Quantification evaluation of structural autograft versus morcellized fragments autograft in patients who underwent single-level lumbar laminectomy

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Abstract. Posterolateral fusion (PLIF) with autogenous bone graft is considered the gold standard for lumbar spinal fusion. However, the fusion rate and effectiveness of locally derived corticocancellous structural autograft vs. morcellized fragments autograft for lumbar PLIF, following single level lumbar laminectomy in patients with symptomatic lumbar spinal stenosis, remain unknown. Thus, the present study aimed to compare the fusion rates of corticocancellous structural autograft and morcellized fragments autograft for the treatment of lumbar PLIF. A randomized self-controlled trial was conducted comprising of 135 patients with symptomatic lumbar spinal stenosis, single level lumbar laminectomy and PLIF, with corticocancellous structural autograft (group 1) and morcellized fragments autograft (group 2). The primary outcome measurements included the PLIF rate, radio density and dimensions of PLIF mass on both sides, which were assessed via X-rays at 3, 6 and 12 months, postoperatively. Furthermore, changes in bilateral bone fusion bridges were assessed via CT scanning, according to the Lenke CT fusion measurement criteria. The follow-up period lasted for 1 year (period between January 2013 and January 2018). Of the 135 patients were initially included in the present study, 7 patients were lost during the following up process. Therefore, data from 128 patents were eventually assessed, 94.8% of surgical levels were observed at Honghui Hospital. According to the Lenke CT fusion measurement criteria, the overall unilateral fusion rates were 71.9% (92/128) in group 1 and 31.3% (40/128) in group 2. Furthermore, both the radio density and dimensions of PLIF mass significantly decreased at a faster rate in group 1 compared with group 2 (radio density; 0.65-0.49 vs. 0.63-0.61; $P<0.05$ and PLIF mass; 398-124 vs. 376-223 mm^2; $P<0.05$). The CT scan results demonstrated that the mean volume of bone graft was significantly greater in group 1 compared with group 2, at 12 months postoperatively (1.47 vs. 1 cm^3; $P<0.05$). Taken together, the results of the present study suggested that corticocancellous structural autograft is more effective for earlier resorption and stabilization of patients undergoing PLIF, compared with morcellized fragments autograft.

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Introduction

Spinal fusion is a surgical procedure used to treat several types of spinal disease, including spinal disc herniation, spondylolisthesis and spinal stenosis (1), which is extensively performed worldwide. The number of lumbar spinal fusion surgeries approximately quadrupled between 1992-2013 in the United States, which led to a significant increase in medical care enrollees, from 0.3-1.1 per 1,000 (2). A previous study reported that spinal fusion surgery accounts for the highest total aggregate hospital costs compared with any other surgical procedure performed in the United States medical care institution, accounting for $12.8 billion in 2011 (3). With the increase in the aging population and the prevalence of degenerative spinal diseases, the number of spinal surgeries are predicted to continue increasing. Of the different types of spinal fusion techniques, posterolateral fusion (PLIF) with autogenous bone graft is considered the gold standard for lumbar spinal fusion (4).

Autogenous bone grafting has osteogenic, osteoinductive and osteoconductive properties (5). Furthermore, it is histocompatible, osteointegrative and does not pose the risk of disease transmission or immune rejection (6). Corticocancellous morcellized fragments and corticocancellous struts from the iliac crest or the laminar process (locally) are commonly used autologous grafts for PLIF (7). However, the fusion rates of these autologous grafts have not yet been fully investigated. Therefore, the present study aimed to prospectively compare the fusion rates and effectiveness of corticocancellous structural autograft and morcellized fragments autograft used in lumbar PLIF, for the treatment of patients with stenosis. The

primary outcome measurements included the PLIF rate, radio density and dimensions of the PLIF mass on both sides, which were assessed using X-ray at 3, 6 and 12 months postoperatively. Changes in bilateral bone fusion bridges were assessed by CT according to the Lenke CT fusion measurement criteria (4). The present study suggested that corticocancellous structural autograft is more effective for earlier resorption and stabilization of patients undergoing PLIF, compared with that of the morcellized fragments autograft.

Patients and methods

Study design. The prospective study was designed to evaluate the radiological changes of bone fusion mass in 135 patients with degenerative lumbar stenosis, who underwent PLIF surgery between January 2013 and January 2016 in Honghui Hospital, Xi'an Jiaotong Unviersity, School of Medicine (Xi'an, China). The present study was approved by the Ethics Committee of Honghui Hospital (approval no. 201000919) and performed according to the 2010 CONSORT guidelines (http://www.consort-statement.org). Written informed consent was provided by all patients prior to the start of the study.

Inclusion and exclusion criteria. Patients with revision surgery (instrumental failure, including screw fixation, rods fixation or fusion failure), sagittal imbalance and scoliosis or patients with pulmonary comorbidity or severe cardiac complications were excluded from the present study. A total of 72 men and 63 women were recruited, with an age range of 50-80 years (mean age, 65.7 years) and the following up period is between January 2013 and January 2018 (24±2.1 months). All patients included in the present study underwent one segment PLIF with pedicle screw fixation. The patient demographics are presented in Table I.

Table I. Patient demographics.

Characteristic	Measurements
Sex	Total number of patients, n
Male	72
Female	63
Mean age, years (range)	65.7 (50-80)
Diagnoses	Total number of patients, n[a]
Back pain	89
Leg pain	125
Numbness of lower limb	92
Intermittent claudication	135
	Mean (range)
ODI	39.6 (34.0-41.0)
VAS (back)	5.3 (0.0-8.0)
VAS (leg)	7.8 (0.0-9.0)

[a]Patient overlap observed. ODI, Oswestry Disability Index; VAS, visual analog scale.

Table II. Lenke classification of posterolateral fusion success.

Grade	Description
Grade A	Solid, with the presence of bilateral trabeculated stout fusion masses
Grade B	Possibly solid, with the presence of a unilateral large fusion mass and a contralateral small fusion mass
Grade C	Probably not solid, with the presence of a bilateral small fusion mass
Grade D	Not solid, with the presence of bone graft reabsorption or obvious bilateral pseudarthrosis

Surgical procedure and bone graft. Corticocancellous struts (group 1) and corticocancellous morcellized fragments (group 2) surgeries were performed within the same patient in each patient in the present study. Briefly, a 3- to 6-inch long incision was made in the midline of the back, and the left and right lower back muscles (erector spinae) were stripped of the lamina on both sides, at multiple levels. The lamina was removed via laminectomy on approach to the spine, in order to visualize the nerve roots. Subsequently, the facet joints, which lie directly above the nerve roots, were trimmed to provide more space for the nerve roots. The nerve roots were extended to one side while the disc space was cleared of all material. A cage made of allograft bone, or posterior lumbar interbody cages with bone graft was subsequently inserted into the disc space to allow efficient bone growth, between the vertebral bodies (2,5). The facet joints were decorticated and bone grafting was performed by connecting each facet joint with the local autologous corticocancellous struts (group 1) or corticocancellous morcellized fragments (group 2). The amount of autologous bone graft was equal for both groups (group 1; 4.5 cm^3 local autologous corticocancellous morcellized fragments and group 2; 3x1.5x1 cm local autologous corticocancellous struts).

Radiographic analysis. Lumbar spinal CT (SOMATOM® Perspective; Siemens Healthineers) scans and X-rays (Polydoros 80/100; Siemens Healthineers) were performed at 3, 6 and 12 months, postoperatively. Quantitative image density of bone mass fusion from the AP X-rays was analyzed in both groups, as previously described (8). Briefly, the mean radio density on the X-rays was calculated using the picture archiving and communication system, which outlines the frame of bone fusion mass and titanium rod and via bone fusion mass that divides the titanium rod (bone fusion mass/titanium rod). Furthermore, the bilateral bone fusion mass dimensions were measured using the ImageJ software (version 1.52; National Institutes of Health). Bone graft volume was determined using the axial 1-mm CT scans at 3 and 12 months postoperatively. A total of three continuous CT images (100 kilovoltage/115 milliampere seconds) were assessed for bone mass fusion according to the Lenke CT fusion measurement criteria for PLIF (Table II), as previously described (9). The bone fusion mass results were divided into two groups, definitely fused and definitely not fused, according to the reported hierarchical combination of the fusion criteria, which were confirmed (Table II) and bilaterally compared between groups 1 and 2.

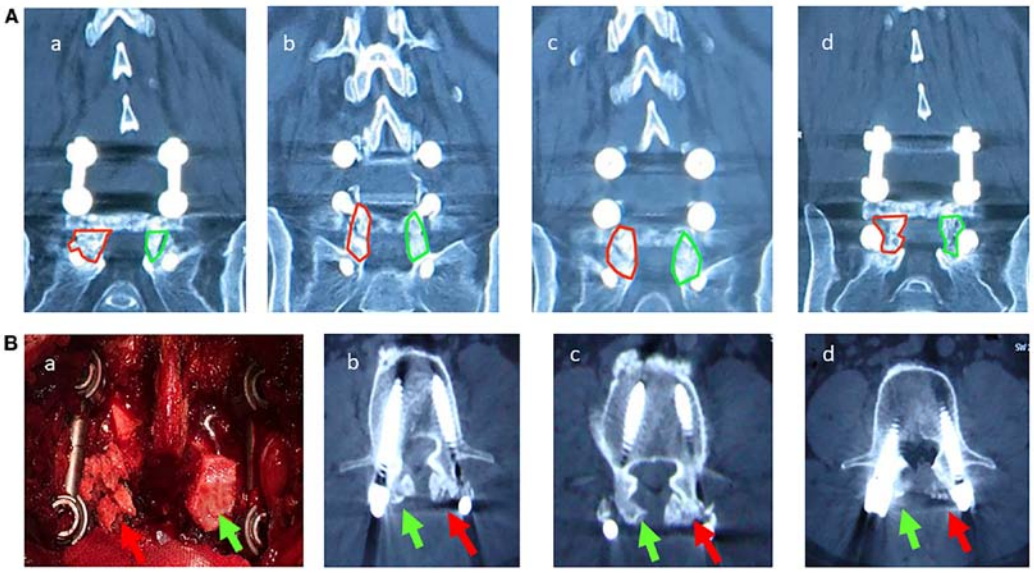

Figure 1. Volume of bilateral bone fusion mass was calculated via CT scanning. CT sagittal plan scanning images obtained (A-a) immediately after operation and (A-b) 3, (A-c) 6 and (A-d) 12 months after operation images. (B-a) Photograph obtained during the operation. Axial plan scanning images obtained (B-b) 3, (B-c) 6 and (B-d) 12 months after operation. Group 1 is marked by a green frame, while group 2 is marked by a red frame. Both groups were evaluated at 3, 6 and 12 months postoperatively.

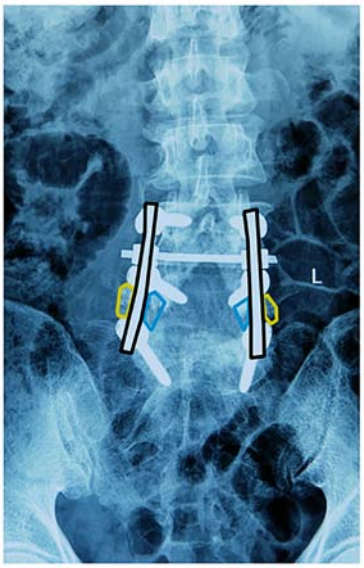

Figure 2. Calculation of fusion mass. Quantitative image density of fusion mass in both groups on anterior and posterior position X-rays was calculated by dividing the bone fusion mass density with the titanium rod density, represented by the black frame in the image, following which bilateral bone fusion mass areas were simultaneously measured. Yellow and blue frames are represent the bone fusion area. L, left side.

Statistical analysis. Statistical analysis was performed using GraphPad Prism software (version 8; GraphPad Software, Inc.). The Linear Mixed Model was used to statistically analyze the radiological differences between radio density and dimensions of PLIF mass in both groups, as previously described (9). Briefly, grey scale images from all groups were analyzed using ImageJ software (version 1.52; National Institutes of Health). Subsequently, McNemar's test was used to compare differences in fusion rates between the groups (9,10). $P<0.05$ was considered to indicate a statistically significant difference.

Results

Demographics information of patients included in the present study and fusion rate. The results demonstrated that spinal fusion was completely achieved in patients with corticocancellous morcellized fragments (group 1), as follows: In four patients at 3-months postoperatively, in 27 patients at 6-months postoperatively and in 40 patients at 12-months postoperatively (Table III). However, 88 patients in group 1 failed to exhibit complete spinal fusion, whereby the fusion mass was detected using X-rays and CT scans, but a definite fusion was not achieved. Conversely, bone fusion was completely achieved in patients with corticocancellous struts (group 2), as follows: In 37 patients at 3-months postoperatively, in 70 patients at 6-months postoperatively and in 92 patients at 12-months postoperatively. However, 36 patients in group 2 failed to exhibit complete spinal fusion (Table III). The overall fusion rate was significantly higher in group 1 (71.9%; 92/128) compared with group 2 (31.3%; 40/128) ($P<0.05$; Table III).

Radiographic analysis results. Radiographic analysis included X-rays and CT scans, where mean density and dimensions of bone fusion masses were determined using the lumbar spine AP images. The mean radio densities of group 2 (0.5067±0.01581, 0.6102±0.01322 and 0.6739±0.01553) were significantly higher than the mean densities of group 1 (0.301±0.01741, 0.3991±0.02081 and 0.4907±0.01079) at 3, 6 and 12 months postoperatively, respectively. Similarly, the dimensions of the fusion masses were significantly higher in group 2 (470.0±5.627, 410.0±6.205 and 351±6.991 mm^2) compared with group 1 (420.3±5.332, 332.0±4.031 and 261±6.011 mm^2) at 3, 6 and 12 months postoperatively, respectively ($P<0.05$; Figs. 1-2; Table III).

Bone fusion success was evaluated via CT scanning at 3, 6 and 12 months postoperatively. The mean volumes were

Table III. Fusion rate of follow-up data.

Time, months (postoperatively)	Group	Grade A, n (%)	Grade B, n (%)	Grade C, n (%)	Grade D, n (%)
3	1	42 (32.8)	51 (39.8)	31 (24.2)	4 (3.1)
	2	11 (8.6)	29 (22.7)	51 (39.8)	37 (28.9)
6	1	22 (17.2)	33 (25.8)	46 (35.9)	27 (21.1)
	2	7 (5.5)	19 (14.8)	32 (25.0)	70 (54.7)
12	1	21 (16.4)	25 (19.5)	42 (32.8)	40 (31.3)
	2	5 (3.9)	12 (9.4)	19 (14.8)	92 (71.9)

significantly higher in group 2 (4.970±0.02739, 4.281±0.0211 and 3.191±0.0341 cm^3) compared with group 1 (4.609±0.02981, 3.610±0.01991 and 2.330±0.01881 cm^3) at 3, 6 and 12 months postoperatively, respectively ($P<0.05$; Fig. 1). This finding suggests that during bone graft incorporation, the bone graft was initially partially resorbed and was subsequently remodeled.

Discussion

Spine fusion is a surgical procedure used to treat different types of spinal disease, including severe spine trauma, spinal infection, spinal deformities and spinal degenerative diseases (11). With the rapid progression of surgical techniques and broadening indications, there has been a rapid increase in spinal fusion surgery (12). However, several factors may lead to the failure of solid fusion, such as pseudarthrosis, which is a major iatrogenic complication (6). Thus, the present study investigated fusion for corticocancellous structural autograft vs. morcellized fragments autograft in patients who underwent decompressive single level lumbar laminectomy and one segment PLIF with pedicle screw fixation. To the best of our knowledge, the present study was the first to compare the fusion rates of two types of structural allografts used for PLIF. The results demonstrated that the corticocancellous structural autograft had a better fusion rate in patients with PLIF compared with the morcellized autograft.

The results of the present study demonstrated that during bone graft incorporation, the bone graft is initially partly resorbed and subsequently remodeled. However, this resorptive phase may weaken the bone graft, particularly during the initial months postoperatively. Several factors may affect the fusion rate. Previous studies have reported that decreased bone graft volume decreases the mass, which consolidates into a thick bone mass and in turn fails to significantly increase the fusion mass (5,7,13). Conversely, increasing the bone graft volume has been demonstrated to induce extensive bone resorption, which in turn decreases the bone matrix for new bone construction, resulting in failure of spinal fusion (14). Thus, the bone graft volume and structural changes essentially determine the fusion rate success. The present study investigated the differences in the fusion rate between the local autologous corticocancellous struts and corticocancellous morcellized fragments, using the same volume.

The results demonstrated simultaneous (at 3 months) and short-term (at 6 months) fusion rates in group 2 (28.9 and 54.7%) and group 1 (3.1 and 21.1%), respectively. These results suggested that the autologous corticocancellous strut is a better choice for patients undergoing PLIF for earlier lumbar fusion. Furthermore, the overall fusion rates at 12 months were 71.9 and 31.3% in groups 2 and 1, respectively. A previous study reported that when autologous iliac bone was used for PLIF, the fusion rate was increased from 40 to 98% (15). The fusion rate in group 1 in the present study was consistent with this previously reported range. However, the fusion rate in group 2 was significantly lower compared with that in group 1 and with that of the previous study. Comparisons between groups 1 and 2 in the present study indicated that local autologous corticocancellous struts attenuates the risk of pseudoarthrosis.

The present study is not without limitations. Firstly, all surgeries were performed by two surgeons from the same institution (Honghui Hospital). Secondly, the follow-up period was relatively short. Thirdly, the present study only examined patients who underwent one-level PLIF.

In conclusion, the results of the present study demonstrated that the short-term fusion rates were higher with corticocancellous structural autografts compared with morcellized fragments autografts for PLIF procedures. Thus, corticocancellous structural autografts may be developed as a safe and effective clinical algorithm by surgeons to provide optimal bone fusion in patients undergoing posterolateral lumbar fusion.

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Availability of data and materials

The datasets used and/or analyzed during the current study are available from the corresponding author on reasonable request.

Authors' contributions

XY, DH and BH designed the present study and analyzed the data. DW, LY and YH analyzed the data. XY and BH acquired

the data, while BH and XY drafted the initial manuscript. All authors have read and approved the final manuscript.

Ethics approval and consent to participate

The present study was approved by the Ethics Committee of Honghui Hospital (approval no. 201000919) and performed according to the 2010 CONSORT guidelines (http://www.consort-statement.org). Written informed consent was provided by all patients prior to the commencement of the study.

Patient consent for publication

Not applicable.

Competing interests

The authors declare that they have no competing interests.

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