posteriorly where he had prior instrumentation and decompression.

The patient underwent discectomy and cage placement at the L3-4 and L4-5 disc spaces and two 10mm x 53mm S-LIFT PEEK cages placed ***(Figure 3)***. Each cage was packed with INFUSE® (Medtronics, Memphis TN) and cancellous allograft. The cage design has an open back design that allows packing of the graft after cage placement to avoid graft spillage during impaction and to constantly expose the graft to the rich psoas blood supply ***(Figure 4A-B)***.

At five visits throughout the year postoperatively the patient reported lessened back pain (graded between 0 and 6/10 on VAS), which was described as being intermittent in nature. At a 13 month follow-up visit, x-rays and CT confirmed L3-4 and L4-5 interbody fusion with nonmarginal bridging bone formation confirming lateral fusion ***(Figures 5A-D)***.

Case Report 2

A 74 year old female presented with prior L4-5 lumbar fusion, chronic lower back pain, difficulty walking, neurogenic claudication, and sciatica. X-ray and magnetic resonance imaging (MRI) showed L4-5 pedicle screws with no interbody,

Les Society
The Less Exposure Surgery Society

This study was sponsored by the LES Society
Learn more about the LES Society at **www.les-society.org**

**Pending Publication*

We have not received any funding for this work in any form from the National Institutes of Health, Wellcome Trust, Howard Hughes Medical Institute, or others.

Figure 5A

Figure 5B

Figure 5C

Figure 5D

Case 1: Postoperative computed tomography (CT) scan showing evidence of lateral fusion: Coronal view (A) showing lateral fusion at L3-4 and L4-5; Axial slices of L4-5 (B-D) showing lateral fusion with nonmarginal bridging bone formation.

Case 2: Preoperative sagittal MRI showing severe L3-4 spinal stenosis, grade 1 L3-4 and L4-5 degenerative spondylolisthesis

Figure 6

Figure 7A

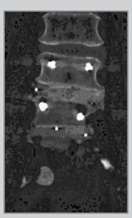

Figure 7B

Case 2: Postoperative computed tomography (CT) scan showing (A) axial and (B) coronal view of lateral interbody fusion at L3-4 with nonmarginal bridging bone formation.

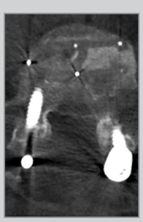

Figure 8A

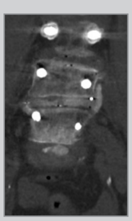

Figure 8B

Case 2: CT Postoperative computed tomography (CT) scan showing (A) axial and (B) coronal view of lateral interbody fusion at L4-5 with nonmarginal bridging bone formation.

grade 1 L3-4, L4-5 degenerative spondylolisthesis, severe L3-4 spinal stenosis, L3-4 bilateral foraminal stenosis; right L5-S1 foraminal stenosis; L5-S1 degenerative disc disease and L3-S1 degenerative facet disease ***(Figure 6)***. The patient underwent a revision L3-S1 decompression and instrumented fusion. A lateral–retroperitoneal trans-psoas approach was used for interbody fusion at L3-4 and L4-5 using S-LIFT PEEK cages. At her 10 month follow-up our patient reported lessened pain and there was radiographic confirmation of L3-4, L4-5 interbody fusion with nonmarginal bridging bone formation confirming lateral fusion ***(Figure 7A-B and Figure 8A-B)***.

Discussion

Both of the surgeries highlighted here involved minimal intraoperative blood loss (less than 150mL) and the lengths of surgery were short (average length of surgery was The S-LIFT is a novel paradigm in lateral cage design which we demonstrated uses the advantages of the psoas' arterial blood supply derived from the lumbar, iliolumbar, obturator, external iliac, and common femoral arteries to recapitulate the body's natural tendency for bridging bone formation[23, 24]. The large central cavity and open backed design allowed for generous bone graft packing after the cage was placed. In fact, the S-LIFT cage will allow between 2.098 and 7.495cm^3 and 2.294 and 8.219 cm^3 of bone graft in the 19 and 22mm sized cages respectively. Since the time of surgery for these two described procedures a new S-LIFT cage has been designed to provide an even larger area for bone graft packing into a large central cavity; this new implant will allow between 2.276 and 8.903 cm3 of bone graft into the cavity of the newer cages. The cage is placed after removing the disc from the intervertebral space to create a cavity into which the S-LIFT cage is inserted extending completely across the endplate to prevent subsidence.

In these two patients the bone formation was localized to the margins of the disc space ***(Figures 5B-D, 7A-B, 8A-B)***. We hope this report will spur further interest in this approach to cage design as trans-psoas intervertebral fusions including this system are very important surgical strategies for primary and revision lumbar spine surgeries.

References

1. Bagby G. The Bagby and Kuslich (BAK) method of lumbar interbody fusion. Spine (Phila Pa 1976). 1999;24:1857.
2. Mundis GM, Akbarnia BA, Phillips FM. Adult deformity correction through minimally invasive lateral approach techniques. Spine (Phila Pa 1976). 2010;35:S312-21.
3. Ozgur BM, Aryan HE, Pimenta L, Taylor WR. Extreme Lateral Interbody Fusion (XLIF): a novel surgical technique for anterior lumbar interbody fusion. Spine J. 2006;6:435-43.
4. Shen FH, Samartzis D, Khanna AJ, Anderson DG. Minimally invasive techniques for lumbar interbody fusions. Orthop Clin North Am. 2007;38:373-86; abstract vi.
5. Eck JC, Hodges S, Humphreys SC. Minimally invasive lumbar spinal fusion. J Am Acad Orthop Surg. 2007;15:321-9.
6. Carragee EJ, Hurwitz EL, Weiner BK. A critical review of recombinant human bone morphogenetic protein-2 trials in spinal surgery: emerging safety concerns and lessons learned. Spine J. 2011;11:471-91.
7. Hsiang JK. Spinal Stenosis. Medscape Reference [serial online]. 2011: Available from: Medscape Reference. Accessed December 13, 2011.
8. Kettler A, Werner K, Wilke HJ. Morphological changes of cervical facet joints in elderly individuals. Eur Spine J. 2007;16:987-92.
9. Tischer T, Aktas T, Milz S, Putz RV. Detailed pathological changes of human lumbar facet joints L1-L5 in elderly individuals. Eur Spine J. 2006;15:308-15.
10. Pye SR, Reid DM, Lunt M, Adams JE, Silman AJ, O'Neill TW. Lumbar disc degeneration: association between osteophytes, end-plate sclerosis and disc space narrowing. Ann Rheum Dis. 2007;66:330-3.
11. Resnick D, Niwayama G, Goergen TG. Comparison of radiographic abnormalities of the sacroiliac joint in degenerative disease and ankylosing spondylitis. AJR Am J Roentgenol. 1977;128:189-96.
12. Krishnarasa B, Vivekanandarajah A, Ripoll L, Chang E, Wetz R. Diffuse Idiopathic Skeletal Hyperostosis (DISH)-A Rare Etiology of Dysphagia. Clin Med Insights Arthritis Musculoskelet Disord. 2011;4:71-5.
13. Sobajima S, Kompel JF, Kim JS, et al. A slowly progressive and reproducible animal model of intervertebral disc degeneration characterized by MRI, X-ray, and histology. Spine (Phila Pa 1976). 2005;30:15-24.
14. Parmar KA, Solomon M, Loefler A, Dalton S. Bridging osteophyte of the anterosuperior sacroiliac joint as a cause of lumbar back pain. Br J Sports Med. 2004;38:e33.
15. Waldron T, Rogers J. An epidemiologic study of sacroiliac fusion in some human skeletal remains. Am J Phys Anthropol. 1990;83:123-7.
16. Turner CH, Akhter MP, Raab DM, Kimmel DB, Recker RR. A noninvasive, in vivo model for studying strain adaptive bone modeling. Bone. 1991;12:73-9.
17. Robling AG, Burr DB, Turner CH. Recovery periods restore mechanosensitivity to dynamically loaded bone. J Exp Biol. 2001;204:3389-99.
18. Srinivasan S, Weimer DA, Agans SC, Bain SD, Gross TS. Low-magnitude mechanical loading becomes osteogenic when rest is inserted between each load cycle. J Bone Miner Res. 2002;17:1613-20.
19. Asparuhova MB, Gelman L, Chiquet M. Role of the actin cytoskeleton in tuning cellular responses to external mechanical stress. Scand J Med Sci Sports. 2009;19:490-9.
20. Turner CH, Forwood MR, Rho JY, Yoshikawa T. Mechanical loading thresholds for lamellar and woven bone formation. J Bone Miner Res. 1994;9:87-97.
21. Sakai D, Kii I, Nakagawa K, et al. Remodeling of actin cytoskeleton in mouse periosteal cells under mechanical loading induces periosteal cell proliferation during bone formation. PLoS One. 2011;6:e24847.
22. SpineFrontierInc. URSA S-LIF Lateral Interbody System 2011. Accessed January 6, 2012.
23. Pillet J, Chevalier JM, Rasomanana D, et al. The principal artery of the psoas major muscle. Surg Radiol Anat. 1989;11:33-6.
24. Hu WK, He SS, Zhang SC, et al. An MRI study of psoas major and abdominal large vessels with respect to the X/DLIF approach. Eur Spine J. 2011;20:557-62.

This study was sponsored by the LES Society
Learn more about the LES Society at **www.les-society.org**

**Pending Publication*

We have not received any funding for this work in any form from the National Institutes of Health, Wellcome Trust, Howard Hughes Medical Institute, or others.