Orthopaedic Surgery (2012), Volume 4, No. 1, 11–14

REVIEW ARTICLE

Are stand-alone cages sufficient for anterior lumbar interbody fusion?

Ji-dong Zhang MD[1], Bart Poffyn MD[2], Gwen Sys MD[2], Dirk Uyttendaele MD[2]

[1]Department of Spine Surgery, Tianjin Hospital, Tianjin, China; and [2]Department of Orthopedic Surgery, Ghent University Hospital, Ghent, Belgium

Anterior lumbar interbody fusion (ALIF) has increased in popularity because it has advantages over posterior fusion. Because there is disagreement about the stability of stand-alone cage ALIF, some surgeons use various types of supplementary fixation, including anterior plates, pedicle screw systems and translaminar screws, to increase segmental stability. Many factors associated with both the cages and endplates influence the time of onset and extent of subsidence after use of stand-alone cage ALIF. A large round cage with an adequate central opening is recommended to facilitate maximum contact with the periphery of the endplate. With regard to the relationship between radiographic fusion and recurrence of symptoms with the development of subsidence, most researchers have reported finding no correlation. Subsidence may be due to a process of bone incorporation between cages and endplates. Does subsidence or nonfusion really matter clinically? Further prospective, randomized controlled trials are very much needed to answer these questions.

Key words: Lumbar vertebrae; Spinal fusion; Transplants

Anterior lumbar interbody fusion (ALIF) was first adopted by Capener[1] for spondylolisthesis and Mercer[2] for the treatment of disc pathology. Recently, ALIF has increased in popularity because it has advantages over posterior fusion, such as direct removal of the cause of pain, provision of a large fusion area, restoration of lumbar lordosis and avoidance of damage to the paraspinal musculature[3–5]. However, several biomechanical studies have suggested that ALIF cages do not provide adequate stability[6–8]. Inadequate immobilization of the intervertebral joint during the process of bone healing has been accepted as the main mechanical reason for nonfusion. Accordingly, several types of supplementary fixation, including anterior plates, pedicle screw systems and translaminar screws, have been utilized to improve segmental stability[9–13]. Meanwhile, other clinical studies on stand-alone ALIF have shown no significant correlation between clinical outcome and fusion rate[14–16]. So far, it is unclear whether stand-alone cages are sufficient for ALIF and what degree of stability is required to guarantee a satisfactory clinical outcome. This review of ALIF focuses on commonly expressed concerns about biomechanical stability, fusion rate, subsidence and clinical outcomes.

Address for correspondence Ji-dong Zhang, MD, Department of Spine Surgery, Tianjin Hospital, Tianjin, China 300211 Tel: 0086-13652090295; Fax: 0086-022-28241184; Email: bird0496@sina.com

Received 5 May 2011; accepted 1 September 2011
DOI: 10.1111/j.1757-7861.2011.00164.x

Biomechanical stability

In the early stages after introduction of ALIF, a number of reports documented that both autogenous and allogeneic cortical and cancellous bone grafts lacked sufficient strength for this procedure[17–19]. The need for three-dimensional initial interbody stability soon led to the development of various cages. Because it is the crucial component of ALIF, the design of the cage greatly affects biomechanical stability. Anthony *et al.* compared the effects of five different stand-alone ALIF cages (I/F, BAK, TIS, SynCage, and ScrewCage) and cage-related features on initial segmental stability in a human cadaveric study[20]. They found that the cages did reduce the range of motion (ROM) and increase the neutral zone (NZ) in all loading directions. The BAK and TIS cages had the largest NZ increase in flexion/extension and lateral bending, respectively. The degree of geometrical cage-endplate surface mismatch is responsible for the differences in NZ between cages. Cages with sharp teeth have larger pull-out forces. Multiple dimensions (height and wedge angle) of the cages influence the initial stability. Also, the residual ROM depends on the degree of micro-motion at the cage-endplate interface.

The initial stability of a stand-alone ALIF cage depends primarily on the compressive forces produced by tension on the remaining annulus fibrosus. However, the compressive force reduces in magnitude by more than 20% of peak value in the first 15 min after cage insertion due to relaxation of the soft tissue[21]. Various types of internal

Orthopaedic Surgery

fixation, such as anterior plates, pedicle screw systems and translaminar screws, have been utilized to enhance the stability of ALIF. Surgeons may choose to use anterior augmentation in place of posterior systems to avoid the additional morbidity and blood loss and reduce the surgical time associated with posterior procedures. Recently, a biomechanical comparison of anterior plate versus posterior transpedicular instrumentation in human cadaveric specimens was reported[12]. In this study, a femoral ring allograft (FRA) was used as interbody construct. Eight cadaveric lumbar spines were tested under 0N, 400N and 800N of preload to simulate the physiologic compressive load on the lumbar spine. Stand-alone FRAs significantly decreased the ROM in all directions; however, the residual ROM was large in flexion-extension ranging between 6.1° and 5.1° under 0N to 800N of preloads. The ATB plate (a particular type of anterior lumbar plate) significantly decreases ROM in flexion-extension, but not in lateral bending and rotation. Compared to the ATB plate, transpedicular instrumentation results in significantly less ROM in flexion-extension and lateral bending, but not in rotation. The result of another biomechanical test showed anterior plate fixation was biomechanically similar to pedicle screw fixation[22]. In the study of Humke *et al.*, translaminar screw fixation and pedicle screw fixation produced similar increases in rigidity provided the anterior annulus was intact[23]. When the anterior annulus is excised, as in ALIF, translaminar fixation is not as strong as pedicle screw fixation.

Fusion rate

In any fusion procedure, the fusion rate is always the aspect that most concerns the surgeon. However, inability to determine bone ingrowth in the intervertebral space accurately has been a major impediment to assessing the quality of spinal fusion. Many attempts have been made to identify bony fusion by radiological techniques, including static anteroposterior and lateral X-rays, lateral flexion/extension views, fluoroscopy, CT, and MRI. The fusion rates reported have varied dramatically according to the radiographic method used. A 96% fusion rate based on flexion/extension X-rays and the application of Food and Drug Administration criteria was reported in a group of ALIF patients. However, when the same patients were assessed by thin-section helical CT, the fusion rate was found to be only 65%[24]. Other forms of fixations in addition to ALIF seem to provide a better biomechanical environment for bony incorporation, which likely results in a higher fusion rate. However, this is not necessarily the case. Naffis *et al.* reported the fusion rates of four ALIF cohorts as assessed by thin-section CT as follows: 25 cases of stand-alone ALIF, 51%; 15 ALIF + translaminar screws, 58%; 17 ALIF + unilateral pedicle screws, 89% ($P < 0.01$) and 24 ALIF + bilateral pedicle screws, 88%($P < 0.01$)[25]. These authors cautioned against the use of translaminar screws to increase the ALIF fusion rate. Thus, ALIF augmented with a pedicle screw system does not necessarily provide better clinical outcomes. Strube *et al.* compared the fusion rate and clinical outcome of one group ($n = 40$) of stand-alone ALIF to another group ($n = 40$) of ALIF with transpedicle fixation[26]. Blood loss was less and duration of surgery significantly shorter in the ALIF group ($P < 0.001$). Pain as assessed by a visual analog scale and the Oswestry Low Back Pain Disability Index improved significantly over time in both groups ($P < 0.001$), but both scores were significantly better in the ALIF group ($P < 0.001$). Patients' satisfaction consistently ranked higher in the ALIF group ($P = 0.042$ at 12 months). No significant differences in the fusion rate were found throughout the study.

Subsidence

Subsidence is characterized by a decrease in the vertical height of the disc space prior to complete bone incorporation. Early reports of ALIF described considerable subsidence (up to 100%) using autografts or allografts[27–29]. With the advent of cages, there was a decrease in both the subsidence rate and the extent of subsidence. Dennis *et al.* reported loss of disc height at all levels, 46% being narrower than their preoperative height[29]. Cheung *et al.* assessed 67 cases of autologous iliac crest ALIF, and found the disc height at the most recent follow-up was about the same as the mean preoperative height[30]. A current study using paired stand-alone rectangular cages showed that, despite reduction in disc height after initial distraction, the disc height at the most recent follow-up was significantly greater than that found preoperatively (13.2 mm vs. 11.6 mm)[31]. As would reasonably be expected, many factors associated with cages and endplates influence the time of onset and extent of subsidence in stand-alone ALIF. Grant *et al.* conducted a biomechanical study to assess regional differences in endplate rigidity and found the posterior part was stronger than the anterior; the periphery stronger than the center; the strongest part was the posterolateral area, just in front of the pedicles; and the superior endplate was much weaker than the inferior endplate[32]. Jae *et al.* identified a difference in subsidence between superior and inferior endplates (superior endplate: 39.1% vs. inferior endplate 17.3%)[31]. Accordingly, a large round cage with an adequate central opening is recommended to facilitate maximum contact with the periphery of the endplate.

As to what stage after surgery cage subsidence occurs, reported results vary considerably. Jae *et al.*[31] reported a median time to subsidence of 2.75 months, the onset of subsidence varying from 0.25 to 8 months after surgery. The 3- and 4-month actuarial rates of subsidence were 63.4% and 70.7%, respectively. Kumar *et al.* found subsidence occurred mainly within the first 15 days after ALIF using femoral strut allografts[27]. Cheung *et al.* found that disc height loss occurred within the first 3 months after ALIF with iliac crest autografts[30]. With regard to the relationship between radiographic fusion and recurrence of symptoms with development of subsidence, the above authors reported no correlation. Subsidence may be the process of bone incorporation between cages and endplates. Because endplates are curved in shape, the cages initially rest only on the peripheral part of them. With vertical load, the cages subside slightly into the endplates, making better contact with the bone and facilitating sound fusion.

Due to widespread concerns about the stability that ALIF provides, numerous types of supplementary fixation such as pedicle screw systems and translaminar screws have been utilized to improve stability. However, posterior fixation is associated with significant damage to the paravertebral muscles, screw displacement-related neurological and vascular complications, and an increased rate of adjacent segment degeneration. Moreover, up to now there has been no evidence to support the contention that ALIF with supplementary fixation results in a better fusion rate or clinical outcome. Thus the following questions arise: is it worth pursuing absolute stabilization and to what extent does stability guarantee sound fusion? As we know, micro-motion facilitates bone union in the fracture healing process. However, the precise mechanism of fusion in ALIF and the exact amount of micro-motion required are still not clear.

For spine surgeons, there is no escaping the question of whether subsidence or nonfusion really matter clinically. Further prospective, randomized controlled trials are very much needed to answer this question.

Disclosure

No benefits of any type have been, or will be, received from a commercial party related directly or indirectly to the subject of this manuscript.

References

1. Capener N. Spondylolisthesis. Br J Surg, 1932, 19: 374–386.
2. Mercer W. Spondylolisthesis: with a description of a new method of operative treatment and notes of ten cases. Edinburgh Med J, 1936, 43: 545–572.
3. Aebi M, Parthasarathy S, Avadhani A, *et al*. Minimal invasive anterior lumbar interbody fusion (mini ALIF). Eur Spine J, 2010, 19: 335–336.
4. Min JH, Jang JS, Lee SH. Comparison of anterior- and posterior-approach instrumented lumbar interbody fusion for spondylolisthesis. J Neurosurg Spine, 2007, 7: 21–26.
5. Ohtori S, Koshi T, Yamashita M, *et al*. Single-level instrumented posterolateral fusion versus non-instrumented anterior interbody fusion for lumbar spondylolisthesis: a prospective study with a 2-year follow-up. J Orthop Sci, 2011, 16: 352–358.
6. Nibu K, Panjabi MM, Oxland T, *et al*. Multidirectional stabilizing potential of BAK interbody spinal fusion system for anterior surgery. J Spinal Disord, 1997, 10: 357–362.
7. Oxland TR, Hoffer Z, Nydegger T, *et al*. A comparative biomechanical investigation of anterior lumbar interbody cages: central and bilateral approaches. J Bone Joint Surg Am, 2000, 82: 383–393.
8. Heth JA, Hitchon PW, Goel VK, *et al*. Abiomechanical comparison between anterior and transverse interbody fusion cages. Spine, 2001, 26: E261–E267.
9. Kim JS, Kim DH, Lee SH, *et al*. Comparison study of the instrumented circumferential fusion with instrumented anterior lumbar interbody fusion as a surgical procedure for adult low-grade isthmic spondylolisthesis. World Neurosurg, 2010, 73: 565–571.
10. Lee DY, Lee SH, Maeng DH. Two-level anterior lumbar interbody fusion with percutaneous pedicle screw fixation: a minimum 3-year follow-up study. Neurol Med Chir, 2010, 50: 645–650.
11. Kim KH, Lee SH, Lee DY, *et al*. Anterior bone cement augmentation in anterior lumbar interbody fusion and percutaneous pedicle screw fixation in patients with osteoporosis. J Neurosurg Spine, 2010, 12: 525–532.
12. Tzermiadianos MN, Mekhail A, Voronov LI, *et al*. Enhancing the stability of anterior lumbar interbody fusion: a biomechanical comparison of anterior plate versus posterior transpedicular instrumentation. Spine, 2008, 33: E38–E43.
13. Anderson DG, Sayadipour A, Shelby K, *et al*. Anterior interbody arthrodesis with percutaneous posterior pedicle fixation for degenerative conditions of the lumbar spine. Eur Spine J, 2011, 20: 1323–1330.
14. Kim JS, Choi WG, Lee SH. Minimally invasive anterior lumbar interbody fusion followed by percutaneous pedicle screw fixation for isthmic spondylolisthesis: minimum 5-year follow-up. Spine J, 2010, 10: 404–409.
15. Lee CS, Hwang CJ, Lee DH, *et al*. Fusion rates of instrumented lumbar spinal arthrodesis according to

surgical approach: a systematic review of randomized trials. Clin Orthop Surg, 2011, 3: 39–47.
16. Kim JS, Kang BU, Lee SH, *et al*. Mini-transforaminal lumbar interbody fusion versus anterior lumbar interbody fusion augmented by percutaneous pedicle screw fixation: a comparison of surgical outcomes in adult low-grade isthmic spondylolisthesis. J Spinal Disord Tech, 2009, 22: 114–121.
17. Glazen PA, Colliou O, Klisch SM, *et al*. Biomechanical analysis of multilevel fixation methods in the lumbar spine. Spine, 1997, 22: 171–182.
18. Dennis S, Watkins R, Landaker S, *et al*. Comparison of disc space heights after anterior lumbar interbody fusion. Spine, 1989, 14: 876–878.
19. Loguidice VA, Johnson RG, Guyer RD, *et al*. Anterior lumbar interbody fusion. Spine, 1988, 13: 366–369.
20. Tsantrizos A, Andreou A, Aebi M, *et al*. Biomechanical stability of five stand-alone anterior lumbar interbody fusion constructs. Eur Spine J, 2000, 9: 14–22.
21. Havey RM, Voronov LI, Gaitanis I, *et al*. Relaxation Response of Lumbar Spine Segments Undergoing Annular Distraction: Implications to Anterior Lumbar Interbody Implant Stability. San Francisco, CA: Orthopedic Research Society, 2004.
22. Nichols TA, Yantzer BK, Alameda S, *et al*. Augmentation of an anterior lumbar interbody fusion with an anterior plate or pedicle screw fixation: a comparative biomechanical *in vitro* study. J Neurosurg Spine, 2007, 6: 267–271.
23. Humke T, Grob D, Dvorak J, *et al*. Translaminar screw fixation of the lumbar and lumbosacral spine. A 5-year follow-up. Spine, 1998, 23: 1180–1184.
24. Santos ER, Goss DG, Morcom RK, *et al*. Radiologic assessment of interbody fusion using carbon fiber cages. Spine, 2003, 28: 997–1001.
25. Anjarwalla NK, Morcom RK, Fraser RD. Supplementary stabilization with anterior lumbar intervertebral fusion – a radiologic review. Spine, 2006, 31: 1281–1287.
26. Strube P, Hoff E, Hartwig T, *et al*. Stand-alone anterior versus anteroposterior lumbar interbody single-level fusion after a mean follow-up of 41 months. J Spinal Disord Tech, 2011, 10: 469–473.
27. Kumar A, Kozak JA, Doherty BJ, *et al*. Interspace distraction and graft subsidence after anterior lumbar fusion with femoral struct allograft. Spine, 1993, 18: 2393–2400.
28. Soini J. Lumbar disc space heights after external fixation and anterior interbody fusion: a prospective 2-year follow-up of clinical and radiaographic results. J Spinal Disord, 1994, 7: 487–494.
29. Dennis S, Watkins R, Sandaker S, *et al*. Comparison of disc space heights after anterior lumbar interbody fusion. Spine, 1989, 14: 876–878.
30. Cheung KM, Zhang YG, Lu DS, *et al*. Reduction of disc space distraction after anterior lumbar interbody fusion with autologous iliac crest graft. Spine, 2003, 28: 1385–1389.
31. Choi JY, Sung KH. Subsidence after anterior lumbar interbody fusion using paired stand-alone rectangular cages. Eur Spine J, 2006, 15: 16–22.
32. Grant JP, Oxland TR, Dvorak MF, *et al*. The effects of bone density and disc degeneration on the structural property distributions in the lower lumbar vertebral endplates. J Orthop Res, 2002, 20: 1115–1120.