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Is It Possible to Get Better Results in Bone Fusion in Laminoplasty Surgery for Lumbar Stenosis? A Novel Autologous Bone Graft Insertion Technique

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ABSTRACT

AIM: To define a novel autologous bone graft insertion technique, and to evaluate its effects on bone fusion in patients with lumbar stenosis who underwent laminoplasty.

MATERIAL and METHODS: Fifty-six patients and 142 vertebrae that underwent autologous bone graft insertion technique between 2009 and 2018 were analysed retrospectively. Demographic data, comorbidities, and perioperative findings of patients were recorded. The midline anteroposterior (AP) diameter was measured at the bone graft insertion levels, and fusion formation was evaluated with computed tomography (CT) and dynamic X-Ray images. Pain scores were assessed preoperatively with the visual analogue scale (VAS) for both legs and Oswestry Disability Index (ODI) for overall life quality. Scores were re-evaluated on 1st day, at 3rd, and 12th months, postoperatively.

RESULTS: Degenerative spinal stenosis was present in 56 patients who underwent autologous bone graft insertion technique. It was found that the diameter of the spinal canal increased by 37% in CT measurements. In postoperative radiological follow-ups, fusion developed in 49 (87.5%) patients. There was a statistically significant decrease in both VAS and ODI scores in the postoperative period when compared to the preoperative evaluations.

CONCLUSION: Bone graft insertion technique supports posterior fusion and protects against dural injuries during revision surgery by creating a barrier over the dura. The prevention of epidural fibrosis formation reduces the symptoms of the postlaminectomy syndrome. The fact that this technique does not require fixation material. Therefore, it reduces expenditure and eliminates the risk of complications related to synthetic materials.

KEYWORDS: Spinal fusion, Stenosis, Laminectomy, Autologous bone graft

ABBREVIATIONS: CT: Computed tomography, **MRI:** Magnetic resonance imaging, **AP:** Anteroposterior, **VAS:** Visual analogue scale, **ODI:** Oswestry disability index

INTRODUCTION

Laminectomy and fusion are the most common treatments for spinal stenosis (1). Spinal fusions often utilize fragmented bones, though their efficacy is questionable. Laminectomy in patients with degenerative spinal stenosis poses long–term risks, including spinal deformity and instability; epidural fibrosis and postlaminectomy membranes also compress the spinal cord and nerve roots (11,16). Several techniques have been established to avoid instability,

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subluxation, and kyphotic deformities following posterior decompression according to the degree and type of pathology and the surgeon's experience (15,25). Therefore, in our study, clinical and radiological outcomes of the novel autologous bone graft insertion technique and cadaveric illustration of surgical procedure were presented and discussed with the relevant literature.

MATERIAL and METHODS

Study Population

We retrospectively reviewed 56 patients who underwent spinal surgery and autologous bone graft insertion technique for degenerative spinal stenosis. This study was approved by the Pamukkale University Clinical Research Ethics Committee (date: 24.09.2019 and number: 16). All operations were supervised by the senior author (MEC). Age, gender, body mass index (BMI), initial diagnosis, education level, habits, comorbidities, duration of surgery, and amount of bone graft insertion levels were recorded.

All patients underwent an X-ray, computed tomography (CT), and magnetic resonance imaging (MRI) in the preoperative period. The midline anteroposterior (AP) spinal canal diameters were measured at insertion levels in the pre/postoperative CT images. CT and dynamic X-ray images were used to assess fusion at the surgical site after one day, three months, and twelve months; callus formation and loosening of instruments were fusion criteria. Failed fusion was assumed for patients with postoperative more significant pain and kyphotic angulation (Cobb angle measurement) post-operation compared to the preoperative period. Patients were evaluated with the Visual Analogue Scale (VAS) and Oswestry Disability Index (ODI) tests (6) in the preoperative period, and on first day, at three months, and at twelve months post-operatively.

Surgical Technique

All patients were anaesthetized with endotracheal intubation and were positioned prone on a radiolucent operating table. A prophylactic antibiotic was administered preoperatively. A median vertical incision was made, and lumbosacral muscles were stripped to the facet joints' lateral edge by subperiosteal dissection. Following level verification with C-arm fluoroscopy, supraspinous and interspinous ligaments were cut with a scalpel at the superior and inferior border of the laminotomy area. The lamina was then vertically cut 2 mm medial of the facet joint inferior articular process with an ultrasonic bone–cutting device (Bone Scalpel, Misonix, USA), or high–speed drill (Anspach high–speed drill, Synthes Inc., USA) and removed en-bloc. At this stage, we determined which device to use according to the size of the distance between the lamina-facet junction intraoperatively and the type of facet joint examined in preoperative CT imaging:a high–speed drill under an operation microscope was preferred for patients with bone anomalies in the posterior or C-J-type (2) facet joint, while an ultrasonic bone–cutting device was used in patients with flat facet joints.

Following surgery, the en-bloc spinous process was positioned in the laminotomy area (Figure 1A-F). Posterior fusion was performed by mixing allograft bone chips with the bones removed by foraminotomy (Figure 2A-D). A surgical drain was placed at the operation site and removed two days after surgery. The patients were given oral antibiotics for one week. Skin sutures were removed on the 15th day.

Statistical Analysis

We performed statistical analyses using SPSS, version 17 (IBM Corp., Armonk, New York, USA). In descriptive statistics: number (n), percentage (%) for categorical variables:arithmetic mean ($\bar{X}$), and standard deviation (SD) are given for continuous

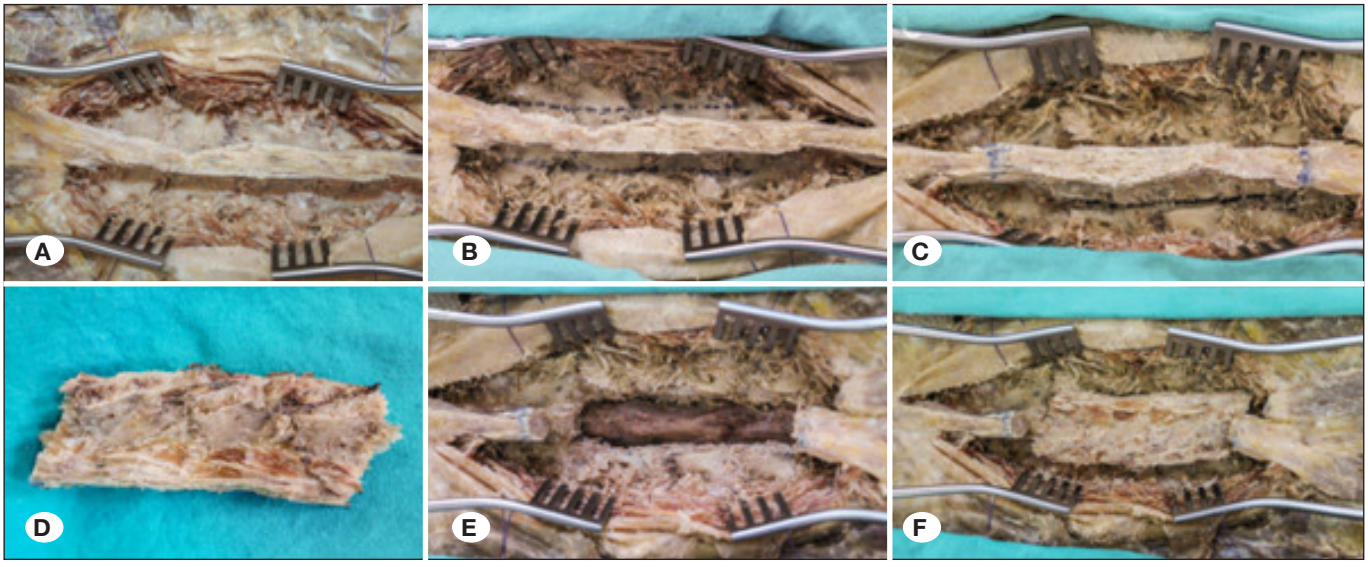

Figure 1: Cadaveric illustration of autologous bone graft insertion. **A)** The lumbosacral muscles were stripped to the lateral edge of the facet joints by subperiosteal dissections of the lumbar. 1-2-3 vertebral laminae were exposed. **B)** Laminae were bilaterally marked on the 2 mm medial of the inferior articular processes. **C, D)** Laminae were cut from the marked lines using a high–speed drill and removed en-bloc. **E)** View of operation area after laminotomy. **F)** Placement of spinous process in the transverse direction.

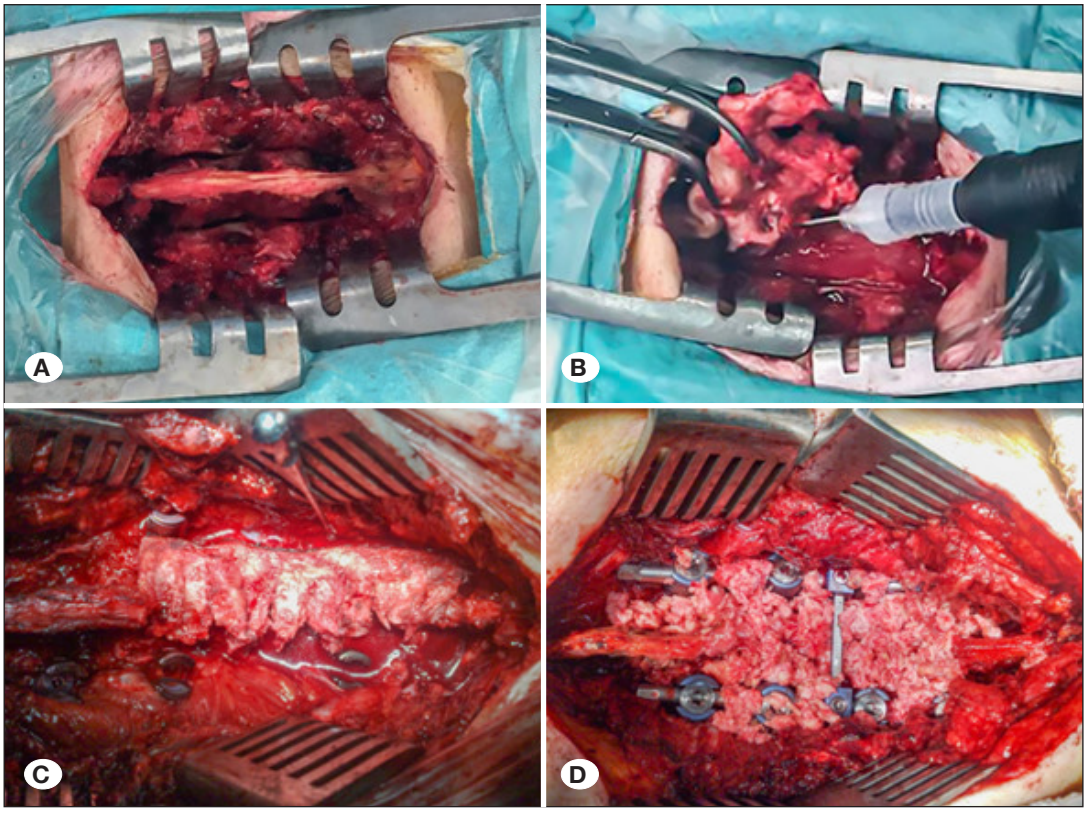

Figure 2: Intraoperative demonstration of autologous bone graft insertion. **A, B)** Laminae were removed en-bloc with an ultrasonic bone–cutting device. **C)** Spinous processes were placed in the transverse plane following pedicle screw implantation and foraminotomy. **D)** Posterolateral fusion by mixing allograft bone chips with bones removed during foraminotomy.

variables. Pearson Chi-square test was used to compare categorical variables. The answers given in the test are suitable for normal distribution were evaluated with Kolmogorov-Smirnov and Shapiro-Wilk's test. Wilcoxon Paired Two-Sample Test and ANOVA test in repeated measurements were used to compare dependent group differences since parametric assumptions were not provided. $p<0.05$ indicated statistical significance.

RESULTS

Forty (71.42%) female and sixteen (28.57%) male subjects were evaluated. The mean age of the patients was 60.64 ± 12.36 years. The mean BMI was 30.06 ± 6. The duration of complaints included ranged from 10 days to 20 years. Admission complaints, initial neurological examinations, diagnosis, and comorbidities are listed in Table I.

Surgery was performed most frequently in the lumbar region (47 patients, 84%) and less frequently in the thoracolumbar (8 patients, 14%) and thoracic (1 patient, 1.7%) regions. Autologous bone grafts were inserted in a total of 142 vertebrae. Forty-nine patients (87.5%) underwent autologous bone graft insertion with pedicle screw implantation, while the remaining seven (12.5%) patients underwent the same but without instrumentation. Those seven patients with lumbar stenosis did not accept instrumentation. One-, two-, three-, and four-level bone graft insertions were performed in eight (14%), fourteen (25%), thirty (53.5%) and four (7%) patients, respectively.

An intraoperative dural tear was observed and sutured under the operating microscope for five (8.9%) patients. Synthetic grafts were not used for any patient. No postoperative CSF leak was detected in any patient during postoperative follow-up. One patient (1.7%) developed consciousness in the postoperative period, and CT revealed pneumocephalus. The patient improved with conservative management.

In the postoperative follow-up, thirty-eight (67.8%) patients who had preoperative motor/sensory deficits completely improved, ten (17.8%) patients partially improved, and one (1.7%) patient developed new motor deficits. However, four (7.1%) patients died during follow-up due to other systemic problems.

Spinal fusion was deemed successful for forty-nine (87.5%) patients in their radiological follow-ups at one day, three months, and twelve months post-surgery. Six patients underwent a revision surgery at the 12-month follow-up because instrumentation failed and screws loosened. Spinal fusion was unsuccessful for four (7.1%) patients. Instrumentation was performed in 1 patient due to newly developing instability who had not previously been instrumented. No epidural fibrosis, postlaminectomy membranes, or other complications were observed in any patient during revision surgeries. No significant difference was found between the number of levels performed with bone graft insertion and successful fusion (Table II). According to anteroposterior measurements, spinal canal diameter increased by an average of 37% (range 6.5% to 104%) in 142 vertebrae. (Figure 3A-D; Figure 4A-D) The increase in the spinal canal diameter was statistically significant (Table III).

Table I: Summary of Patients' Complaints, Neurological Examinations and Initial Diagnosis at Admission, and Comorbidities

Variable		Rate
Admission complaints		
Neurogenic claudication		82%
Low back pain		35%
Urinary incontinence		26%
Paraparesis		10%
Paraesthesia		5%
Impotence		3%
Neurological examination at admission		
Motor deficit		70%
Motor and sensory deficit		14%
Sensory deficit		2%
No deficit		14%
Initial diagnosis		
Degenerative spinal disease	Spondylolisthesis	66%
	Lumbar stenosis	25%
	Cervical spondylotic myelopathy (OPLL)	1.8%
Intradural tumour		5.4%
Tethered cord		1.8%
Comorbidities		
Hypertension		48%
Diabetes mellitus type 2		35%
Chronic obstructive pulmonary disease		16%
Rheumatoid arthritis		7%
Thyroid function disorders		7%
Chronic kidney failure		1.7%
Smoking		26%
Alcohol use		10%
Haematological disorder		None
No additional comorbidity		28%

Table II: Fusion Development Rate according to the Number of Bone Graft Insertion Levels

Number of levels with laminoplasty	Fusion positive		Fusion negative		p
	n	%	n	%	
1 level	7	87.5	1	12.5	0.933
2 levels	13	92.8	1	7.1	
3 levels	26	86.7	4	13.3	
4 levels	3	75.0	1	25.0	

Table III: The Average Anteroposterior Diameter of 142 Vertebrae in the Pre/Postoperative Period

Diameter of spinal canal	Mean ± SD (mm)	p
Preoperative	17.12 ± 2.67	<0.001
Postoperative	23.3 ± 3.85	

Table IV: The VAS and ODI All Follow-Up Time Points

Time	VAS (Mean ± SD)	ODI (Mean ± SD)	p
Preoperative	6.9 ± 1.3	47.92 ± 20.28	<0.001
Postoperative 1st day	4.33 ± 1.69	39.03 ± 19.46	
3 months	3.05 ± 1.76	30.60 ± 18.93	
12 months	2.70 ± 1.87	28.03 ± 18.98	

There was a statistically significant difference between preoperative VAS/ODI values and those recorded at one day, three months, and twelve months' post-operation (p<0.001). (Table IV) There was no significant relationship between the postoperative decrease of VAS values and whether fusion was successful (p=0.522). There was no statistically significant relationship between smoking and failed fusion (p=0.188).

DISCUSSION

Facet–sparing laminectomy and foraminotomy are often performed to treat spinal stenosis (8,12). However, these techniques may deform and imbalance the spine, accelerate spondylosis, and compress delicate neural structures (11,16,17,19). In addition, epidural fibrosis occurs after 15–40% of lumbar laminectomies, and the revision surgery rate has been reported as 18–23% (5).

Mullin et al. reported an instability rate of 54% according to lateral dynamic x-ray images taken at long–term follow-ups with patients who underwent laminectomy revealed an instability rate of 54%, which often requires additional fusion surgery (20). Bone fusion development is provided with instrumentation.

Laminoplasty is performed following 40% of unsatisfactory laminectomies. Its techniques using 1/0 nylon suture, titanium mini plaque or steel wires are frequently used to surgically treat spinal stenosis secondary to degenerative lumbar spondylosis, ossification of the posterior longitudinal ligament, intradural intramedullary, or intradural extramedullary tumours (10). Hida et al. performed laminoplasty by rotating 90 degrees and fixing the removed laminae transversely with a titanium miniplate during thoracolumbar intradural tumour surgery. Calluses were observed in the reconstructed lamina at 25 months post-surgery, but the screws and plates remained in place. Fusion occurred over approximately three months (9).

Posterolateral fixation reportedly increases the fusion rate in patients suffering degenerative lumbar spondylolisthesis and

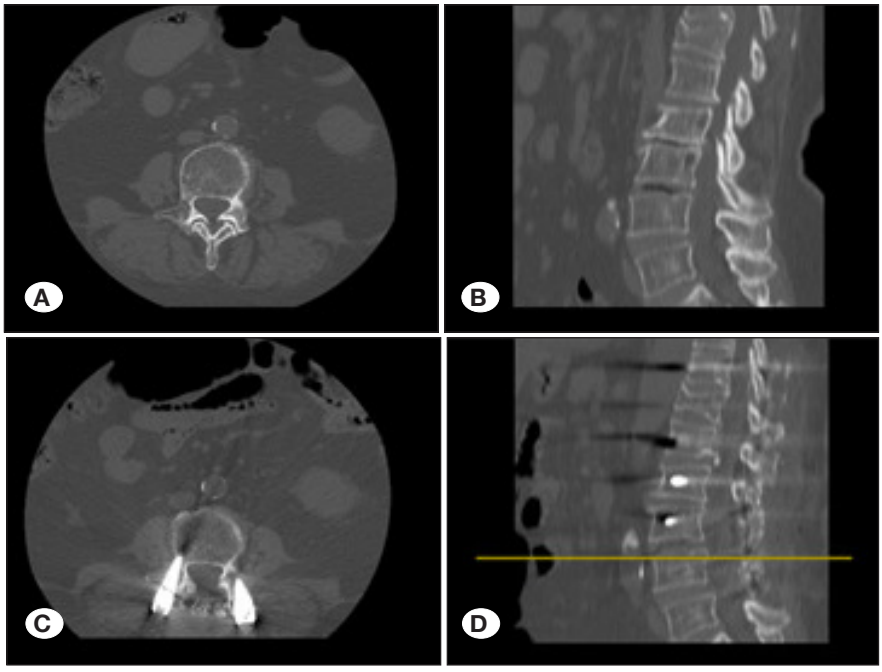

Figure 3: Preoperative/postoperative CT images of the patient who underwent L2-L3-L4 bone graft insertion. **A)** Preoperative L4 vertebra axial view, **B)** preoperative sagittal view, **C)** postoperative L4 vertebra axial view, **D)** postoperative sagittal view.

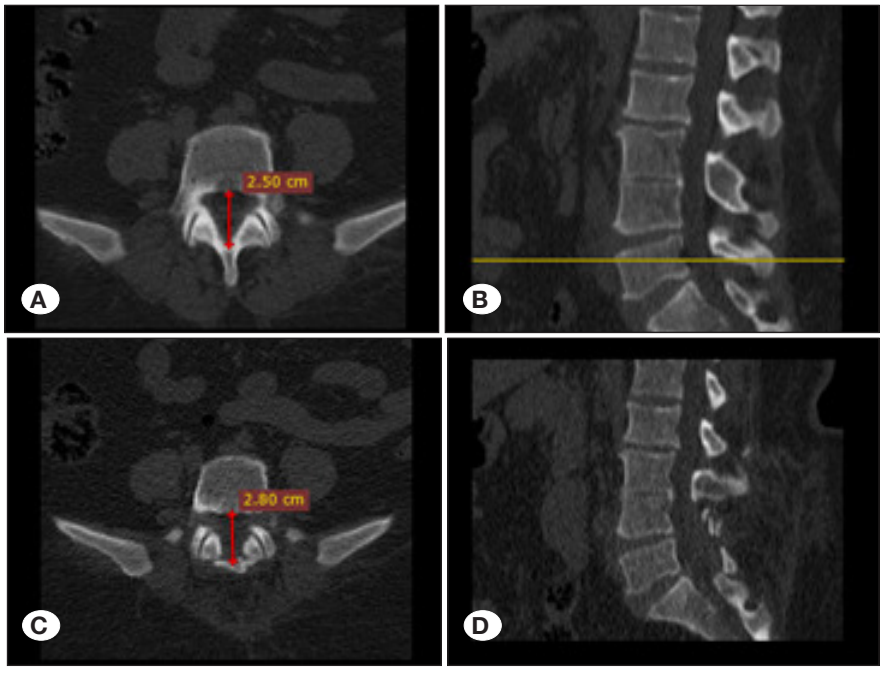

Figure 4: CT images of AP canal diameter measurement. **A)** Preoperative L5 vertebra axial view AP canal measurement, **B)**preoperative sagittal view, **C)** postoperative L5 vertebra axial view AP canal measurement, **D)** postoperative sagittal view.

improves clinical results. Booth et al. followed 41 patients retrospectively for approximately six years and reported a solid fusion rate of 85% (3). Kotil reported similar results for forty patients suffering isthmic spondylolisthesis; following total laminectomy, allograft bone chips were inserted into the intervertebral disc, and posterolateral fixation was performed with polyaxial screws rods (13). The shifted lamina was shifted back in place before autograft bone grafts were inserted into the joint space (14). In the presented study, spinal fusion was successful without adjacent level degeneration in 95% of patients. Moreover, a meta-analysis of 25 articles examining various degenerative spondylolisthesis treatments revealed that fusion rates were higher (93%) for procedures with instrumentation (18). Indeed, additional posterior fixation may better promote fusion in degenerative lumbar spondylolisthesis.

Chen et al. reported successful fusion with in post-operative 3–9 months in eighteen patients who underwent titanium miniplate canal laminoplasty with the lumbar vertebral lamina reimplantation (4). Park et al. described a new laminoplasty

technique using translaminar screws for five patients with intradural lesions in the thoracic and lumbar region (22). Bone fused in two patients at fifteen months after block laminoplasty with translaminar screw fixation. Still, more studies are needed to analyze the biomechanical effects and longer-term outcomes.

In the present study, autologous bone grafts were inserted in patients experiencing degenerative spinal stenosis by removing the spinous process with a high–speed drill or ultrasonic bone–cutting device. The spinous process was transversely placed in the laminectomy area during the closure. To our knowledge, the spinous process placement at the laminectomy site without stripping the interspinous ligaments is described first in the literature. Therefore, in our study, the clinical and radiological results of the autologous bone graft insertion technique were discussed in light of the literature. In addition, the anatomical study of the applied surgical procedure on the cadaver was described and photographed (Figure 1).

Previous laminoplasty studies ensured that the laminoplasty was fixed in the laminectomy site with a miniplate, nylon suture, or steel wire, and the supraspinous ligament was repaired (9,21). This is because these studies did not perform posterolateral fixation, in which increased stress on the laminoplasty site during spinal flexion, extension, and rotation may displace the graft. In our study, 87.5% of the patients underwent posterolateral fixation, and there was no extra load on the bone graft insertion site. As a result, this procedure may decrease blood accumulation in the surgical area and reduce epidural fibrosis (9,10,23). In addition, when revision surgery is required, the spinous processes are used as a natural barrier over the dura, reducing the risk of dural tear and nerve root injury. En-bloc spinous processes can also improve clinical outcomes, preventing loosened screws, fractures, and revision surgery. In addition, bone allografts tend to promote fusion better and are less likely to promote when compared to bones placed in the form of small pieces. Tools such as a high–speed drill or ultrasonic bone–cutter shorten the operation time. They may also prevent entrapment neuropathy and tendinitis (7) in spine surgeries, which often occur when using instruments such as the Kerrison Rongeur.

Whether the length of the spinous process can sufficiently close the laminotomy defect is questionable. However, Sobottke et al. (24) showed that the size of the spinous process is adequate. The preserved spinous process's length in this study also sufficiently covered the space between the facet joints. The bone graft did not escape into the canal or cause neurological complications. Generally, the bone graft flap was located somewhat obliquely. Flap resorption and epidural fibrosis were not observed in any patient. Follow-ups confirmed that fusion was successful in 87.5% of patients that preoperative complaints improved for 90% of the patients, which agree with other studies (3,18).

Limitations

Retrospective character, small sample size, and lack of comparative results are limitations of our study. A more extensive study should better evaluate all laminoplasty methods.

CONCLUSION

This study inserted autologous bone grafts in patients who underwent facet-sparing surgery and posterolateral fixation by placing the spinous process transversely in the laminotomy area. This technique supports posterior fusion, prevents dural and nerve injuries commonly experienced during revision surgery, and does not require fixation materials. Together, autologous bone grafts and posterolateral fixation may improve surgical treatments for spinal stenosis.

AUTHORSHIP CONTRIBUTION

The authors confirm contribution to the paper as follows:

Study conception and design: EE, FY, MEC

Data collection: YOT, YD

Cadaveric Dissection: YOT, FY

Analysis and interpretation of results: FY

Draft manuscript preparation: YOT, FY, SC, YD

Critical revision of the article: EE, MEC

Other (study supervision, funding, materials etc.): EE, MEC

All authors (YOT, SC, YD, FY, EE, MEC) reviewed the results and approved the final version of the manuscript.

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