Prospective Study

A Novel Inextensible Endoscopic Tube Versus Traditional Extensible Retractor System in Single-Level Minimally Invasive Transforaminal Lumbar Interbody Fusion: A Prospective Observation Study

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Background: Currently, various retractor systems are widely used for access to the lumbar spine in minimally invasive transforaminal lumbar interbody fusion (MIS-TLIF). Nevertheless, studies concerning the comparison of extensible retractor and inextensible tube systems are quite rare.

Objectives: This article was to compare perioperative characteristics, clinical outcomes, and multifidus muscle injury of obconic inextensible tube versus extensible retractor system for single-level MIS-TLIF.

Study Design: A prospective observational study on 91 patients with a mean follow-up of 20.0 ± 4.1 months.

Setting: This study was conducted by a university-affiliated hospital in a major Chinese city.

Methods: From April 2015 to May 2016, 91 consecutive patients who underwent MIS-TLIF procedure using an obconic inextensible endoscopic tube or extensible retractor system were enrolled in this study. Operation parameters such as incision length, blood loss, postoperative drainage volume, surgical time, analgesic use rate, time to ambulation, and postoperative hospitalization days were evaluated. The concentration of white blood cells, c-reactive protein (CRP) interleukin-6, interleukin-8, tumor necrosis factor alpha, and creatine phosphokinase (CPK)-MM of the enrolled patients were measured for postoperative traumatic stress and muscle injury. Multifidus muscle edema and atrophy were evaluated by T2-weighted magnetic resonance imaging (MRI) at 3 different time points (preoperative, postoperative, and 1-year follow-up). Clinical outcomes such as Visual Analog Scale (VAS) score, Japanese Orthopedic Association (JOA) score, Oswestry Disability Index (ODI) score, fusion rates, and MacNab criteria were assessed for patients' symptoms.

Results: In terms of baseline characteristics, the 2 groups were similar regarding sample size, gender, age, symptoms duration, operation level, body mass index, physical examination, and all the clinical outcomes measures ($P > 0.05$). Perioperative analysis showed that the inextensible group had comparative incision length, blood loss, operation time, time to ambulation, and postoperative hospitalization ($P > 0.05$). The inextensible tubular group had less postoperative drainage volume and analgesic use rate ($P < 0.05$). The concentration level of CPK-MM and CRP was lower in the inextensible tubular group compared with the extensible retractor group. No significant difference was found between the 2 groups regarding MRI T2 signal intensity ratio of multifidus muscle at the immediate postoperative period. The MRI T2 signal intensity ratio of multifidus muscle was lower in the inextensible tubular group than the extensible retractor group at the 1-year follow-up period. The VAS scores for low back pain and leg pain improved significantly in both groups after surgery, as did the JOA and ODI scores. However, there were no significant differences between the 2 groups regarding the preoperative and final follow-up VAS, JOA, and ODI scores, fusion rates, and the distribution of the MacNab criteria.

Limitations: This was not a randomized controlled trail, which could provide more evidence-based medicine conclusions.

Conclusions: The obconic inextensible endoscopic tube system via the transforaminal approach for lumbar interbody fusion is a safe and sufficient technique. When compared with the extensible retractor system, it has comparable clinical outcomes, with additional significant benefits of less postoperative drainage volume and analgesic use rate, less multifidus muscle injury in terms of lower CPK-MM levels at immediate postoperative period, less change in CRP, and less change in MRI T2 signal intensity ratio of multifidus muscles at 1-year follow-up.

Key words: Minimally invasive, endoscopic, lumbar interbody fusion, tubular, multifidus muscle

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The aim of minimally invasive spine surgery (MISS) is to minimize procedure-related tissue injury and to facilitate expedited patient recovery. Thus, MISS outcomes are usually contextualized by shorter postoperative courses, reduced blood loss, and decreased postoperative pain remaining (1). Open instrumented lumbar fusions require extensive multisegment subfascial musculature retraction, increased operative duration and blood loss, and thus have been reported by some to be associated with significant perioperative morbidity (2). Therefore, minimally invasive transforaminal lumbar interbody fusions (MIS-TLIF) have gained popularity (3). Typically, MIS-TLIF procedures require extensible retractor systems for access to the lumbar spine for achieving decompression, bone grafting, fusion, and implanted screw under direct visualization (4). Retractor blades always split paravertebral multifidus muscles toward both sides. Although the incision on the skin is small, the inside traction injury could be much deeper and serious. However, the notion of minimally invasive means not only short incisions, but also less extensive iatrogenic paraspinal injury and maximized clinical outcomes (5,6). Previous studies have documented the harmful effects of extensive paraspinal muscular dissection and retraction lumbar surgery (7-10). Indeed, retractor blades have been shown to increase intramuscular pressure that can ultimately lead to ischemia (11). Moreover, damage to lumbar musculature has been shown to be correlated to retraction pressure performed during surgery (12,13). In this report, a novel minimally invasive endoscopic transforaminal lumbar interbody fusion (TLIF) approach is described. This novel obconic tubular endoscopic system is employed to facilitate minimally invasive endoscopic decompression and fusion integration. Furthermore, an obconic tube reported herein was designed with a series of telescoping tubes designed to minimize retraction and intramuscular retraction. Therefore, this study was designed to determine whether the novel endoscopic tube in MIS-TLIF procedure reduces undesirable changes in multifidus and potential effects. We also investigated clinical outcome, perioperative characteristics, and complications between the inextensible tube versus the extensible retractor system for single-level MIS-TLIF.

Methods

This study was approved by the ethics committee of the Third Military Medical University and conducted by a university-affiliated hospital in a major Chinese city. All procedures performed in studies involving human patients were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards. Informed consent was obtained from all individual patients included in the study. All of the medical records were anonymous, and no patient information was extracted except for research purposes.

Patients Characteristics

A total of 91 prospective consecutive patients who underwent single-level MIS-TLIF procedure using a novel endoscopic tube (MetrxVISTA, Medtronic Sofamor Danek, Memphis, TN) and extensible retractor system (Mast Quadrant Retractor System, Medtronic Sofamor Danek, Memphis, TN) between April 2015 and May 2016 were included in this series. The written informed consents were obtained from all patients at study entry. The inclusion criteria of this study were those with mainly complaints of low back pain; varying degrees of radicular pain and neurologic symptoms; single-level lumbar disc herniation or stenosis with one-grade lumbar spondylolisthesis demonstrated by

anteroposterior, lateral, oblique, and flexion-extension plain radiographs, computed tomography (CT) scans, and magnetic resonance imaging (MRI); and a lack of response to extensive conservative therapy for at least 3 months before surgery. Exclusion criteria were the presence of a significant unrelated spinal abnormality, presence of bony metastasis, patients with previous surgery, lumbar injury, infection, and a behavioral disorder that could impair patient cooperation.

Hospital charts of the patients meeting the study inclusion criteria were further reviewed for information on relevant characteristics. Forty-five cases in the tube group and 46 cases in the retractor group were finally enrolled with a mean follow-up of 20.0 ± 4.1 months (12-month minimum; effective rate, 100%). At the final follow-up period, one case in the retractor group was lost to follow-up because the patient could not be contacted by telephone or mail.

Clinical Evaluation

Clinical outcomes such as Visual Analog Scale (VAS) score, Japanese Orthopedic Association (JOA) score, Oswestry Disability Index (ODI) score, fusion rates, and MacNab criteria were assessed. Operation parameters such as operation time, incision length, blood loss, drainage volume, analgesic use rate, time to ambulation, and postoperative hospitalization days were also recorded. Postoperative complications and symptom re-recurrence requiring reoperation were assessed through review of medical record documentation and/or telephone interviews with patients. Fusion was considered to have occurred if the trabecular bone had been bridged, as seen on a postoperative CT scan (4). The authors used the modified MacNab criteria for outcome assessment at 1-year follow-up (14).

Evaluation of Multifidus Injury and Inflammatory Response

The concentration of white blood cells (WBC), interleukin (IL)-6, IL-8, c-reactive protein (CRP) tumor necrosis factor alpha (TNF-a), and creatine phosphokinase (CPK)-MM of the enrolled patients were measured at preoperation and first, third, and fifth day after surgery. Serum CPK-MM concentrations were measured with an enzyme-linked immunoassay (ELISA, Abcam, Cambridge, UK). Other inflammatory markers were tested by the clinical laboratory of our institution. Multifidus muscle edema and atrophy were evaluated by T2-weighted MRI at 3 different time points (preoperative, postoperative, and 2-year follow-up). MRI was performed on a 3.0 Tesla system (GE Healthcare, Chicago, IL). All images were obtained using a T2-weighted fast spin echo pulse sequence, with matrix size 320 x 160, field of view 340 x 340 mm, and bandwidth 31.2 Hz/Px. Slice thickness was 4 mm and interslice gap was 1 mm. The MRI radiologists were blind to the operation method. They used the most similar axial images at the same spinal level for comparison. Measurement were obtained with a Picture Archiving and Communication System (PACS) workstation. Mean signal intensity of unilateral gross multifidus muscle on a T2-weighted axial image was evaluated quantitatively at the operative and adjacent 2 levels by measurements repeated in the grayscale histogram software of PACS. The mean signal intensity of the psoas muscle in the same axial image was also evaluated as control from a 300 mm2 circular region of interest. T2-weighted signal intensity ratio was determined by mean signal intensity of the psoas muscle divided by mean multifidus signal intensity.

Surgical Techniques

Obconic Endoscopic Tubular System in TLIF

Following induction of general anesthesia, patients are positioned prone on a radiolucent operative table. The endoscopic video monitor should be placed on the opposite side of the surgeon. It is important to have an enough space between the surgeon and the video tower to ensure adequate visualization during the endoscopic portion of the operation. Using fluoroscopic guidance, lateral and anteroposterior fluorographs are obtained to ensure adequate visualization of the pedicles at the operative level. Next, a 2 to 3 cm incision is planned 4.0 to 4.5 cm lateral to midline at the appropriate interspace. The approach is performed on the side ipsilateral to the most severe radiculopathy. A needle is used to advance through the fascia and between the paraspinal musculature to reach the junction of the transverse process and facet. Serial dilators are then used to create a muscle-preserving surgical corridor. Next, an appropriate-length and diameter tubular endoscopic working channel (MetrxVISTA, Medtronic Sofamor Danek) is docked over the facet. The endoscope is inserted into the tubular retractor and secured in place using the locking arm on the ring attachment (Fig. 1). The remainder of the procedure is performed under endoscopic guidance.

A total facetectomy is performed using a high-speed drill and Kerrison Rongeur (Fig. 2). Bone re-

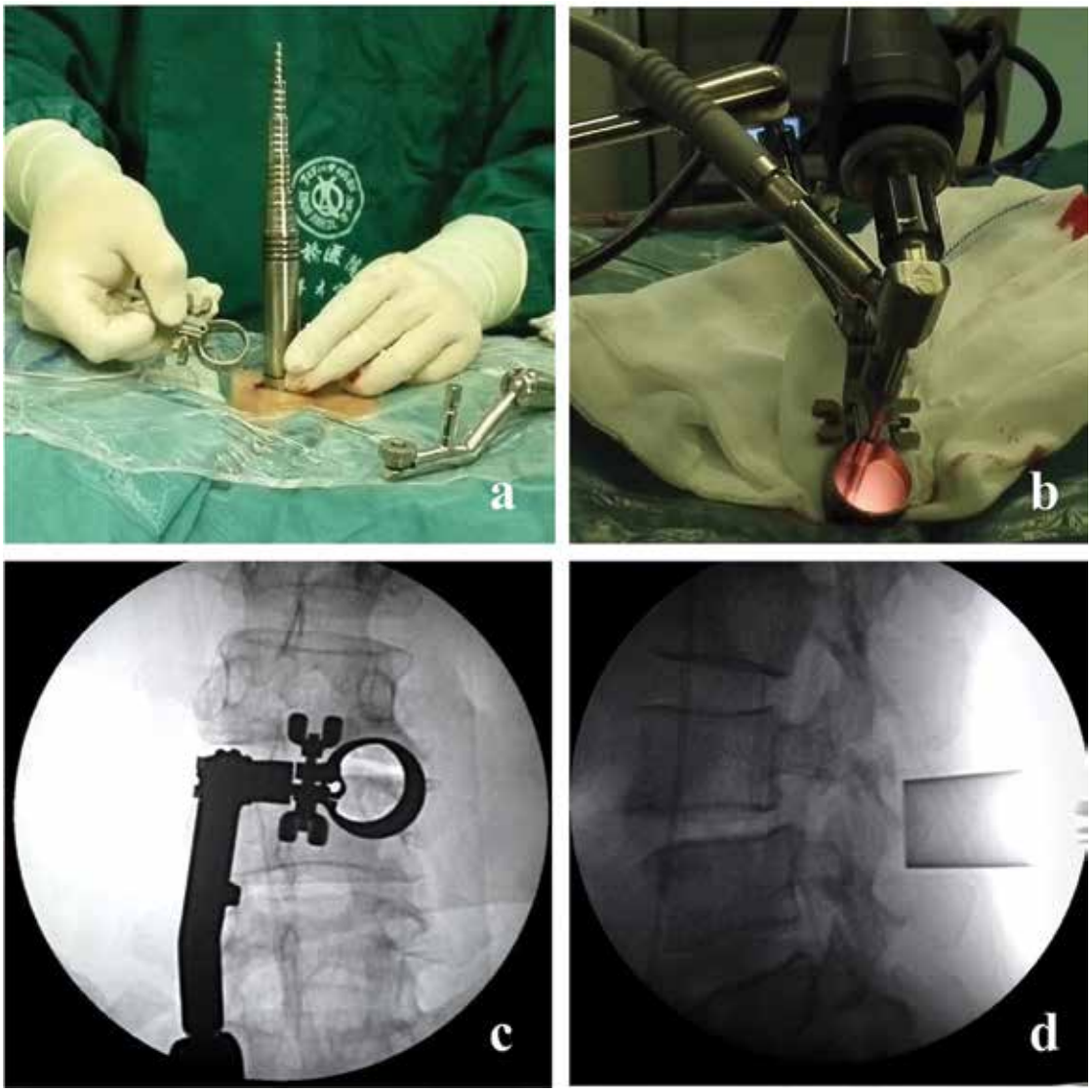

Fig. 1. *(A) Serial dilators were used to create a muscle-sparing surgical corridor; (B) an appropriate-length and diameter tubular endoscopic working channel was docked on the facet joint complex. The endoscope was then inserted into the tubular retractor; (C) AP fluoroscopic view of the working channel; (D) lateral fluoroscopic view of the working channel.*

moved during the facetectomy is denuded of all soft tissue and used later in the case as autograft. The ligamentum flavum is to visualize the ipsilateral exiting and traversing nerve roots. The annulus is exposed medial and inferior to the exiting nerve root with little or no need for neural retraction. Visualization of the annulus is imperative for access to the intervertebral disc space. Epidural veins are coagulated with bipolar cautery, and thrombin-soaked Gelfoam is used for additional hemostasis, if necessary. Prior to preparation of the end plate, the exiting and traversing nerve roots are identified and protected. The transforaminal space is visualized and the anatomic landmarks should be noted including traversing and exiting nerve root as well as the pedicle of the inferior level. Pituitary rongeurs, curettes, and end plate shavers are used to prepare the end plate. The cartilaginous material is removed from each end plate, but their cortical portions are retained. Distrac-

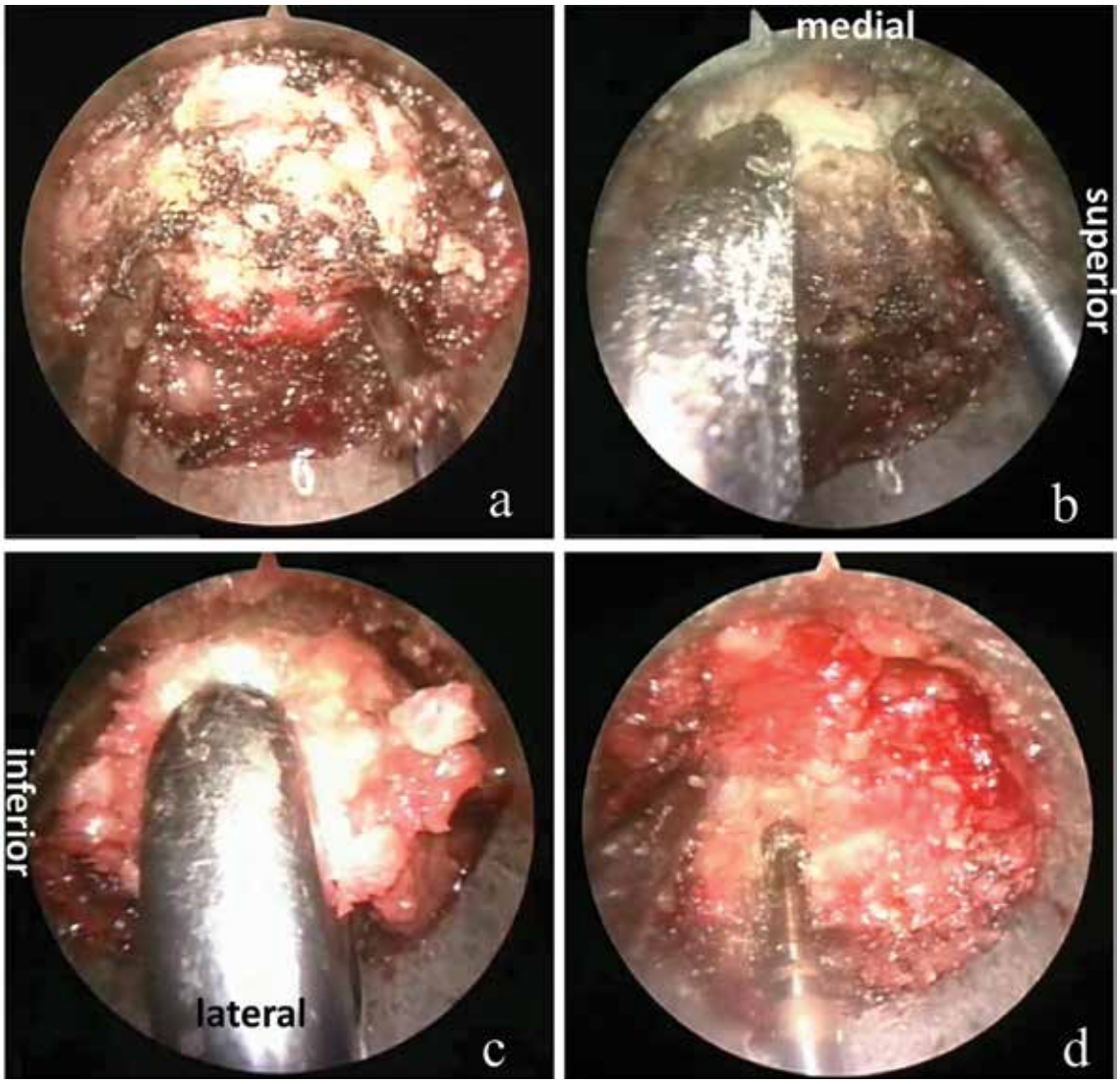

Fig. 2. *(A) Adequate visualization of facetectomy; (B) the inferior articular process was carried out using a high-speed drill; (C) resected inferior articular of upper vertebra was removed; (D) the superior articular process was resected until the medial and superior wall of the pedicle is abutted.*

tion across the disc space is then performed using interbody distractors inserted into the disc space through the ipsilateral working channel. Depending on surgeon preference, structural allograft bone, cages, or local autologous bone graft is placed into the interspace. Local autograft is placed anteriorly and contralateral to the annulotomy within the interbody space, and the nerve root is again examined to ensure adequate decompression (Fig. 3). Once the interbody fusion has been performed, the tubular retractor is removed and the ipsilateral Sextant (Medtronic, Sofamor Danek, Memphis, TN) pedicle screw-rod construct is placed through the same incision. Care should be taken under fluoroscopic guidance that the screw is advanced collinear to the K-wire to prevent any bending or breakage of the wire. Following placement of the screws, the extensions are aligned. After securing the connecting rods with the set screws, fluoroscopic imaging confirms appropriate posi-

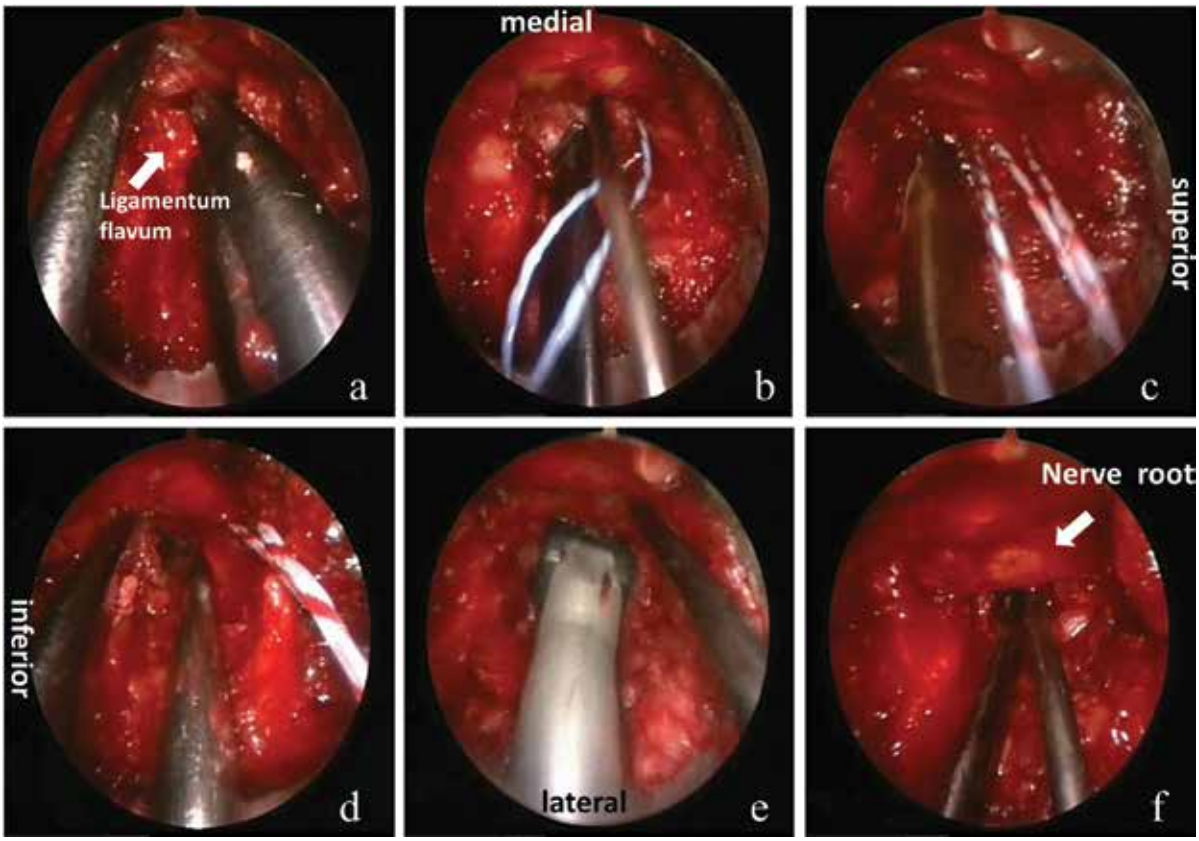

Fig. 3. *(A) Removal of the ligamentum flavum; (B) visualization of the annulus; (C) deal with the intervertebral disc space; (D) prepare the end plate; (E) trial and placement of the interbody cage; (F) interbody distractors inserted into the disc space.*

tioning of the instrumentation. Once the pedicle screw-rod instrumentation is inserted into the contralateral pedicle along the guidewire under fluoroscopic guidance, the upper and lower spines are pressured along the rod, and the screw rods are then tightened using a torque wrench. A subfascial Hemovac is inserted, and a standard multilayer closure is performed.

Extensible Retractor System in TLIF

The Mast Quadrant Retractor System in TLIF was performed as described by Wang et al (4). A 4.0 to 4.5 cm longitudinal paramedian incision was made for placement of the Quadrant Retractor System. This incision was used for decompression, disc space preparation, autograft, placement of interbody cage, and the procedure was accomplished under direct visualization without microscope or microendoscope. Retractor blades of the Quadrant system usually need to be distracted toward 2 sides. The same implants were used for the Quadrant group.

Statistical Analyses

Statistical analyses of the data were performed using SPSS Version 21.0 (IBM Corporation, Armonk, NY). The Student t test was used to compare continuous variables of the 2 groups. Repeated measures analysis of variance was performed for evaluating serum levels of inflammatory markers (CRP, IL-6, IL-8, and TNF-a), CPK-MM, and WBC at 4 time points of different groups. The chi-square analyses and the Fisher exact test (contingency table analyses) were used for categorical variables, depending on sample size. P values (2-sided) < 0.05 were statistically significant.

Results

Patients Characteristics

The analysis identified 91 patients meeting the study criteria, with a follow-up of 20.0 ± 4.1 months. There were no statistically significant differences in the demographic data of the 2 groups ($P > 0.05$) (Table 1). Perioperative analysis showed that the endoscopic tube group had comparative incision length, blood loss, time to ambulation, and postoperative hospitalization compare with the Quadrant retractor group (Table 2). The endoscopic tube group had less postoperative drainage volume and analgesic use rate than the Quadrant group ($P < 0.05$). The tubular surgical time was on average 16 minutes longer than the retractor surgical time, but this difference was not found to be significant ($P = 0.081$).

Evaluation of Multifidus Injury and Inflammatory Response

The concentration level of CPK-MM and CRP was lower in the tube group compared with the retractor group. The CPK-MM concentration level reached a peak at the first day after surgery and returned to baseline by 5 days in both groups. The CRP level peaked on day 3 and then fell back at the fifth day (Fig. 4). There were no significant differences with respect to WBC, IL-6, IL-8, and TNF-a between the 2 groups (Table 3). The MRI T2 signal intensity ratio of multifidus muscle was significantly lower in the tube group than the retractor group at the 1-year follow-up period (Fig. 5). The MRI T2 signal intensity ratio of multifidus muscle was higher in the retractor group than the tube group at immediate postoperative period, but no significant difference was found (Fig. 6).

Clinical Assessment

The VAS scores for low back pain and leg pain improved significantly in both groups after surgery, as did the JOA and ODI scores. However, there were no significant differences between the 2 groups in regard to preoperative, postoperative 6 months, postoperative 1 year, and final follow-up VAS, JOA, and ODI scores, and the distribution of the MacNab criteria (Table 4). Of the 91 patients with adequate follow-up, 57 (62.6%) had excellent improvement, 26 (28.6%) had good improvement, 6 (6.6%) had fair improvement, and 2 (2.2%) had poor results according to the MacNab criteria assessment. At 1 year postoperatively, CT scans confirmed that solid bone graft fusion had occurred in all patients, and there were no clinical or radiographic signs of nonunion. There was one case of hematoma in the retractor group

Table 1. *Demographic characteristic of the enrolled patients.*

	Tube	Retractor	*P* Value
Cases	45	46	-
Gender (n)			0.701
Male	13	15	
Female	32	31	
Age (years)			0.545
Range	22-80	33-80	
Mean ± SD	55.98 ± 10.41	57.33 ± 10.75	
Duration of disease			0.104
< 0.5 year	6	14	
0.5-1 year	2	4	
1-5 years	19	18	
> 5 years	18	10	
Operation level			0.208
L3-L4	0	4	
L4-L5	40	28	
L5-S1	5	14	
Body mass index, n			0.935
< 18.5	1	1	
18.5-23.9	16	16	
24-27.9	20	22	
≥ 28	8	7	
Physical examination			
Motor deficit, n/N (%)	17/45 (37.78)	19/46 (41.30)	0.731
Sensory deficit, n/N (%)	6/45 (13.33)	4/46 (8.70)	0.522

Abbreviation: SD, standard deviation

Table 2. *Perioperative data of all patients.*

	Tube (n = 45)	Retractor (n = 46)	*P* Value
Operation time (min)	180.49 ± 35.19	164.02 ± 51.91	0.081
Incision length (cm)	3.94 ± 0.28	3.91 ± 0.29	0.628
Blood loss (mL)	182.00 ± 106.19	191.30 ± 93.37	0.658
Drainage volume (mL)	54.71 ± 36.53	123.98 ± 86.18	< 0.001*
Time to ambulation	2.04 ± 0.77	2.48 ± 1.07	0.113
Postoperative hospitalization stay (days)	6.38 ± 1.48	6.72 ± 1.13	0.221
Analgesic ratio (yes/no)	18/27	30/16	0.021*

*P values (2-sided) < 0.05 were statistically significant between the 2 groups

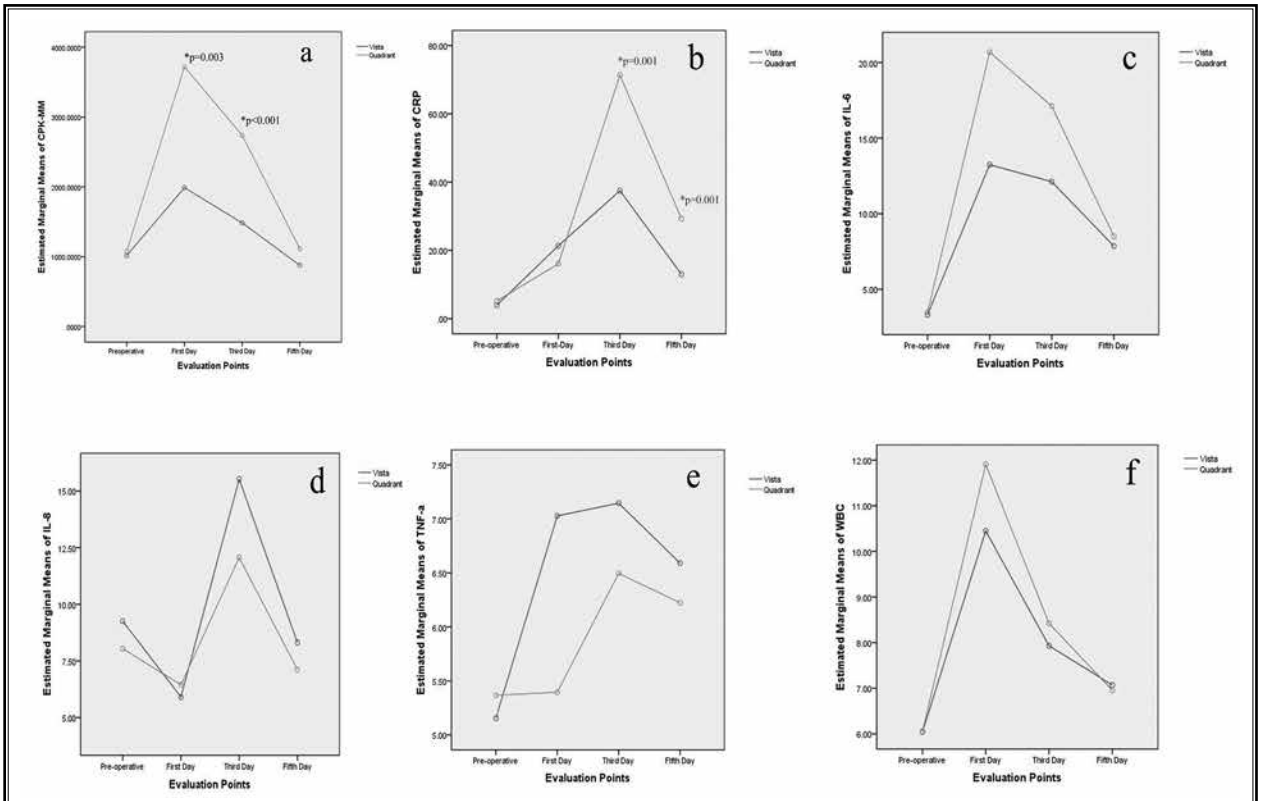

Fig. 4. *Line graph showing serum levels of inflammatory markers (CRP, IL-6, IL-8, and TNF-a), CPK-MM, and WBC measured at 4 time points (preoperative, first, third, and fifth day after surgery). The mean serum CPK-MM levels of the VISTA group were significantly lower than those of the Quadrant group at both first (P = 0.003) and fifth (P < 0.001) day postoperatively. *P values (2-sided) < 0.05 were statistically significant between the 2 groups.*

Table 3. *Serum levels of inflammatory markers (CRP, IL-6, IL-8, and TNF-a), CPK-MM, and WBC measured at 4 time points.*

	Preoperative			First Day		
	Tube	**Retractor**	***P* Value**	**Tube**	**Retractor**	***P* Value**
CPK-MM (U/L)	1,017.22 ± 305.89	1,078.85 ± 465.02	0.632	1,988.26 ± 982.41	3,719.58 ± 2,065.44	0.003*
CRP (mg/L)	3.96 ± 1.66	5.19 ± 3.09	0.121	21.36 ± 15.90	16.07 ± 8.97	0.195
IL-6 (pg/mL)	3.32 ± 1.33	3.48 ± 1.88	0.790	13.24 ± 9.23	20.69 ± 15.01	0.129
IL-8 (pg/mL)	9.25 ± 7.57	8.04 ± 6.38	0.655	5.91 ± 1.88	6.45 ± 3.47	0.663
TNF-a (pg/mL)	5.15 ± 0.95	5.37 ± 1.04	0.576	7.03 ± 5.36	5.40 ± 1.96	0.349
WBC (109/L)	6.04 ± 1.50	6.05 ± 1.27	0.983	10.45 ± 2.33	11.91 ± 2.79	0.057

Third Day			Fifth Day			Total *P* Value
Inextensible	**Extensible**	***P* Value**	**Inextensible**	**Extensible**	**P Value**	**Between Group**
1485.05 ± 722.53	2,739.96 ± 1,081.38	< 0.001*	876.95 ± 329.20	1,112.80 ± 843.55	0.268	0.001*
37.49 ± 24.19	71.34 ± 33.32	0.001*	13.01 ± 8.46	29.29 ± 19.02	0.001*	0.003*
12.12 ± 10.54	17.11 ± 13.77	0.283	7.86 ± 3.99	8.50 ± 6.17	0.748	0.154
15.53 ± 13.22	12.06 ± 9.27	0.417	8.31 ± 5.51	7.11 ± 3.02	0.446	0.363
7.15 ± 2.52	6.50 ± 1.73	0.397	6.59 ± 1.97	6.22 ± 1.99	0.622	0.191
7.93 ± 1.77	8.42 ± 2.39	0.425	7.07 ± 2.02	6.96 ± 2.15	0.849	0.353

**P* values (2-sided) < 0.05 were statistically significant between 2 groups at 4 time points (preoperative, first, third, and fifth day after surgery).

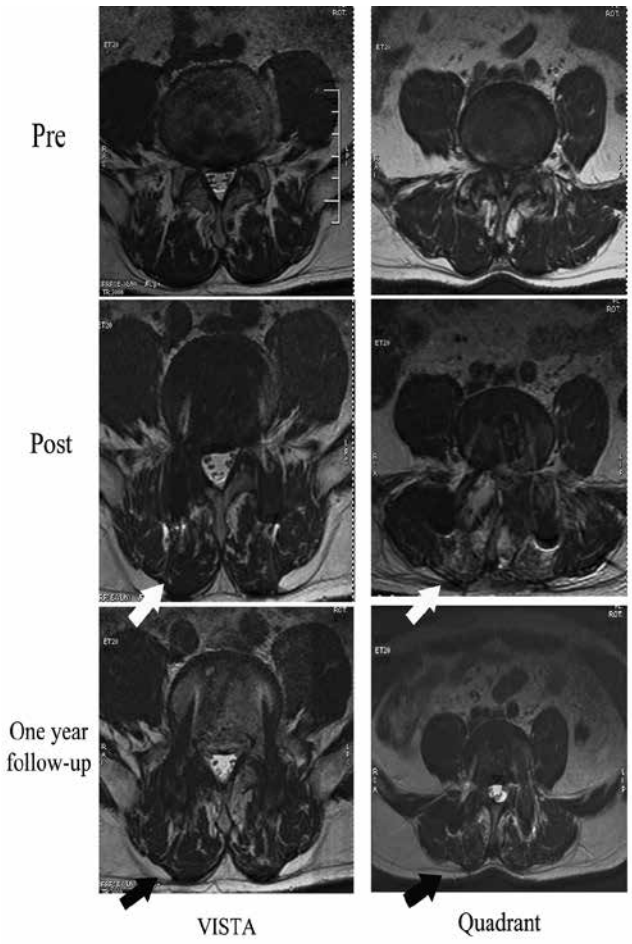

Fig. 5. *MRI changes of the multifidus muscles in a man aged 50 years in the VISTA group were compared with a man aged 49 years in the Quadrant group at preoperative, postoperative, and 1-year follow-up. Note the significant multifidus muscle atrophy on the follow-up imaging of the Quadrant group.*

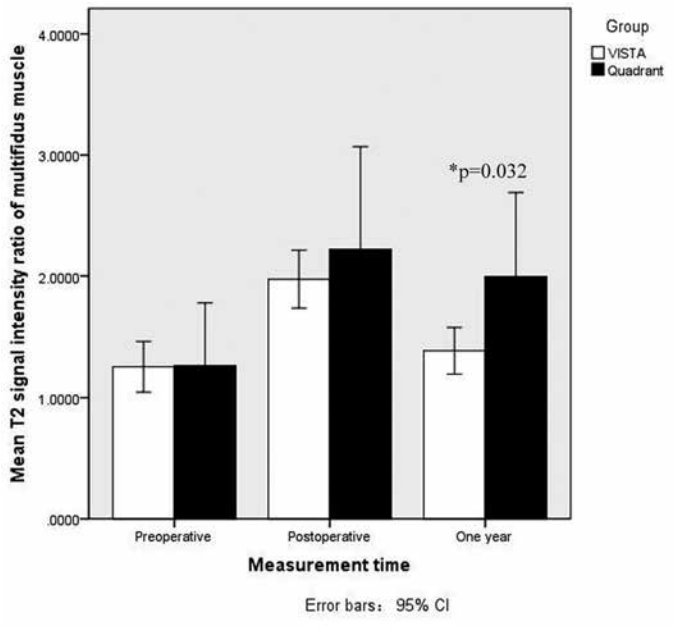

Fig. 6. *Bar graph showing preoperative, postoperative, and 1-year follow-up differences in mean MRI T2 signal intensity ratio of multifidus muscle between the 2 groups. The mean MRI T2 signal intensity ratio of multifidus muscle of the VISTA group was significantly lower than the Quadrant group at 1-year follow-up period ($P = 0.032$). *P values (2-sided) < 0.05 were statistically significant between the 2 groups.*

on the first day after surgery, and no complication was observed in the tube group. The hematoma was removed under percutaneous endoscopic lumbar surgery.

Discussion

Minimally invasive techniques have revolutionized the management of pathologic conditions in various surgical disciplines (1). As these techniques have evolved, they have facilitated the performance of lumbar fusions (2,15). MISS allows for decreased soft-tissue manipulation, which may have the benefit of reducing blood loss and facilitating an expeditious postoperative recovery (15-18). Among the spinal fusion methods, TLIF can lead to reduction in nerve root traction while being able to address central and neural-foraminal stenosis via direct and indirect decompression (7,10,18). The lateral approach used for MISS makes subsequent revision surgery less challenging (19,20). Despite this, surgical techniques based on the Mast Quadrant and pedicle screw–based retractor systems require direct visualization and require paraspinal musculature separation. Multiple authors have documented the harmful effects of the extensive muscle dissection and retraction that normally occur during lumbar procedures (8,12,13). Meanwhile, the traditional cylindrical tubular retractors, which are an extension of the microdiscectomy system, may limit the scope of operation. Thus, we have described a novel method for performing TLIF using a minimally invasive endoscopic approach.

Table 4. *Preoperative, follow-up VAS, JOA, ODI scores, and MacNab criteria assessment.*

	Tube	Retractor	*P* Value
Lower back pain VAS score, mean ± SD			
Preoperative	7.10 ± 0.58	6.98 ± 0.65	0.348
Postoperative 6 months	1.91 ± 1.00	2.12 ± 0.96	0.303
Postoperative 1 year	1.37 ± 0.77	1.61 ± 0.87	0.164
Final follow-up	0.82 ± 1.13	0.85 ± 1.07	0.912
Lower extremity pain VAS score, mean ± SD			
Preoperative	5.78 ± 1.11	5.65 ± 1.12	0.592
Postoperative 6 months	1.75 ± 0.94	1.80 ± 0.64	0.792
Postoperative 1 year	0.98 ± 1.09	1.24 ± 0.76	0.196
Final follow-up	0.56 ± 1.25	0.28 ± 0.72	0.205
JOA score, mean ± SD			
Preoperative	11.36 ± 2.70	11.67 ± 2.21	0.539
Postoperative 6 months	20.84 ± 3.67	20.15 ± 2.84	0.318
Postoperative 1 year	23.04 ± 4.15	22.61 ± 3.31	0.582
Final follow-up	24.33 ± 4.07	23.80 ± 3.50	0.508
ODI score, mean ± SD			
Preoperative	54.33 ± 4.07	53.46 ± 3.49	0.272
Postoperative 6 months	16.60 ± 11.36	17.20 ± 8.35	0.776
Postoperative 1 year	14.62 ± 11.40	14.96 ± 8.84	0.876
Final follow-up	12.71 ± 11.94	12.46 ± 9.28	0.910
MacNab criteria assessment, n			0.353
Excellent	31	26	
Good	9	17	
Fair	4	2	
Poor	1	1	

Abbreviation: SD, standard deviation

Innovative Design

The novel tubular endoscopic system, which evolved from the microendoscopic discectomy (MED) technique, is able to achieve minimally invasive endoscopic decompression and fusion integration. The novel tubular system was designed with a larger outer diameter exterior and smaller diameter interior, thereby generating an obconic shaped working channel (Fig. 7). The ability to create a working channel between the muscle fibers permits access to the posterior elements without excessively striping the deep musculature. Indeed, the larger outside caliber can permit more degrees of freedom for the surgeon. The novel tubes include 4 inner diameter specifications (a: 17-21.5 mm, b: 19-23.5 mm, c: 21-25.5 mm, and d: 23-27.5 mm) and 4 heights (42 mm, 52 mm, 62 mm, and 72 mm). Two simple diagrammatic sketches describe the advantages of the novel tube over the traditional cylindrical tube and Quadrant system (Fig. 8). The special obconic tubular endoscopic working channel was designed with a larger outer and smaller inside caliber, which could minimize deep muscles injury compared with the Quadrant system while permitting superior visualization.

In the current study, the authors successfully performed the endoscopic MIS-TLIF procedure in 45 patients using the novel tubular retractor system. Prior to surgery, the distance between the skin and facet joint as well as the height of the intervertebral disc space were measured to facilitate choosing the appropriate tubular retractor size. This preoperative preparation can help guide the surgeon to obtain the widest surgical corridor that concurrently minimizes iatrogenic

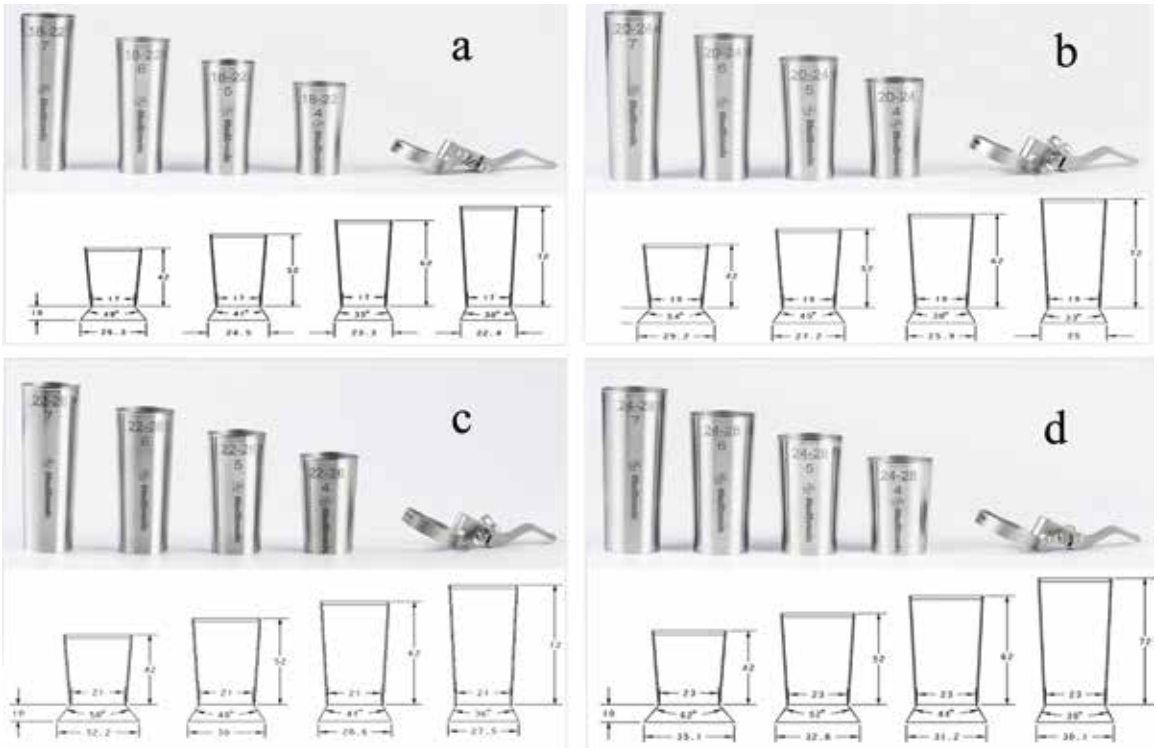

Fig. 7. *The novel tubes include 4 outer diameter specifications (a: 18-22 mm, b: 20-24 mm, c: 22-26 mm, and d: 24-28 mm) and 4 height types (42 mm, 52 mm, 62 mm, and 72 mm).*

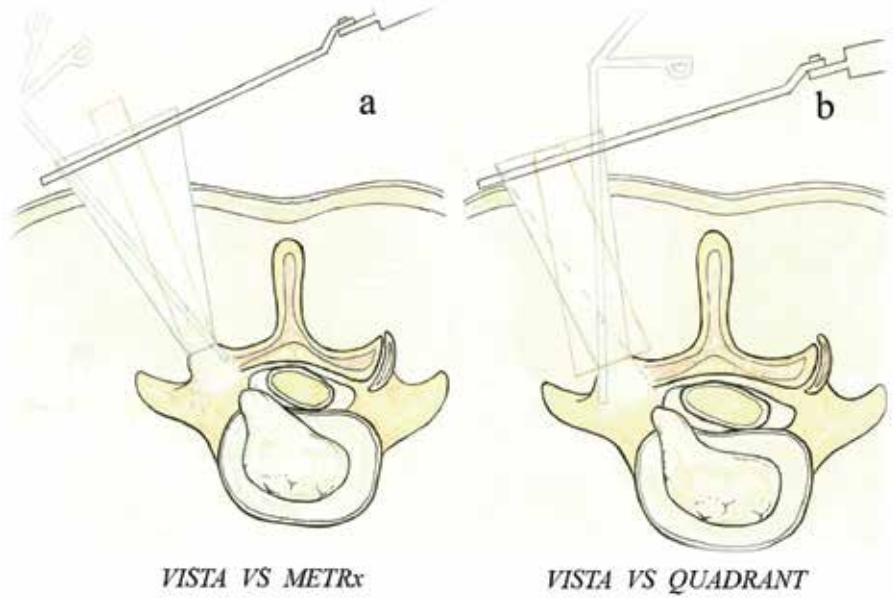

Fig. 8. Simple diagrammatic sketch describes the advantages of the novel tube than the traditional cylindrical tube and Quadrant system.

injury of paraspinal musculature. Then, we compared perioperative characteristics, clinical outcomes, and multifidus muscle injury of the obconic inextensible endoscopic tube for single-level MIS-TLIF with the Quadrant Retractor System. The results of the current study demonstrated that the tubular group was superior to the Quadrant retractor group in postoperative drainage volume and analgesic use rate. The endoscopic tube group had comparative incision length, blood loss, time to ambulation, and postoperative hospitalization, compared with the Quadrant retractor group. The tubular surgical time was on average 16 minutes longer than the retractor surgical time, but this difference was not found to be significant. It may be owing to more time spent on the percutaneous pedicle screw insertion and learning curve of new technique (17,21). The VAS scores for low back pain and leg pain improved significantly in both groups after surgery, as did the JOA and ODI scores. However, there were no significant differences between the 2 groups regarding preoperative, postoperative 6 months, postoperative 1-year, and final follow-up VAS, JOA, and ODI scores, fusion rates, and the distribution of the MacNab criteria. There was one case with local epidural hematoma who complained of new radicular symptoms in the retractor group on the first day after surgery, and no complication was observed in the tube group. In previous study, we suggest that reoperation should be performed within 1 week after surgery. Delay reexploration beyond this period increases the risk of persistent pain caused by irreversible nerve injury (22). Therefore, the patient underwent reoperation with percutaneous endoscopic lumbar technique the second day after prior surgery. The new radiculopathy was resolved immediately after reoperation without neurologic sequelae.

Previous studies have documented the harmful effects of extensive paraspinal muscular dissection and retraction lumbar surgery (7-10). Indeed, retractor blades have been shown to increase intramuscular pressure that can ultimately lead to ischemia (23). Moreover, damage to lumbar musculature has been shown to be correlated to retraction pressure performed during surgery (12,13). Muscle injury during spinal surgery increases the serum concentration of CPK-MM, which is routinely used for muscle injury evaluation at the immediate postoperative period (24,25). Lumbar interbody fusion surgery can cause operative trauma-induced stress, so we also took inflammatory markers (CRP, IL-6, IL-8, and TNF-a) and WBC as observation index. The concentration level of CPK-MM and CRP was lower in the tube group compared with the retractor group. The CPK-MM concentration level reached a peak on the first day after surgery and returned to baseline by 5 days in both groups, which was similar to the previous studies (24,26). The CRP level peaked on day 3 and then fell back at the fifth day. There were no significant differences with respect to WBC, IL-6, IL-8, and TNF-a between the 2 groups. The long-term evaluation of multifidus injury is assessed on MRI by a deposition of fat and connective tissue, which gives high-signal intensity in T2-weighted images in the advanced stages (6). The MRI T2 signal intensity ratio measurements in the evaluation of multifidus injury and atrophy have been demonstrated as an accuracy means (11). Muscle swelling due to edema up to 10 months postoperative indicating that atrophy of multifidus needs a long-term follow-up (11,26). In the current study, the MRI T2 signal intensity ratio of multifidus muscle was significantly lower in the tube group than the retractor group at the 1-year follow-up period. The MRI T2 signal intensity ratio of multifidus muscle was higher in the retractor group than the tube group at the immediate postoperative period, but no significant difference was found.

The minimally invasive endoscopic tubular TLIF is technically demanding, owing to the small working area and the need for longer and bayoneted surgical instruments (21). However, the video tower of the endoscopic system may facilitate teaching, as compared with other MIS-TLIF procedures. It is a drawback that the endoscopic tube and the Quadrant retractor group procedures were separately performed by 2 experienced surgeons in our study. In our country, it is difficult to use randomization principles because we cannot arrange operative plans for all patients. A randomized controlled trail should be considered to provide more evidence-based medicine conclusions.

Conclusions

The obconic inextensible endoscopic tubular system via the transforaminal approach for lumbar interbody fusion induced less multifidus muscle damage in terms of lower CPK-MM levels, less change in CRP at the immediate postoperative period, and less change in T2 signal intensity ratio at 1-year follow-up than the extensible retractor system. For the clinical outcomes, the tubular group had comparable clinical outcomes, with additional significant benefits of less postoperative drainage volume and analgesic use rate compared with the extensible retractor group.

References

1. Foley KT, Holly LT, Schwender JD. Minimally invasive lumbar fusion. *Spine* 2003; 28:S26-S35.
2. Schwender JD, Holly LT, Rouben DP, Foley KT. Minimally invasive transforaminal lumbar interbody fusion (TLIF): Technical feasibility and initial results. *J Spinal Disord Tech* 2005; 18:S1-S6.
3. Holly LT, Schwender JD, Rouben DP, Foley KT. Minimally invasive transforaminal lumbar interbody fusion: Indications, technique, and complications. *Neurosurg Focus* 2006; 20:1-5.
4. Wang J, Zhou Y, Zhang ZF, Li CQ, Zheng WJ, Liu J. Minimally invasive or open transforaminal lumbar interbody fusion as revision surgery for patients previously treated by open discectomy and decompression of the lumbar spine. *Eur Spine J* 2011; 20:623-628.
5. Fan SW, Hu ZJ, Zhao FD, Zhao X, Huang Y, Fang X. Multifidus muscle changes and clinical effects of one-level posterior lumbar interbody fusion: Minimally invasive procedure versus conventional open approach. *Eur Spine J* 2010; 19:316-324.
6. Mayer HM. The ALIF concept. *Eur Spine J* 2000; 9:S035-S043.
7. Gejo R, Matsui H, Kawaguchi Y, Ishihara H, Tsuji H. Serial changes in trunk muscle performance after posterior lumbar surgery. *Spine* 1999; 24:1023-1028.
8. Rantanen J, Hurme M, Falck B, et al. The lumbar multifidus muscle five years after surgery for a lumbar intervertebral disc herniation. *Spine* 1993; 18:568-574.
9. Styf JR, Willén J. The effects of external compression by three different retractors on pressure in the erector spine muscles during and after posterior lumbar spine surgery in humans. *Spine* 1998; 23:354-358.
10. Tender GC, Serban D. Minimally invasive transforaminal lumbar interbody fusion: Comparison of two techniques. *Chirurgia (Bucur)* 2014; 109:812-821.
11. Hu ZJ, Xu WB, Chen S, et al. Accuracy of magnetic resonance imaging signal intensity ratio measurements in the evaluation of multifidus muscle injury and atrophy relative to that of histological examinations. *Spine* 2014; 39:E623-E629.
12. Kawaguchi Y, Matsui H, Tsuji H. Back muscle injury after posterior lumbar spine surgery: A histologic and enzymatic analysis. *Spine* 1996; 21:941-944.
13. Kawaguchi Y, Matsui H, Tsuji H. Back muscle injury after posterior lumbar spine surgery: Part 2: Histologic and histochemical analyses in humans. *Spine* 1994; 19:2598-2602.
14. Cheng J, Zheng W, Wang H, et al. Posterolateral transforaminal selective endoscopic diskectomy with thermal annuloplasty for discogenic low back pain: A prospective observational study. *Spine* 2014; 39:B60-B65.
15. Ahn J, Tabaraee E, Singh K. Minimally invasive transforaminal lumbar interbody fusion. *J Spinal Disord Tech* 2015; 28:222-225.
16. Kepler CK, Anthony LY, Gruskay JA, et al. Comparison of open and minimally invasive techniques for posterior lumbar instrumentation and fusion after open anterior lumbar interbody fusion. *Spine J* 2013; 13:489-497.
17. Lee JC, Jang HD, Shin BJ. Learning curve and clinical outcomes of minimally invasive transforaminal lumbar interbody fusion: Our experience in 86 consecutive cases. *Spine* 2012; 37:1548-1557.
18. Peng CWB, Yue WM, Poh SY, Yeo W, Tan SB. Clinical and radiological outcomes of minimally invasive versus open transforaminal lumbar interbody fusion. *Spine* 2009; 34:1385-1389.
19. Lowe TG, Tahernia AD. Unilateral transforaminal posterior lumbar interbody fusion. *Clin Orthop Relat Res* 2002; 394:64-72.
20. Rosenberg WS, Mummaneni PV. Transforaminal lumbar interbody fusion: Technique, complications, and early results. *Neurosurgery* 2001; 48:569-575.
21. Nandyala SV, Fineberg SJ, Pelton M, Singh K. Minimally invasive transforaminal lumbar interbody fusion: One surgeon's learning curve. *Spine J* 2014; 14:1460-1465.
22. Wang J, Zhou Y. Perioperative complications related to minimally invasive transforaminal lumbar fusion: Evaluation of 204 operations on lumbar instability at single center. *Spine J* 2014; 14:2078-2084.
23. Mayer TG, Vanharanta H, Gatchel RJ, et al. Comparison of CT scan muscle measurements and isokinetic trunk strength in postoperative patients. *Spine* 1989; 14:33-36.
24. Arts MP, Nieborg A, Brand R, Peul WC. Serum creatine phosphokinase as an indicator of muscle injury after various spinal and nonspinal surgical procedures. *J Neurosurg Spine* 2007; 7:282-286.
25. Nanji AA. Serum creatine kinase isoenzymes: A review. *Muscle Nerve* 1983; 6:83-90.
26. Suwa H, Hanakita J, Ohshita N, Gotoh K, Matsuoka N, Morizane A. Postoperative changes in paraspinal muscle thickness after various lumbar back surgery procedures. *Neurol Med Chir (Tokyo)* 2000; 40:151-154.