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Application of tridimensional intravertebral bone graft combined with AxiaLIF technique in lumbar interbody fusion

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Abstract

Lumbar interbody fusion techniques are becoming more and more minimally invasive. AxiaLIF technique can be used in low back pain caused by degenerative disc disease or minor spondylolisthesis, but there are risks for fusion failure. Intravertebral bone graft is performed in painful osteoporotic or posttraumatic vertebral compression fractures (VCFs). Until now, no attempt has been made to apply intravertebral bone graft with AxiaLIF technique.
So first, we hypothesize a novel method for tridimensional intravertebral bone graft with a special designed bone grafting instrument and describe it vividly. The special instrument would mainly consist of a hollow tube and a rod, the distal parts of them would be shape into 45o slope, so the direction of grafting would be decided by the slope. By rotating the tube we can deliver cancellous bone granules in one plane, but by retreating the tube we can perform tridimensional intravertebral bone graft. Second, intravertebral bone graft is supposed to be performed combined with AxiaLIF technique in order to create biologic vertebral reconstruction and raise fusion rate. We believe this is the first description of such a method, future clinical studies are needed to validate these hypotheses.

Keywords
Spine fusion, Internal fixation, AxiaLIF technique, Tridimensional intravertebral bone graft

Introduction

To obtain spinal stability, interbody fusion is needed for low back pain caused by degenerative disc disease or minor spondylolisthesis. In traditional procedure, for anatomical reasons, soft tissues are seriously tored open, bone structure is damaged inevitably, and some new oppression occurs because of scars emerging in vertebral canal laterly. This can lead to continuous back pain after surgeries in partial patients(1,2). Sometimes, the back pain can even cover the truly postoperative effect, a few researchers call it a “fusion disease”(3).

Limits and disadvantages of anterior, posterior, and direct lateral approaches to the lumbar spine

have resulted in the development of minimally invasive techniques. In 2004, a presacral approach (a percutaneous, presacral, minimally invasive approach) was reported for L5-S1 interbody fusion, this axial procedure is called AxiaLIF technique laterly(4). The main feature of AxiaLIF technique is the novel minimally invasive presacral approach, this technique avoids dissection anteriorly, posteriorly, and laterally to the spine, it does not result in injury and disruption of the bilateral facet joints, anterior/posterior longitudinal ligament, or annulus, similarly it does not damage nerve roots or posterior musculature, and avoids the risks of many postoperative complications(4-10). AxiaLIF technique was superior to other fusion ones in mean operative time; blood loss; hospital stay and costs(5,6). But all these studies were small sample size, short-term follow-up and not Randomized Controlled Trials. The potential risk is fusion cage cuts vertebral bone substance, it can cause the cage sinking and fusion failure, easy to see among osteoporotic patients(5-7).

Until now, no attempt has been made to apply intravertebral bone graft with AxiaLIF technique. This article tries to combine intravertebral bone graft to AxiaLIF technique, in order to improve fusion rate and avoid postoperative complications.

Idea

The grafting area locates in not intravertebral but intervertebral space, because AxiaLIF technique pays more attention to interbody fusion(4-6). So, the cage can cut the intravertebral cancellous bone easily, this would lead to bone absorption around the cage, or facet screws, pedicle screws loosening, and result in fusion failure finally. We have checked the latest articles, no one has proposed a new deal to apply intravertebral bone graft combined with AxiaLIF technique in lumbar interbody fusion. Raising bone mineral density, performing intravertebral bone graft can improve pullout strength of the cage and the screws. When using AxiaLIF technique, we hypothesize intravertebral bone graft should be performed with a special designed bone grafting instrument as soon as we finish reaming and discectomy, then the cage could be put into secondly.

The special designed bone grafting instrument would mainly consist of a hollow tube and a rod, the distal parts of them would be shape into 45o slope, so the direction of grafting would be decided by the slope. The rod could compress the cancellous bone, perform impaction bone grafting. The instrument could rotate and move up and down through the bony channel made already. Rotating could make it possible to deliver granular bone in any direction but limiting in a single plane; moving continuously could make it possible for tridimensional bone graft. Referring to preoperative CT or MR, more bone can be added at the weak spot. This procedure allows the delivery of allograft and/or autograft bone, with its osteoinductive, osteoconductive, and osteogenic properties. Human Bone Morphogenetic Protein (BMP) can be used too, good results have been obtained with BMP in spinal fusion in recent years, it is well known that BMP can induce bone mesenchymal stem cells (BMSCs) aggregation and impel them directionally differentiate into osteoblasts(11,12).

Method

1. The patient is placed prone and prepped in the usual sterile fashion on a radiolucent table. Digital C-arm fluoroscopy is essential for proper anatomical localization of the affected disk. Next, on the anterior cortex of the sacrum at the junction of the S1 and S2 vertebral bodies, a guide pin is advanced via a presacral approach, tapped gently into the sacrum towards L5 by a cannulated slap hammer. A drill is used to initiate channel creation, osseous working channel is subsequently enlarged with reamer, the reamer is available in 7.5 mm diameter, and then discectomy is performed(8,10).
2. Thereafter, the bone grafting instrument is advanced through the sacrum and intervertebral disc into the upper vertebra, until it comes advanced to within 5 mm of the superior endplate of the vertebra. The reamer is available in 7.5 mm diameter, so the same size is osseous working channel. Let outer diameter of the tube be 6.5 mm, diameter of the rod be 5 mm, proximal part of tube be funnel shaped, it is easier to fill with bone granules. The cancellous bone granules are implanted with the size of 4-5 mm, direction of the slope controls the direction of grafting. Rotating the tube, delivering cancellous bone granules in one plane; then retreating the tube by 5mm, performing the same action until it comes advanced to within 5 mm above the inferior endplate, retreating and delivering are the core contents. Same operations with the lower vertebra, thus tridimensional intravertebral bone graft is perfectly done. We can use the instrument for intervertebral bone graft as well, but not let the bone oppress dura sac.
3. Finally the 3D AxiaLIF Rod^{TM}(TranS1 Inc.) is inserted slowly under fluoroscopy, the incision is irrigated and closed in the standard fashion.

Discussion

Imperfectly designed device might cause serious clinic effects, orthopaedic surgeons would not have forgotten the pain of patients treated with cervical fusion cage of early stage(13,14). At that time, cervical cages were cylindrical and were screwed

into the disc space. The plane of the thread was parallel to cervical longitudinal axis, so the effect of the screw thread cutting into the cortex bone occurred inevitably, it led to cage sinking and fusion failure. Now cubic cervical cages are replaced of cylindrical ones and do not have thread anymore; the anterior edge of some cubic cages extends upwards and downwards, it can play partial role of anterior cervical plates.

The main feature of AxiaLIF technique is the novel approach. On the anterior cortex of the sacrum at the junction of the S1 and S2 vertebral bodies, the guide pin is tapped gently into the sacrum towards L5 using a cannulated slap hammer. Osseous working channel is created within the sacrum, this technique avoids exposure of never roots and dura sac, it does not result in injury and disruption of the bilateral facet joints, anterior/posterior longitudinal ligament, or annulus, similarly it does not damage nerve roots or posterior musculature, and can avoid the risks of many postoperative complications. AxiaLIF technique is also in accord with biomechanical characteristics of spine(4-10). 3D AxiaLIF Rod™ is specially designed with differential thread diameter and pitch, it is conical shape but the head of the cone is cut off(8-10). This provides axial supporting and firmly fixation as it is inserted; allows for distraction across the disc space, thereby restoring the intervertebral disc and neuroforaminal height; restores the whole height and physiological curvature of the lumbar. Reduction can be seen of the folded flavum, posterior longitudinal ligament and the herniated anulus, the symptoms of stenosis of nerve root canal and central vertebral canal are improved too(7,8). The thread plane is vertical to lumbar longitudinal axis, it can reduce the effects of longitudinal cutting, this is the reason why AxiaLIF technique is widely used recently, and the clinical reports increase gradually(7,10). We could find only 7 (table 1) articles about AxiaLIF technique in literature, none of them had mentioned tridimensional intravertebral bone graft, we believe this is the first description of such a method.

Table 1. Reported articles about AxiaLIF technique

Author	Year	Journal	main contents
Cragg et al(4)	2004	J Spinal Disord Tech	cadaver, animal and human pilot study
Ledet et al(5)	2006	Expert Rev Med Devices	early clinic study, special case report
Marotta et al(6)	2006	Neurosurg Focus	early clinic study, special case report
Aryan et al(7)	2008	Minim Invas Neurosurg	later clinic study with follow-up
Yuan et al(8)	2006	J Spinal Disord Tech	anatomical study of the percutaneous presacral space
Ledet et al(9)	2005	J Biomech Eng	Biomechanical evaluation of AxiaLIF screw
Shen et al(10)	2007	Orthop Clin North Am	review article

35 patients (20 F:15 M, mean age 54 years) were reported accepted this treatment(7). Average follow-up was 17.5 months, mean operative time for the L5-S1 AxiaLIF procedure was 42 minutes, mean blood loss for the axiaLIF portion of the procedure was 30 ml. Fusion rate at 1 year was 80% in the group stand alone AxiaLIF and was 100% in the group AxiaLIF with pedicle screws, overal fusion rate was 91%. Oswestry disability index (ODI) dropped from 42 to 22 and Visual Analogue Scale scores (VAS) from 75 to 31. With posterior fixation, the author thought AxiaLIF provided instant supporting and stability, raised the fusion rate dramatically, but it was only from mechanical point of view. We believe, from biomechanical point of view, that intravertebral bone graft can create biologic vertebral reconstruction, raise bone mineral density, maintain spinal stability at later stage and reduce the possibility of loosening. It is essential for osteoporotic patients, meanwhile intravertebral bone graft is not conflict with posterior fixation.

From systematic review of literature, we found that intravertebral bone graft had been reported treated for posttraumatic vertebral compression fractures over 20 years ago(15). In 1986, a Germany doctor injected bone granules into vertebra via pedicle when finishing reduction and posterior fixation. There are not many related articles about intravertebral bone graft after that, other researchers reported that this procedure had not improved fusion rate(16,17). We think, these researchers might have been limited by the deficient spine internal fixation theory of their times, posterior fixation via pedicles is far less than those needed to cure thoracolumbar burst fractures. Intravertebral bone graft cannot provide instant supporting and stability.

Allograft and/or autograft bone was used to avoid serious complications from Polymethylmethacrylate(PMMA) of Vertebrop-

lasty and Kyphoplasty (18-20). Cancellous bone is osteoconductive and osteoinductive and can be used to create biologic vertebral reconstruction, it will be more effective together with BMP. So it is possible for performing tridimensional intravertebral bone graft.

As a result, we believe it is possible to perform tridimensional intravertebral bone graft with a special designed instrument based on AxiaLIF technique. It can add bone in vertebra; create biologic reconstruction; provide firmly bony bed for 3D AxiaLIF Rod™; reduce the possibility of loosening; and improve the clinical effect. But the proportional coefficient of quantity or volume between graft and a single vertebra should be determined; and the healing time be observed. Moreover, deepening the screw thread can increase the pullout strength of the cage, may be another method of improving stability of the 3D AxiaLIF Rod™.

Overview Box

AxiaLIF technique can be used as minimally invasive technique in lumbar interbody fusion, but there are risks for fusion failure. Intravertebral bone graft is performed in vertebral compression fractures (VCFs). Until now, no attempt has been made to apply intravertebral bone graft with AxiaLIF technique, so we add them together. In AxiaLIF technique, they injected bone granules into vertebra and the granules were very small, so we suggest we should use tridimensional intravertebral bone graft and the granules are big as 4-5 mm. Cancellous bone is osteoconductive and osteoinductive, we would spend more time on each surgery but create biologic vertebral reconstruction.

We think we should choose randomized controlled trials to test this idea, select 20-30 proper patients and divide them into 2 groups as A and B, one group for AxiaLIF and the other for tridimensional intravertebral bone graft combined with AxiaLIF. We should observe fusion rate, mean operative time; blood loss; hospital stay and costs.

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