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Retrospective Study**Radiological and clinical outcomes of midline lumbar fusion on sagittal lumbar-pelvic parameters for degenerative lumbar diseases**

Wang YT *et al.* Sagittal lumbar-pelvic alignment of MIDLF

Yue-Tian Wang, Bing-Xu Li, Shi-Jun Wang, Chun-De Li, Hao-Lin Sun

Abstract**BACKGROUND**

Improving the sagittal lumbar-pelvic parameters after fusion surgery is important for improving clinical outcomes. The impact of midline lumbar fusion (MIDLF) on sagittal lumbar-pelvic alignment for the management of degenerative lumbar diseases is still unknown.

AIM

This study aimed to analyze the effects of short-segment MIDLF and minimally invasive transforaminal lumbar interbody fusion (MIS-TLIF) on sagittal lumbar-pelvic parameters.

METHODS

We retrospectively analyzed 63 patients with degenerative lumbar diseases who underwent single-segment MIDLF or MIS-TLIF. The imaging data of patients were

collected before surgery and at the final follow-up. The radiological sagittal parameters included the lumbar lordosis (LL), lower LL, L4 slope (L4S), L5 slope, L5 incidence (L5I), L1 axis and S1 distance (LASD), pelvic incidence (PI), pelvic tilt (PT), sacral slope (SS), and PI-LL mismatch (PI-LL). Additionally, the clinical outcomes, including lower back and leg pain visual analog scale (VAS) and Oswestry disability index (ODI) scores, were also analyzed.

RESULTS

In both groups, LL and Lower LL significantly increased, while L5I and LASD significantly decreased at the final follow-up compared to that recorded prior to operation ($P < 0.05$). In the MIDLF group, L4S significantly decreased compared to that recorded prior to operation ($P < 0.05$), while the mean SS significantly increased and the PT significantly decreased compared to that recorded prior to operation ($P < 0.05$). In the MIS-TLIF group, SS slightly increased and the mean PT value decreased compared to that recorded prior to operation, but without a statistically significant difference ($P > 0.05$). However, the PI-LL in both groups was significantly reduced compared to that recorded prior to operation ($P < 0.05$). There was no significant difference in the sagittal lumbar-pelvic parameters between the two groups prior to operation and at the final follow-up ($P > 0.05$). In addition, the change in sagittal lumbar-pelvic parameters did not differ significantly, except for Δ LASD within the two groups ($P > 0.05$). The mean lower back and leg pain VAS and ODI scores in both groups were significantly improved three months after surgery and at the final follow-up. Though the mean ODI score in the MIDLF group three months after surgery was slightly higher than that in the MIS-TLIF group, there was no significant difference between the two groups at the final follow-up.

CONCLUSION

Short-segment MIDLF and MIS-TLIF can equally improve sagittal lumbar parameters such as LL, Lower LL, L5I, and LASD in the treatment of lumbar degenerative diseases. However, MIDLF had a larger impact on pelvic parameters than MIS-TLIF.

Key Words: Minimally invasive; Interbody fusion; Cortical bone trajectory; Sagittal lumbar-pelvic parameters

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Core Tip: It was important for clinical outcomes to improve the sagittal lumbar-pelvic parameters after fusion surgery. However, whether midline lumbar fusion (MIDLF) and minimally invasive transforaminal lumbar interbody fusion (MIS-TLIF) differ in the impact of the sagittal lumbar-pelvic alignment for degenerative lumbar diseases is still unknown. The current study compared the imaging data and clinical efficacy of MIDLF with those of MIS-TLIF to evaluate the impact of the two procedures on the sagittal lumbar-pelvic parameters in the treatment of lumbar degenerative diseases.

INTRODUCTION

Posterior lumbar fusion surgery is an effective ⁸ method for the treatment of lumbar degenerative diseases such as lumbar spinal stenosis, lumbar disc herniation, and degenerative lumbar spondylolisthesis^[1]. The traditional open posterior fusion approach has many issues, including massive paraspinal muscle dissection, increased operational bleeding and postoperative complications, and a long recovery time^[1,2]. Recently, minimally invasive posterior fusion operations have been recognized to promote rapid postoperative recovery^[3]. Minimally invasive transforaminal lumbar interbody fusion (MIS-TLIF) has benefited an increasing number of patients by establishing the operation channel through the muscle space, which reduces the

surgical incision, thereby allowing the pedicle screws to be inserted percutaneously, ultimately contributing to less trauma and bleeding^[4]. Although percutaneous pedicle screw insertion could achieve rigid three-column fixation, some scholars remain concerned that this minimally invasive operation might lead to limited improvement of sagittal lumbar-pelvic alignment^[4,5].

Midline lumbar interbody fusion (MIDLF) is also considered a limited invasive procedure with a modest muscle dissection^[6]. The technique of cortical bone trajectory (CBT) screw placements not only contributes to enhancing screws' holding power by increasing cortical bone contact but also reduces the paraspinal soft tissue dissection following a medial to lateral screw-insertion direction, which facilitates the early recovery of patients postoperatively^[6-8]. However, the length and diameter of CBT screws used in MIDLF tend to be smaller than those of traditional pedicle screws, so the supporting strength of CBT screws on the anterior column of lumbar vertebrae might be not as good as that of the traditional pedicle screws, which can achieve three-column lumbar fixation^[9]. In addition, little research has focused on the improvement of sagittal lumbar-pelvic parameters with MIDLF.

5 Studies have confirmed that it is important for clinical outcomes to improve the sagittal lumbar-pelvic parameters after fusion surgery. However, whether MIDLF and MIS-TLIF differ in terms of the impact of sagittal lumbar-pelvic alignment for management of degenerative lumbar diseases is still unknown. The current study compared the imaging data and clinical efficacy of MIDLF with those of MIS-TLIF to evaluate the impact of both procedures on the sagittal lumbar-pelvic parameters in the treatment of lumbar degenerative diseases.

MATERIALS AND METHODS

Patients

Patients seen at Peking University First Hospital (China, Beijing) from January 2019 to March 2021 who met the study inclusion and exclusion criteria were enrolled. This study was approved by the Human Subjects Institutional Review Board of Peking

University First Hospital. Patients who underwent single-segment MIDLF and MIS-TLIF for lower back pain, unilateral or bilateral lower-limb radiating pain, numbness, or intermittent claudication after strict conservative treatments for at least three months with complete preoperative and postoperative lateral lumbar X-ray images and at least one year of follow-up data after surgery were included. We excluded individuals with spinal tumors, tuberculosis, infection, scoliosis, or fractures; a history of spinal surgery; postoperative complications such as surgical site infection, cage displacement, or fixation failure; or without radiological images available from the study.

Surgical selection and technique

In our center, both MIDLF and MIS-TLIF could be employed for the treatment of degenerative lumbar diseases, such as lumbar disc herniation, lumbar spinal stenosis, and lumbar spondylolisthesis. MIDLF was more likely to be performed in patients with osteoporosis or osteopenia, as the CBT technique could enhance the screw stability. Furthermore, MIDLF tends to be used for central decompression of the lumbar canal due to central lumbar disc herniation, lumbar spinal stenosis, or lumbar spondylolisthesis, while MIS-TLIF is preferred for treating unilateral nerve root compression or nerve root canal stenosis caused by intervertebral disc herniation.

In the MIDLF group, after anesthesia and preoperative preparation, a median lumbar incision was made and the bilateral paraspinal muscle was dissected to expose the lamina and the lateral margin of the facet joint. CBT screw paths were set, following a mediolateral and caudocephalad direction to ensure the screws made adequate contact with the cortical bone. Then, thorough spinal canal and nerve root decompression was performed by facetectomy and resection of the partial vertebral lamina and thickening of the ligamentum flavum of the lesion segment. Next, the intervertebral disc on the lesion side was completely removed, and the cartilage endplate was scraped to the subchondral bone. After the intervertebral space was cleaned up and expanded, autologous bone grains were implanted into the anterior intervertebral space. Then, an appropriate cage with autologous bone was placed into the interbody space. CBT

screws were inserted following the prepared paths, and the rods and nuts were connected. After creating a bone graft bed, a posterolateral bone graft was performed using local autologous bone grains mixed with allograft bone. Finally, a drainage tube was placed, and the wound was closed layer by layer.

In the MIS-TLIF group, after anesthesia and preoperative preparation, an incision was made from the middle line between the caudal and the cranial pedicle at the affected level. The subcutaneous tissue was dissected and moved to one side. Next, the working channel was placed through the space of the multifidi muscle to expose the unilateral facet joint after inserting an expansion sleeve progressively. A thorough decompression of the spinal canal and nerve root was performed by facetectomy and resection of partial vertebral lamina and ligamentum flavum. After performing a discectomy and scraping the cartilage endplate, an appropriate cage filled with autologous bone was placed. Then, the pedicle screws were percutaneously implanted under the guidance of fluoroscopy. After applying appropriate intervertebral pressure, the rods and nuts were installed. Finally, the drainage tube was placed and the wound was closed.

Radiological outcomes

Full-length X-ray radiographs of the spine were taken for all patients in a relaxed standing position. The following preoperative and final follow-up sagittal lumbar-pelvic parameters were measured by two independent spinal surgeons using PACS software: lumbar lordosis (LL), lower LL, L4 slope (L4S), L5 slope (L5S), L5 incidence (L5I), L1 axis and S1 distance (LASD), pelvic incidence (PI), pelvic tilt (PT), sacral slope (SS), and PI-LL mismatch (PI-LL) (Figure 1). The mean value of three measurements from each surgeon was used. The change in each parameter (Δ LL, Δ Lower LL, Δ L4S, Δ L5S, Δ L5I, Δ LASD, Δ PI, Δ PT, and Δ SS) was also calculated by subtracting the preoperative value from the value recorded at the final follow-up.

Clinical outcomes

The clinical outcomes were evaluated preoperatively, at three months after surgery, and at the final follow-up. The degree of pain in the lower back and lower limbs was evaluated using a visual analog scale (VAS), while lumbar function was evaluated with the Oswestry disability index (ODI). The VAS and ODI scores were compared between the two groups prior to operation and at each follow-up visit.

Statistical analyses

SPSS 23.0 (IBM Corp., Armonk, NY, United States) was used for analysis. According to the normality of the data, the quantitative variables were presented as mean \pm standard deviation or median (min, max) values, and qualitative variables were shown using numbers. A paired *t*-test or paired Wilcoxon test was used for intragroup comparison of continuous variables, and two independent-samples *t*-tests were used for the intergroup comparison. The chi-squared test or Fisher's exact test was used for the analysis of categorical variables. A two-tailed *P* value of < 0.05 was chosen to indicate a statistically significant difference.

RESULTS

²In the MIDLF group, there were 14 men and 20 women, with an age of 62.94 ± 13.03 years old. Twenty cases were diagnosed with lumbar spinal stenosis, 11 cases were diagnosed with lumbar disc herniation, and three cases were diagnosed with lumbar spondylolisthesis. In the MIS-TLIF group, there were 16 men and 13 women, with an age of 58.76 ± 8.65 years old. Eight cases were diagnosed with lumbar spinal stenosis, 19 cases were diagnosed with lumbar disc herniation, and two cases were diagnosed with lumbar spondylolisthesis. ⁴There was no significant difference in general information, such as age, gender, body mass index, or follow-up time, between the two groups (Table 1, $P > 0.05$). ¹³

The average operative duration ²in the MIDLF group was similar to that in the MIS-TLIF group ($P = 0.190$); however, the average volume of blood estimated to have been lost during surgery in the MIS-TLIF group was significantly ⁹less than that in the MIDLF

group ($P = 0.013$). The patients in the MIDLF group required a similar length of hospital stay after surgery as those in the MIS-TLIF group ($P = 0.085$) (Table 1).

In the MIDLF group, LL and Lower LL significantly increased at the final follow-up; L4S, LASD, and L5I significantly decreased compared to that recorded prior to operation ($P < 0.05$); and L5S decreased at the final follow-up, but the difference was not statistically significant ($P > 0.05$). As for sagittal pelvic parameters, PI was similar to that recorded prior to operation, while SS significantly increased ($P = 0.008$) and PT significantly decreased ($P = 0.014$) compared to those recorded prior to operation. In the MIS-TLIF group, LL and Lower LL significantly increased ($P < 0.05$) and LASD and L5I significantly decreased ($P < 0.05$) at the final follow-up compared to those recorded prior to operation, while L4S and L5S were similar at the final follow-up to the pre-operation values ($P > 0.05$). For the sagittal pelvic parameters, SS increased and PT decreased compared to those values recorded prior to operation, but there was no statistically significant difference in either ($P > 0.05$). Meanwhile, the PI-LL in both groups significantly decreased compared to that seen prior to operation ($P < 0.05$). When it came to the inter-group comparison performed at each time point, there was no significant difference in the postoperative sagittal lumbar-pelvic parameters between the two groups ($P > 0.05$). The Δ LASD value in the MIS-TLIF group was significantly larger than that in the MIDLF group, while no significant differences were found in Δ LL, Δ Lower LL, Δ L4S, Δ L5S, L5SI, Δ PI, Δ PT, Δ SS, or Δ PI-LL between the two groups. A typical case of MIDLF is shown in Figure 2, and the sagittal lumbar-pelvic parameters in both groups are shown in Table 2.

There was no significant difference in lower back pain VAS scores between the two groups at pre-operation and the final follow-up, but the lower back pain VAS score in the MIS-TLIF group at three months after surgery was significantly lower than that in the MIDLF group. There was also no significant difference in leg pain VAS scores between the two groups three months after surgery and at the final follow-up, though the pre-operation leg pain VAS score in the MIS-TLIF group was significantly greater than that in the MIDLF group. Both the lower back pain and leg pain VAS scores three

months³ after surgery and at the final follow-up were significantly improved compared to the pre-operation scores in both groups ($P > 0.05$). The mean ODI scores of the two groups were significantly improved at three months after surgery and the final follow-up ($P < 0.05$). The mean ODI in the MIDLF group at three months after surgery was slightly higher than that in the MIS-TLIF group despite comparable preoperative values. However,² there was no significant difference in ODI scores between the two groups at the final follow-up. The clinical outcomes of the two groups are shown in Table 3.

DISCUSSION

Lumbar fusion surgery can restore the spinal sagittal balance and improve lumbar-pelvic alignment, which is highly significant for alleviating lumbar symptoms and maintaining long-term clinical outcomes^[10]. There is a correlation between LL and lower back pain; indeed, a previous study confirmed that a reduction in LL might lead to greater local stress and eventual aggravation of lower back discomfort, and the appropriate restoration of LL was proposed to achieve better clinical outcomes after surgery^[11]. Lower LL could significantly increase the lordosis of the lumbosacral segment and restore the curve of the upper lumbar spine, which is helpful for improving the overall LL^[12]. Additionally, as the loss of Lower LL might be relevant to adjacent segmental degeneration, the importance of improving Lower LL should be considered when performing lumbar fusion surgery^[12,13]. In our study, LL and Lower LL in the MIDLF and MIS-TLIF groups were significantly refined and contributed to relief from postoperative symptoms at the final follow-up. Moreover, statistical analysis showed that there was no significant difference in Δ LL or Δ Lower LL within the two groups. Therefore, it was considered that short-segment MIDLF and MIS-TLIF have an equal ability to improve LL and Lower LL in the treatment of lumbar degenerative diseases. This result was consistent with the findings of Elmekaty *et al*^[14], who found that MIDLF and MIS-TLIF have an almost similar capability to improve the sagittal balance in the treatment of single-level lumbar spondylolisthesis.

L4S, L5S, and L5I could reflect the balance of the lower lumbar to some extent^[15]. In our study, L5I in both groups and L4S in the MIDLF group significantly decreased at the final follow-up compared to pre-operation. Additionally, in terms of refining the balance of the lower lumbar vertebrae, the capacities of both minimally invasive surgeries were perhaps similar up to the point of the final follow-up. Moreover, the improvement in sagittal parameters such as LASD would be helpful for restoring the sagittal lumbar-pelvic alignment. Indeed, Funao *et al*^[15] demonstrated that LASD contributed to pain relief after surgery. Both MIDLF and MIS-TLIF significantly improved the distance between the L1 axis and S1 after the operation, reducing the extra load caused by postoperative gravity compensation and eventually benefiting the restoration of sagittal balance. The improvements in LL and Lower LL, the reduction of spondylolisthesis, and the restoration of intervertebral height might be the factors that make a contribution to the improvement of LASD. Furthermore, we found that Δ LASD in the MIS-TLIF group was significantly larger than Δ LASD in the MIDLF, which might indicate that MIS-TLIF has a better ability to improve LASD.

The improved sagittal lumbar parameters could also reduce the compensation of PT. In our practice, MIDLF had a certain impact on the sagittal pelvic parameters, while MIS-TLIF made a limited difference. The results showed that SS significantly increased and PT significantly decreased after surgery in the MIDLF group. Notably, both groups acquired better PI-LL values compared to pre-operation. Some studies on fusion surgery have reported an improvement in sagittal lumbar parameters to some extent in the treatment of lumbar degenerative diseases, among which open-transforaminal lumbar interbody fusion (O-TLIF) could significantly improve LL and the intervertebral height; however, the improvement of pelvic parameters remains controversial^[16]. Certain studies have also indicated that O-TLIF could significantly improve pelvic parameters, such as SS and PT, but others do not support this conclusion^[17,18]. Considering MIS-TLIF, although some scholars contended that the minimally invasive approach will limit its ability to improve sagittal lumbar-pelvic parameters, previous studies found that it could still improve LL and pelvic parameters^[19,20]. Champagne *et*

al^[21] demonstrated that, although the incision made during MIS-TLIF is significantly smaller than that made during O-TLIF, it was not inferior to TLIF for improving sagittal parameters. However, Hawasli *et al*^[22] argued the short-segment MIS-TLIF does not affect the radiological pelvic parameters. Our results seem to concur with the results of Hawasli *et al*. Since the anchorage length of CBT screws in MIDLF is relatively shorter than that of the traditional pedicle screws in MIS-TLIF, the control force of the anterior column in MIDLF would be weaker than that during MIS-TLIF from a biomechanical perspective. However, we found a significantly superior position of MIDLF to MIS-TLIF in the improvement of the sagittal pelvic parameters, which confirmed that MIDLF could achieve excellent stability. Although the improvement of spinal sagittal alignment was important, it might not be the main purpose in the long term for short-segment lumbar fusion^[23]. The relief of patients' primary symptoms tended to depend more on the exact intraoperative decompression and the stability of internal fixation.

In terms of clinical outcomes, the patients in both groups showed improved VAS and ODI scores at three months after surgery and the final follow-up compared to those recorded prior to operation, although the mean ODI score in the MIDLF group at three months after surgery was slightly higher than that in the MIS-TLIF group, which might be attributable to a greater proportion of lumbar disc herniation cases in the MIS-TLIF group than the MIDLF group. The symptoms of lumbar disc herniation would be relieved better in the short term than those of other diseases, such as lumbar spinal stenosis.

This study has some limitations that warrant discussion. First, this was a single-cohort retrospective study, so it might be underpowered, limiting its ability to detect many changes. Second, the study contained a small sample size, and some patients with missing imaging data were excluded, which could have caused some selection bias. Furthermore, the follow-up time was short and long-term imaging data were lacking, which are necessary to continue the follow-up investigation.

CONCLUSION

Short-segment MIDLF and MIS-TLIF can equally improve sagittal lumbar parameters such as LL, Lower LL, L5I, and LASD in the treatment of lumbar degenerative diseases. However, MIDLF had a better ability than MIS-TLIF to improve pelvic parameters.

ARTICLE HIGHLIGHTS

Research background

The impact of single-segment midline lumbar fusion (MIDLF) on sagittal lumbar-pelvic alignment for management of degenerative lumbar diseases is still unknown.

Research motivation

Comparing ⁵ the impact of MIDLF and minimally invasive transforaminal lumbar interbody fusion (MIS-TLIF) on sagittal lumbar-pelvic parameters can help to better understand minimally invasive lumbar surgery.

Research objectives

This study aimed to compare the effects of single-segment MIDLF and MIS-TLIF on sagittal lumbar-pelvic parameters.

Research methods

We retrospectively analyzed 63 patients with degenerative lumbar diseases who underwent single-segment MIDLF or MIS-TLIF. The sagittal lumbar-pelvic parameters and clinical outcomes of the two groups were compared.

Research results

Both MIDLF and MIS-TLIF can improve lumbar lordosis (LL), lower LL, L5 incidence (L5I), and L1 axis and S1 distance (LASD). Nevertheless, MIDLF showed a better ability to improve pelvic parameters than MIS-TLIF. ¹² However, there was no significant difference between the two groups in terms of clinical outcomes at the final follow-up.

Research conclusions

Short-segment MIDLF and MIS-TLIF can equally improve sagittal lumbar parameters such as LL, Lower LL, L5I, and LASD in the treatment of lumbar degenerative diseases. However, MIDLF had a larger impact on pelvic parameters than MIS-TLIF.

Research perspectives

MIDLF is a good choice for the treatment of short-segment degenerative lumbar diseases.

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