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ORIGINAL RESEARCH ARTICLE

COMPARATIVE ANALYSIS OF MINIMALLY INVASIVE SURGERY VERSUS TRADITIONAL OPEN SURGERY FOR SPINAL FUSION IN LUMBAR DISC DEGENERATION

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ABSTRACT

Background: Lumbar disc degeneration (LDD) is a prevalent condition leading to chronic lower back pain and functional impairment. Spinal fusion is a well-established treatment, with minimally invasive surgery (MIS) emerging as an alternative to traditional open surgery (OS). This study compares clinical, radiological, and functional outcomes of MIS and OS for spinal fusion in LDD.

Methods: This retrospective cohort study analyzed 120 patients diagnosed with LDD, treated with spinal fusion (60 MIS, 60 OS) between 2015 and 2020. Outcomes were assessed over 5 years, using the Oswestry Disability Index (ODI) and Visual Analogue Scale (VAS) for pain. Complication rates, length of hospital stay, and radiological outcomes (fusion success and alignment) were also evaluated.

Results: MIS demonstrated significant reductions in hospital stay (3.2 vs. 6.1 days, $p < 0.01$) and complication rates (10% vs. 25%, $p < 0.05$). Both groups showed comparable ODI and VAS improvements, but MIS patients experienced faster recovery in the first year. Radiological outcomes were similar, with fusion success rates of 95% in MIS and 93% in OS.

Conclusion: MIS for spinal fusion offers comparable clinical and radiological outcomes to OS while reducing complications and recovery time. These findings highlight MIS as a viable alternative to OS for LDD patients.

Keywords: Lumbar disc degeneration, minimally invasive surgery, traditional open surgery, spinal fusion, comparative analysis, outcomes

INTRODUCTION

Lumbar disc degeneration (LDD) is one of the most common causes of chronic lower back pain, significantly affecting quality of life and imposing a substantial socioeconomic burden. It is characterized by the progressive degeneration of intervertebral discs, leading to mechanical instability, nerve compression, and debilitating pain. For patients unresponsive to conservative treatments, spinal fusion is a widely accepted surgical intervention aimed at stabilizing the spine and alleviating symptoms[1-2].

Traditional open surgery (OS) has been the gold standard for spinal fusion, providing direct visualization and access to the affected area. However, it is associated with extensive soft tissue dissection, increased blood loss, longer recovery times, and higher complication rates. In contrast, minimally invasive surgery (MIS) has emerged as an alternative technique, offering the advantages

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of smaller incisions, reduced muscle disruption, and quicker postoperative recovery. Despite these potential benefits, concerns remain regarding MIS's learning curve, limited surgical field visibility, and potentially inadequate fusion in complex cases[3].

Comparative studies evaluating the outcomes of MIS and OS for spinal fusion are essential to guide clinical decision-making. While both approaches aim to achieve similar goals—pain relief, functional restoration, and spinal stabilization—their differing methodologies may influence patient outcomes [4]. This study aims to provide a comprehensive analysis of MIS and OS in spinal fusion for LDD, focusing on clinical, radiological, and functional outcomes over a 5-year follow-up.

MATERIALS & METHOD

Study Design and Setting

This retrospective cohort study was conducted at a tertiary care spine center. Data were collected from patients undergoing spinal fusion for LDD between 2015 and 2020.

Participants

Inclusion Criteria:

- Patients aged 30–70 years diagnosed with LDD requiring spinal fusion.
- Patients undergoing MIS or OS as their primary surgical intervention.
- Availability of clinical and radiological follow-up data for 5 years.

Exclusion Criteria:

- Patients with multi-level lumbar disease.
- Previous lumbar spine surgeries.
- Systemic comorbidities affecting bone healing (e.g., osteoporosis, diabetes).

Surgical Procedures

- **MIS Group:** Spinal fusion was performed through percutaneous pedicle screws and minimally invasive retractors under fluoroscopic guidance.
- **OS Group:** Traditional open surgery involved extensive soft tissue dissection, direct visualization, and placement of pedicle screws and rods.

Outcome Measures

1. **Clinical Outcomes:** Oswestry Disability Index (ODI) for functionality and Visual Analogue Scale (VAS) for pain.
2. **Radiological Outcomes:** Fusion success (assessed via CT scans) and spinal alignment (measured as Cobb angle).
3. **Perioperative Data:** Blood loss, length of hospital stay, and complication rates.

Statistical Analysis

- Continuous variables were analyzed using independent t-tests.
- Categorical variables were compared using chi-square or Fisher’s exact tests.

A p-value of <0.05 was considered statistically significant.

RESULTS

(**Interpretation:** The table highlights that both MIS and OS groups had comparable baseline demographics, ensuring a balanced comparison. The mean age and BMI of the groups were similar, and the male predominance was consistent across both groups.

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Group	Age (Mean ± SD)	Male (%)	BMI (Mean ± SD)
MIS	52.0 ± 8.0	67%	25.2 ± 3.5
OS	53.0 ± 9.0	63%	26.0 ± 3.8

Table 2. Perioperative Outcomes

Interpretation: MIS resulted in significantly lower blood loss, shorter hospital stays, and a reduced complication rate compared to OS, emphasizing its perioperative advantages.

Outcome	MIS (Mean ± SD)	OS (Mean ± SD)	p-value
Blood Loss (mL)	220 ± 50	450 ± 100	<0.01
Hospital Stay (days)	3.2 ± 0.8	6.1 ± 1.2	<0.01
Complication Rate (%)	10%	25%	0.03

Table 3. Clinical Outcomes (Oswestry Disability Index - ODI)

Interpretation: Both groups demonstrated substantial ODI improvements over 5 years, with similar long-term functional outcomes. MIS patients experienced faster recovery in the first year.

Group	Pre-Treatment ODI (%)	Post-Treatment ODI (%)
MIS	60 ± 10	15 ± 5
OS	58 ± 12	18 ± 6

Table 4. Clinical Outcomes (Visual Analogue Scale - VAS)

Interpretation: Both groups achieved significant pain reduction post-treatment, with comparable VAS scores at the 5-year mark. MIS patients reported slightly lower pain levels at earlier follow-ups.

Group	Pre-Treatment VAS	Post-Treatment VAS
MIS	8 ± 1	2 ± 1
OS	8 ± 2	2 ± 1

Table 5. Radiological Outcomes

Interpretation: Fusion success rates and spinal alignment were comparable between MIS and OS groups, highlighting the effectiveness of both techniques in achieving the desired surgical outcomes.

Group	Fusion Success (%)	Spinal Alignment Success (%)
MIS	95	92
OS	93	91

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Table 6. Complication Details

Interpretation: MIS had significantly fewer complications compared to OS. Infection and neurological deficits were more frequent in the OS group, while hardware failure was rare in both groups.

Complication Type	MIS Count	OS Count
Infection	3	10
Hardware Failure	2	5
Neurological Deficits	5	10
None	50	35

Table 7. Impact of Age on Outcomes

Interpretation: Younger patients (<40 years) showed greater functional improvement, regardless of surgical technique. MIS demonstrated slightly better outcomes in older patients compared to OS.

Age Group	MIS ODI Improvement (%)	OS ODI Improvement (%)
<40 years	35	30
40–60 years	30	28
>60 years	25	22

Table 8. Impact of BMI on Outcomes

Interpretation: Patients with lower BMI (<25 kg/m²) showed greater ODI improvements. MIS outcomes were consistently better across all BMI categories.

BMI Group	MIS ODI Improvement (%)	OS ODI Improvement (%)
<25 kg/m²	32	30
25–30 kg/m²	28	25
>30 kg/m²	24	20

Table 9. Time to Fusion Success

Interpretation: MIS achieved faster fusion success compared to OS. The majority of MIS patients showed successful fusion within 12 months, while OS patients took longer to achieve similar outcomes.

Time (Months)	MIS Fusion Success (%)	OS Fusion Success (%)
3	60	50
6	80	70
12	95	93
24	95	93

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Table 10. Regression Analysis of Predictors of Success

Interpretation: Age, BMI, and disease stage were significant predictors of ODI improvement in both groups. MIS demonstrated stronger associations for these predictors compared to OS.

Predictor	Odds Ratio (MIS)	Odds Ratio (OS)	p-value
Age <40 years	1.8	1.5	0.01
BMI <25 kg/m²	2.2	1.8	0.02
Stage 1 Disease	2.5	2.0	0.001

DISCUSSION

This study provides a comprehensive analysis of the clinical, radiological, and perioperative outcomes of minimally invasive surgery (MIS) versus traditional open surgery (OS) for spinal fusion in patients with lumbar disc degeneration (LDD). The findings highlight that while both approaches achieve comparable long-term results, MIS offers distinct advantages in terms of recovery time, complication rates, and perioperative outcomes[5].

Key Findings

The results indicate that MIS and OS achieve similar long-term functional and radiological outcomes. Improvements in the Oswestry Disability Index (ODI) and Visual Analogue Scale (VAS) were significant in both groups, with comparable fusion success rates and spinal alignment at 5 years. However, MIS demonstrated faster recovery in the first year, lower complication rates (10% vs. 25%), shorter hospital stays, and reduced blood loss. These advantages make MIS a compelling alternative to OS, particularly for younger, healthier patients seeking faster postoperative recovery[6].

Clinical Outcomes

Functional recovery, as measured by ODI, and pain relief, as assessed by VAS, showed substantial improvements in both groups. MIS patients experienced faster recovery during the first year, likely due to reduced soft tissue disruption and quicker mobilization. By the 5-year mark, both groups achieved comparable scores, confirming the effectiveness of spinal fusion in addressing the symptoms of LDD regardless of the surgical approach.

The faster recovery associated with MIS aligns with findings from other studies, such as Wang et al., who reported accelerated functional improvements in MIS patients during early follow-ups. This advantage is particularly relevant for patients aiming to return to work or daily activities promptly after surgery[7].

Radiological Outcomes

Radiological assessments revealed comparable fusion success rates (95% in MIS vs. 93% in OS) and spinal alignment (92% vs. 91%). These results underscore the effectiveness of MIS in achieving stable spinal constructs, despite the limited surgical exposure inherent in minimally invasive techniques. Concerns about inadequate visualization and suboptimal implant placement in MIS appear to be unfounded, as advanced imaging guidance and surgical expertise mitigate these challenges[8].

Perioperative Outcomes

One of the most striking advantages of MIS is its superior perioperative profile. The study demonstrated significantly lower blood loss, shorter hospital stays, and reduced complication rates in MIS compared to OS. These findings are consistent with the minimally invasive nature of MIS, which preserves soft tissue integrity and reduces surgical trauma.

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The shorter hospital stays (3.2 vs. 6.1 days) associated with MIS translate into reduced healthcare costs and enhanced patient satisfaction. Moreover, the reduced complication rate (10% in MIS vs. 25% in OS) highlights the safety of MIS, making it a favorable option for patients at higher risk of perioperative morbidity[9].

Complications

While complications were observed in both groups, MIS had fewer adverse events compared to OS. The most common complications in OS were infections and neurological deficits, likely due to extensive soft tissue dissection and prolonged operative time. MIS, with its smaller incisions and reduced exposure, minimizes these risks.

The low rate of hardware failure in both groups (MIS 2%, OS 5%) indicates the durability of spinal implants regardless of the surgical approach. However, OS remains slightly more prone to implant-related issues due to the increased mechanical stresses associated with traditional techniques[10].

Impact of Patient Characteristics

Age: Younger patients (<40 years) demonstrated greater functional improvements compared to older patients, regardless of the surgical technique. This finding is likely attributed to better healing capacity and fewer comorbidities in younger individuals. MIS showed a slight advantage in older patients, suggesting its suitability for high-risk populations who might not tolerate the invasiveness of OS.

BMI: Patients with lower BMI (<25 kg/m²) achieved better outcomes in both groups, but MIS outcomes were consistently superior across all BMI categories. Obesity, a known risk factor for surgical complications, appears to have a more pronounced impact on OS outcomes, likely due to the extensive tissue manipulation required.

Time to Fusion Success

The time to achieve fusion success was shorter in MIS, with 95% of patients achieving successful fusion within 12 months compared to 93% in OS at the same interval. This difference may be attributed to the precision of implant placement and reduced postoperative inflammation associated with MIS. Faster fusion rates in MIS are clinically significant, as they reduce the duration of restricted mobility and enhance overall recovery[5].

Comparison with Existing Literature

The findings of this study align with existing literature emphasizing the advantages of MIS in spinal fusion. A meta-analysis by Xu et al. reported similar trends, highlighting faster recovery, reduced perioperative morbidity, and comparable long-term outcomes with MIS. However, this study provides additional insights into predictors of success, such as age, BMI, and disease stage, further refining patient selection criteria for MIS.

While OS remains a reliable option for complex multi-level or revision surgeries, the evidence strongly supports MIS as the preferred approach for single-level lumbar fusion in appropriately selected patients[6].

Limitations

Despite its strengths, this study has several limitations:

1. **Retrospective Design:** The lack of randomization limits the ability to control for confounding variables, such as surgeon expertise and patient comorbidities.
2. **Single-Center Study:** The findings may not be generalizable to other healthcare settings with varying resources and surgical expertise.
3. **Exclusion of Multi-Level Diseases:** By focusing on single-level LDD, the study does not address the applicability of MIS in more complex cases.

Future research addressing these limitations is necessary to validate and expand on these findings.

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Future Directions

To enhance the evidence base for MIS, future studies should focus on:

1. **Multi-Center Randomized Trials:** Large-scale trials comparing MIS and OS across diverse populations and healthcare settings.
2. **Cost-Effectiveness Analyses:** Evaluating the economic impact of shorter hospital stays and reduced complications in MIS compared to OS.
3. **Longer Follow-Up:** Extending the follow-up period beyond 5 years to assess implant longevity, reoperation rates, and patient satisfaction.
4. **Expanding Indications:** Exploring the feasibility and outcomes of MIS in multi-level and complex spinal pathologies.

Clinical Implications

The findings of this study support the integration of MIS into standard clinical protocols for spinal fusion in LDD. The superior perioperative outcomes, coupled with comparable long-term results, position MIS as the preferred option for patients seeking faster recovery and lower surgical risks. However, OS remains a critical tool for cases requiring extensive visualization and multi-level interventions.

CONCLUSION

Minimally invasive surgery demonstrates significant advantages over traditional open surgery in the treatment of lumbar disc degeneration. With faster recovery, fewer complications, and comparable clinical and radiological outcomes, MIS represents a transformative approach to spinal fusion. Continued advancements in technology and surgical techniques are expected to further enhance its efficacy and applicability.

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