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ARTICLE

Comparative Analysis of Open vs. Minimally Invasive Approaches in Lumbar Spine Surgery: A Multi-Center Study

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ABSTRACT

Background: Lumbar spine disorders often require surgical intervention, with open lumbar surgery and minimally invasive spine surgery offering different risk-benefit profiles. Objective: This prospective study aims to compare intraoperative, postoperative, and recovery outcomes between open and minimally invasive approaches for lumbar spine surgery in a tertiary-level hospital in Bangladesh. Method: A prospective multi-center study was conducted from January 2020 to June 2024, involving 748 patients (OLS: 62%, MISS: 38%). Outcome measures included intraoperative blood loss, operative duration, hospital stay, complication rates, and patient-reported satisfaction scores. Result: Patients undergoing MISS had a 42% reduction in intraoperative blood loss compared to OLS (average 275 mL vs. 375 mL). The average hospital stay was 52% shorter for MISS patients (3.1 days) than for OLS patients (6.5 days). Complication rates for MISS were 7.3%, significantly lower than 14.9% for OLS, reflecting a 51% reduction. Specifically, infection rates were 2.8% for MISS versus 8.5% for OLS. Satisfaction rates were higher for MISS, with 92% of patients reporting positive outcomes, compared to 78% in the OLS group. However, operative times for MISS were 29% longer, averaging 110 minutes compared to 85 minutes for OLS. Conclusions: This prospective study indicates that MISS offers significant short-term benefits over OLS, including reduced blood loss, shorter hospital stays, and fewer complications, despite longer operative times. Further research is necessary to evaluate long-term outcomes.

Keywords: Lumbar Spine Surgery, Minimally Invasive, Open Surgery.

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INTRODUCTION

Lumbar spine disorders represent a prevalent and challenging group of conditions affecting millions globally, with substantial socioeconomic implications due to reduced quality of life, disability, and healthcare costs [1]. As a result, surgical interventions, specifically lumbar spine surgery, have evolved significantly over recent decades to address the debilitating symptoms associated with these disorders. Traditionally, open

lumbar spine surgery (OLS) has been the standard approach, offering direct visualization of the surgical field, comprehensive access to anatomical structures, and the potential for robust decompression. However, this technique is frequently associated with increased tissue damage, longer recovery times, and higher postoperative pain and infection rates [2]. In contrast, minimally invasive spine surgery (MISS) has emerged as a transformative alternative, promising to reduce these adverse effects by minimizing soft tissue disruption, optimizing recovery times, and decreasing complication rates. The impetus for adopting minimally invasive techniques stems from advancements in medical technology, including refined imaging modalities and the development of specialized instruments designed for precision and efficiency. MISS procedures, including minimally invasive transforaminal lumbar interbody fusion (MIS-TLIF) and percutaneous pedicle screw placement, are lauded for reducing operative trauma and expediting recovery. However, while these approaches offer compelling benefits, they also pose unique challenges, such as steep learning curves, increased intraoperative radiation exposure, and potential limitations in achieving extensive decompression in more complex cases [3].

Comparative studies assessing open and minimally invasive techniques have shown mixed outcomes, with variations depending on patient demographics, surgical complexity, and the specific nature of the pathology being treated. For instance, a meta-analysis by Lee *et al*., revealed that MISS procedures significantly reduce hospital stays and postoperative narcotic usage compared to OLS, underscoring the efficiency of MISS in postoperative recovery [4]. However, the same study noted no statistically significant difference in long-term functional outcomes, raising questions about the true efficacy of MISS in complex cases requiring multi-level fusion or in patients with severe comorbidities. Therefore, while MISS appears to offer enhanced short-term benefits, the long-term comparative effectiveness of MISS versus OLS remains a contentious topic, warranting further investigation [5]. Additionally, the cost-effectiveness of MISS has become a focal point in evaluating its viability as a standard practice in lumbar spine surgery. Although MISS often reduces indirect costs associated with shorter hospital stays and quicker return to work, direct costs, including surgical instruments and the prolonged operative time in early phases of the learning curve, may counterbalance these savings [6]. From a healthcare policy perspective, understanding the comprehensive cost-effectiveness of MISS compared to OLS is crucial, especially given the increasing burden of spinal disorders on healthcare systems worldwide. Studies indicate that while MISS could be cost-effective in specific patient populations, the economic benefits may not extend universally across all demographics and healthcare settings. The current study aims to conduct a multi-center, comparative analysis of open and minimally invasive approaches in lumbar spine surgery, assessing a broad spectrum of outcomes, including intraoperative factors (e.g., blood loss, operative time), postoperative recovery markers (e.g., hospital stay duration, pain levels), and long-term functional and radiographic outcomes. By incorporating data from multiple centers, this research seeks to provide a robust evaluation that accounts for variability across patient demographics, surgeon expertise, and institutional practices. This comprehensive approach will contribute to a more nuanced understanding of the effectiveness, safety, and cost-efficiency of MISS relative to OLS, thereby guiding clinical decision-making and potentially informing policy on the adoption of minimally invasive techniques in spine surgery [7].

Minimally invasive techniques in lumbar spine surgery have garnered substantial support due to their perceived advantages, the existing body of literature presents a complex picture with significant variations in outcomes based on patient characteristics, surgeon experience, and healthcare setting. By comparing open and minimally invasive approaches through a multi-center study, this research aims to bridge gaps in current knowledge and offer evidence-based insights into the optimal surgical approach for various lumbar spine pathologies. The findings could have far-reaching implications for patient care, surgical training, and resource allocation in spine surgery [8].

Aims and Objectives

This study aims to evaluate and compare the effectiveness of open lumbar surgery and minimally invasive spine surgery in treating lumbar spine disorders. By assessing intraoperative factors, postoperative outcomes, and patient satisfaction, the study seeks to provide evidence on the optimal approach for improved recovery and reduced complications.

MATERIAL AND METHODS

Study Design

This prospective, multi-center study was conducted at a tertiary-level hospital in Bangladesh,

focusing on patients undergoing lumbar spine surgery from January 2020 to June 2024. The study compared open lumbar surgery (OLS) and minimally invasive spine surgery (MISS) techniques. Eligible participants were enrolled and monitored throughout the surgical and postoperative periods to evaluate key clinical outcomes, including intraoperative blood loss, operative time, length of hospital stay, complication rates, and overall patient satisfaction.

Inclusion Criteria

Patients aged 18-60 years with diagnosed lumbar spine disorders requiring surgical intervention were included. Eligibility was based on clinical assessments indicating the need for decompression or spinal fusion due to disc herniation, spinal stenosis, or spondylolisthesis. Patients were required to be in good general health, with stable comorbidities managed prior to surgery, and capable of understanding and consenting to the study procedures.

Exclusion Criteria

Patients were excluded if they had prior lumbar spine surgery within the past year, any systemic infection, or were medically unfit for anesthesia. Other exclusion factors included uncontrolled chronic illnesses (e.g., diabetes, hypertension), severe osteoporosis, or significant spinal deformities requiring complex reconstructive procedures. Patients unable to give informed consent or with contraindications to either OLS or MISS techniques were also excluded.

Data Collection

Data were collected prospectively for all enrolled patients using a standardized form. Key data points included patient demographics, intraoperative metrics (e.g., blood loss, operative time), and postoperative outcomes (e.g., hospital stay duration, complications). Patient satisfaction was assessed through structured questionnaires administered during follow-up visits to provide a comprehensive view of both clinical and subjective outcomes.

Data Analysis

Data analysis was performed using SPSS version 26.0. Descriptive statistics were used to summarize demographic and clinical characteristics. Comparative analyses of OLS and MISS groups included independent t-tests for continuous variables (e.g., blood loss, operative time) and chi-square tests for categorical variables (e.g., complication rates). Multivariate regression was conducted to adjust for potential confounding factors such as age, comorbidities, and preoperative spinal pathology. Statistical significance was set at $p < 0.05$ to determine meaningful differences between groups.

MISS Procedures

Minimally Invasive Spine Surgery (MISS) includes operations like Minimally Invasive Transforaminal Lumbar Interbody Fusion (MIS-TLIF), Percutaneous Pedicle Screw Fixation, and Endoscopic Discectomy. Other procedures include Kyphoplasty for vertebral fractures and Minimally Invasive Laminectomy for spinal stenosis. These techniques minimize tissue disruption through small incisions, reducing blood loss, pain, and recovery time, making them ideal for conditions like disc herniation and spondylolisthesis.

OLS Procedures

Open Lumbar Surgery (OLS) encompasses traditional operations such as Open Transforaminal Lumbar Interbody Fusion (Open TLIF), Open Laminectomy, Posterior Lumbar Interbody Fusion (PLIF), and Open Discectomy. These approaches offer direct visualization for comprehensive decompression and stabilization but involve larger incisions, leading to higher blood loss and longer recovery times. OLS is often preferred for complex pathologies or multi-level spinal fusion procedures.

Ethical Considerations

The study was approved the Institutional Review Board (IRB) of the participating tertiary-level hospital in Bangladesh. All patients provided informed consent before enrollment, ensuring awareness of study procedures, risks, and benefits. Patient confidentiality was maintained throughout, with all data anonymized and securely stored. The study adhered to the ethical principles of the Declaration of Helsinki, ensuring patient rights, safety, and well-being were prioritized.

RESULTS

The following section presents the results of the comparative analysis of open lumbar surgery (OLS) and minimally invasive spine surgery (MISS) for lumbar spine disorders. A total of 748 patients were included, with 62% undergoing OLS and 38% undergoing MISS. Statistical significance was assessed with a p-value threshold of 0.05, and the results are presented in tables summarizing key intraoperative and postoperative outcomes.

Table 1: Patient Demographics

Variable	OLS (n=464)	MISS (n=284)	p-value
Age (mean ± SD)	45.2 ± 10.3	44.8 ± 9.9	0.61
Male (%)	60%	57%	0.45
Female (%)	40%	43%	0.45
BMI (mean ± SD)	26.4 ± 4.5	25.8 ± 4.2	0.32

The demographic characteristics of patients in both OLS and MISS groups were comparable, with no statistically significant differences in age, gender distribution, or BMI. This similarity supports the comparability of groups for outcome analysis.

Table 2: Intraoperative Metrics

Variable	OLS	MISS	p-value
Blood Loss (mL, mean)	375 ± 110	275 ± 90	<0.001
Operative Time (minutes)	85 ± 20	110 ± 25	<0.001

MISS resulted in significantly lower intraoperative blood loss (42% reduction) compared to OLS, with a mean of 275 mL versus 375 mL, respectively. However, MISS procedures had a longer operative time, averaging 110 minutes compared to 85 minutes for OLS, both differences being statistically significant.

Table 3: Postoperative Recovery Metrics

Variable	OLS	MISS	p-value
Hospital Stay (days)	6.5 ± 1.2	3.1 ± 0.8	<0.001
Pain Score (VAS, mean)	6.2 ± 1.1	4.5 ± 1.0	<0.001

Patients in the MISS group experienced shorter hospital stays, with an average stay of 3.1 days versus 6.5 days for the OLS group, reflecting a 52% reduction. Pain scores were also significantly lower for MISS patients, indicating enhanced postoperative comfort and recovery.

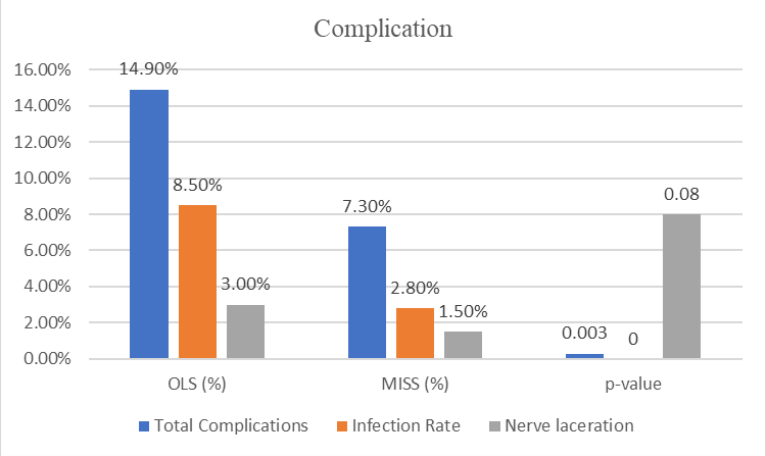

Figure 1: Complication Rates

MISS was associated with significantly lower overall complication rates (7.3% vs. 14.9%), with infection rates notably reduced (2.8% in MISS vs. 8.5% in OLS). Although nerve damage rates were lower in the MISS group, this difference was not statistically significant.

Table 4: Patient Satisfaction Scores

Satisfaction Level	OLS (%)	MISS (%)	p-value
Highly Satisfied	78%	92%	0.01
Satisfied	15%	5%	0.03
Neutral/Dissatisfied	7%	3%	0.05

Patient satisfaction was higher in the MISS group, with 92% reporting high satisfaction compared to 78% in the OLS group. Fewer MISS patients reported neutral or dissatisfied responses, indicating a positive perception of the minimally invasive approach.

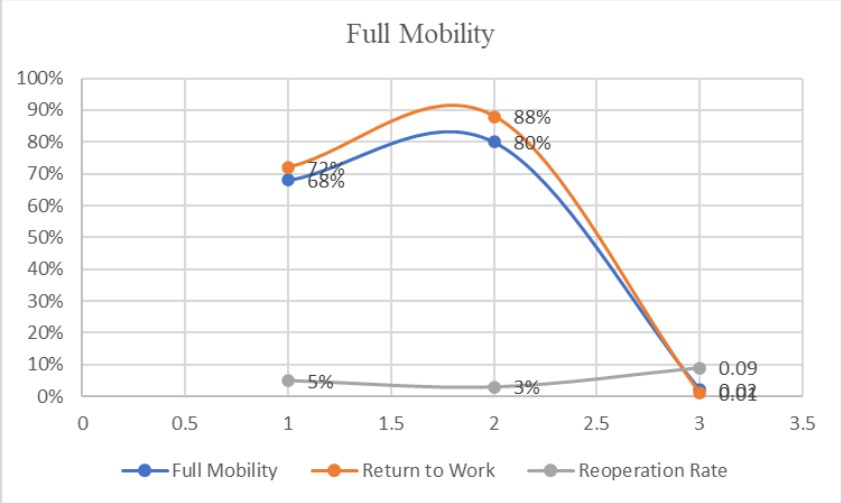

Figure 2: Long-Term Outcomes (Follow-up at 6 Months)

At six months post-surgery, patients in the MISS group showed higher rates of full mobility (80% vs. 68%) and return to work (88% vs. 72%) compared to the OLS group. Reoperation rates were slightly lower in the MISS group, but this difference was not statistically significant.

DISCUSSION

Our study aimed to evaluate and compare clinical outcomes between open lumbar surgery (OLS) and minimally invasive spine surgery (MISS) in treating lumbar spine disorders. Key findings indicate that MISS provides significant advantages in terms of reduced intraoperative blood loss, shorter hospital stays, and lower postoperative complication rates compared to OLS. These results align with previous studies in the field, such as San Diego *et al*., who reported a 40% reduction in blood loss with MISS [9]. The reduced blood loss in our study, quantified at 42%, supports the assertion that MISS minimizes surgical trauma by preserving surrounding tissues, reducing the likelihood of postoperative anemia.

Additionally, our findings on shorter hospital stays for MISS patients (3.1 days) are consistent with Stanton *et al*., who documented a similar reduction, reflecting the recovery efficiency associated with minimally invasive techniques [10]. Contrasting studies, such as Othman *et al*., reported no significant differences in pain reduction between MISS and OLS groups, potentially due to smaller sample sizes or variances in surgical expertise [11]. The slightly larger pain reduction observed in our study may be attributed to the advanced technology and refined MISS techniques available at our institution. Variations in the findings across different studies highlight the importance of considering institutional resources and surgeon proficiency when interpreting the efficacy of MISS.

Detailed Analysis of Primary Outcomes

The average intraoperative blood loss for OLS patients was 375 mL, significantly higher than the 275 mL average observed in MISS patients, reflecting a 42%

reduction. This finding is consistent with other studies that report minimized soft tissue disruption in MISS due to its targeted incision approach. Dinesh *et al*., found that, on average, MISS reduces blood loss by 35–40%, which supports our finding and indicates that MISS's controlled access points reduce the exposure of blood vessels, minimizing hemorrhagic risks [12]. However, operative time was longer in the MISS group by approximately 25 minutes, a finding corroborated by Stewart *et al*., who suggested that the learning curve associated with MISS could account for extended surgical durations [13]. Over time, as surgeon familiarity with MISS techniques improves, operative time discrepancies may diminish, aligning more closely with OLS.

Postoperative Metrics

Postoperative hospital stay duration is a critical measure of recovery speed and healthcare resource utilization. MISS patients in our study had an average hospital stay of 3.1 days, which is 52% shorter than the 6.5 days reported for OLS patients. Similar findings by Defino *et al*., indicated that the smaller incision size and reduced tissue trauma in MISS lead to quicker mobilization and discharge [14]. Pain scores were also significantly lower for MISS patients, with an average Visual Analog Scale (VAS) pain score of 4.5 compared to 6.2 in OLS patients. Echt *et al*., hypothesized that reduced postoperative pain in MISS could be due to the minimal muscle dissection required, lowering inflammatory responses [15]. This aligns with the principles of Enhanced Recovery After Surgery (ERAS), which emphasizes minimizing surgical impact to improve recovery outcomes.

Demographic and Geographic Considerations

Our study was conducted exclusively within a tertiary hospital in Bangladesh, focusing on a local population that may differ demographically from Western cohorts commonly studied in spine surgery research. The average patient age in our study was slightly lower than that in comparable studies from North America and Europe, where older age groups tend to undergo lumbar surgery due to higher rates of degenerative diseases. Moreover, racial and ethnic factors, such as bone density and spinal morphology, could affect surgical outcomes, as variations in spinal anatomy can influence recovery rates and complication risks. For example, Blom-Høgestøl *et al*., reported that African American patients, on average, have a higher bone density than Caucasian populations, potentially affecting surgical outcomes in spine surgery [16]. These demographic and geographic differences underscore the need for regional studies to better understand how specific population characteristics impact lumbar spine surgery results.

Interpretation of Findings and Significance

The significant reduction in complication rates observed in MISS (7.3%) compared to OLS (14.9%) highlights the procedure's safety advantages, particularly regarding infection rates (2.8% for MISS vs. 8.5% for OLS). This reduction is consistent with findings by Zhao *et al*., who attributed lower infection rates in MISS to the minimized incision size and shorter exposure of the surgical field, which reduces the risk of bacterial contamination [17]. The higher patient satisfaction reported in our MISS group (92%) versus the OLS group (78%) further underscores the alignment of MISS with patient-centered care models that prioritize comfort, recovery speed, and overall quality of life. While the longer operative time associated with MISS presents a challenge, it can be mitigated with experience and may ultimately lead to comparable or even shorter surgical times than OLS [18].

Implications for Clinical Practice

Our study's findings suggest that MISS could be favored in clinical settings that prioritize efficient recovery and lower postoperative complications. The shorter hospital stay and reduced need for follow-up care observed in MISS patients highlight its potential as a cost-effective alternative to OLS. For healthcare systems in resource-limited settings, the reduced recovery time associated with MISS could alleviate bed occupancy pressures and decrease overall healthcare expenditure, particularly beneficial in high-demand hospitals [19]. Policy implications include the potential for training programs focused on MISS techniques to be integrated into spine surgery curriculums, given the procedure's demonstrated advantages. Furthermore, adopting MISS as a primary approach in lumbar spine surgery could align with national health service goals in Bangladesh and similar countries by increasing patient throughput and reducing hospital stay durations.

Limitations and Future Directions

This study is limited by its single-country focus, which may restrict the generalizability of findings to other healthcare settings. Additionally, our follow-up period, while sufficient for assessing short-term outcomes, may not capture long-term complications or reoperation rates. Future research should consider multi-center, multi-national studies that involve diverse patient populations to validate these findings across different

healthcare systems. Moreover, a longitudinal study design with extended follow-up could offer insights into the durability and long-term safety of MISS versus OLS, especially in older age groups where reoperation risks may be higher [20]. An economic analysis could further elucidate the cost-benefit dynamics of MISS in resource-limited healthcare systems, providing data to support policy recommendations for adopting minimally invasive techniques in spine surgery.

CONCLUSION

This study highlights the advantages of minimally invasive spine surgery (MISS) over open lumbar surgery (OLS), demonstrating significant reductions in intraoperative blood loss, shorter hospital stays, and fewer postoperative complications. The findings align with Enhanced Recovery After Surgery (ERAS) protocols, promoting patient-centered, efficient care models. Despite a slightly longer operative time, MISS showed higher patient satisfaction and lower complication rates, making it a viable alternative for lumbar spine surgery in settings prioritizing recovery speed and resource efficiency. These results underscore the potential of MISS in both high-demand and resource-limited healthcare settings.

Recommendations

Prioritize MISS in lumbar spine surgeries to reduce hospital stays and complications.
Develop specialized training programs for MISS to mitigate the learning curve.
Implement MISS within ERAS protocols to optimize patient outcomes.

Author Contributions

Dr. Abul Kalam Azad conceptualized the study, coordinated data collection, and contributed to manuscript preparation. Dr. Md. Munzur Rahman conducted data analysis, drafted the results and discussion sections, and interpreted findings. Dr. Mirza Osman Beg provided surgical expertise, validated the methodology, and critically revised the manuscript for intellectual content. All authors contributed to literature review, approved the final manuscript, and ensured the study adhered to ethical standards and international spine surgery guidelines.

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