Prospective Randomized Study Comparing ELIFT Through Kambin's Triangle With Cortical Bone Trajectory–Based Interbody Arthrodesis for Degenerative Disc Disease

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Structured Abstract

Background: Degenerative disc disease (DDD) is a leading cause of chronic back pain and functional impairment. Traditional midline surgical techniques, although effective, require extensive muscle dissection and nerve root retraction, increasing postoperative pain and delaying recovery. The endoscopic lumbar interbody fusion technique (ELIFT) employs a percutaneous oblique extraforaminal approach through Kambin's triangle minimizing tissue trauma, avoiding nerve manipulation, and provide direct access to the disc space access for decompression and arthrodesis. This prospective, randomized, single-surgeon study compares clinical, functional, and radiologic outcomes of this extraforaminal approach with midline cortical bone trajectory (CBT) fixation in patients with single-level lumbar degenerative pathology.

Methods: Forty patients were prospectively enrolled. The most frequently treated level was L5–S1 (65% of cases). Group 1 (n = 30) underwent midline CBT pedicle screw fixation with decompressive hemilaminectomy and posterior arthrodesis using bilateral PEEK cages in an outpatient surgery center (OSC). Group 2 (n = 10) underwent the procedure via a unilateral extraforaminal approach through Kambin's triangle, with PEEK cage placement and percutaneous bilateral transfacet pedicle screws; treated levels included L3–L4, L4–L5, and L5–S1. Clinical outcomes were assessed using the Visual Analogue Scale (VAS) for back and leg pain and the Oswestry Disability Index (ODI). Radiologic fusion was evaluated on dynamic flexion–extension radiographs at ≥24 months. Complications were recorded.

Results: The cohort comprised 33 males and 7 females, aged 28–75 years (mean 58 ± 3 years), with a mean body mass index of 29 ± 1.15 kg/m². In the CBT group, VAS back pain improved from 7.8 ± 0.5 to 2.5 ± 0.7 ($p = 0.001$) and ODI improved significantly ($p = 0.027$). Radiographic fusion at two years was high and comparable to the Kambin group ($p = 0.855$). One patient developed transient L5 radiculitis during physical activity, requiring revision six years later; no additional complications were observed. In the Kambin group (mean age 47.5 years; mean BMI 29.8 kg/m²; 10% male), VAS improved from 7.8 to 4.0 ($p = 0.001$) and ODI from 53% to 24.4% ($p = 0.02$) at final follow-up (>24 months). Five patients (50%) experienced complications, including three transient nerve-related symptoms, one cage prominence secondary to overpacking, and one nonunion requiring revision. Most events were transient and occurred during the procedural learning phase.

Conclusion: This prospective randomized single-surgeon study demonstrates that this approach provides pain relief, functional improvement, and radiographic outcomes comparable to midline cortical bone trajectory-based interbody arthrodesis while preserving facet integrity and minimizing neural disruption. Although early complication rates were higher, most events were transient and associated with the procedural learning phase. With refinement and experience, this tissue-preserving method may serve as a reproducible alternative for lumbar interbody arthrodesis in outpatient degenerative disc disease cases. Larger multicenter studies are warranted to validate long-term safety, reproducibility, and efficacy.

Level of Evidence: II

Keywords: Endoscopic lumbar interbody fusion, ELIFT, Kambin's triangle, cortical bone trajectory, degenerative disc disease, lumbar fusion, tissue preservation, less exposure spine surgery, LESS

Introduction

Low back pain remains one of the leading causes of disability worldwide, affecting nearly 80% of adults at some point in their lives (Kelsey JL –1980). Among its etiologies, degenerative disc disease (DDD) is a predominant source of chronic pain and functional impairment. This condition encompasses lumbar disc degeneration, facet hypertrophy, osteophyte formation, spinal and foraminal stenosis, and segmental deformity (de Schepper EI-2010). These structural changes lead to progressive disc height loss, annular fissuring, and secondary segmental instability. When conservative measures fail, surgical arthrodesis becomes and established strategy to restore segmental stability, alleviate pain, and improve function (Yoshihara H –2015) (Eliyas JK-2011) (Nasca RJ-2013). Operative strategies include anterior, posterior, transforaminal, and lateral or oblique approaches (ALIF, PLIF, TLIF, LLIF/OLF), which aim to restore disc height, achieve foraminal decompression, and provide segmental stabilization through interbody support (Pradhan BB-2002) (Mobbs RJ –2015). Despite their effectiveness, conventional approaches often require extensive paraspinal muscle dissection, dural exposure, and partial facet removal, contributing to higher intraoperative blood loss, postoperative pain, and prolonged recovery (Kim Y-H –2020).

Minimally invasive spine (MIS) techniques were developed to address these limitations by reducing tissue trauma while maintaining reliable arthrodesis outcomes (Oppenheimer JH –2009). Posterior MIS approaches, such as PLIF and TLIF performed through smaller incisions, allow access to the disc space with less muscle disruption than traditional open surgery. In parallel, posterior fixation strategies have evolved with the cortical bone trajectory (CBT) screw technique, which follows a mediolateral, caudocephalad path to maximize cortical purchase near the pedicle isthmus (Santoni BG –2009) (Mullin JP -2016) (Delgado-Fernandez J-2017) (Cofano F-2020). Biomechanical and clinical evidence indicates that this fixation achieves outcomes comparable to traditional pedicle screws while reducing soft-tissue dissection, facilitating outpatient workflows, and aligning with MIS principles (Li H-M –2018). Nevertheless, the technique still requires a midline posterior approach with subperiosteal muscle stripping and partial facet exposure, which may lead to postoperative discomfort and muscle atrophy (Matsukawa K-2017). Facet-based stabilization, including transfacet screws and instrumented facet arthrodesis, provides an alternative or complementary strategy for posterior column control, offering durable stability with less disruption of midline soft tissues (Ham CH –2025) (Miyashita T-2024) (Lang Z-2022) (Chin KR –2024).

Over the last decade, lumbar interbody procedures performed under endoscopic visualization have emerged as a further refinement of the MIS philosophy, aiming to minimize iatrogenic soft-tissue injury, blood loss, and postoperative pain while allowing direct decompression and interbody reconstruction (Kolcun JPG-2019) (20). These approaches utilize Kambin's triangle a posterolateral working corridor bounded by the exiting nerve root anteriorly, the superior endplate of the caudal vertebra inferiorly, and the traversing nerve root medially to access the disc space under continuous endoscopic visualization(Fanous AA,- 2020) (Tumialán LM-2019) (Humphreys SC- 2024) (Wang TY-2021). Initially developed for discectomy, this technique has since been adapted for interbody arthrodesis with facet preservation, allowing percutaneous cage placement and posterior stabilization via transfacet pedicle screws (Lee S – 2007).

The ELIFT technique represents the next step in this evolution (Bruce C –2013) . By combining a percutaneous extraforaminal approach through Kambin's triangle with discectomy, endplate preparation, and interbody cage placement, this method minimizes muscle and bone disruption while preserving the posterior tension band. Compared with midline CBT fusion, it avoids routine nerve root retraction and reduces soft-tissue trauma, making it feasible in outpatient settings under short-duration anesthesia.

Despite increasing clinical interest, high- quality prospective data comparing this approach with established minimally invasive interbody procedures remain limited. Most published reports consists of single-arm feasibility studies or technical descriptions, leaving a critical knowledge gap regarding pain relief, arthrodesis rates, complication profiles, and functional recovery. To address this gap, the present prospective, randomized, single-surgeon study evaluates this method against midline CBT-based stabilization in patients with single-level degenerative pathology. We hypothesize that this facet-preserving, percutaneous method achieves comparable or superior outcomes while further minimizing tissue disruption. These findings may inform future multicenter investigations and support further evaluation of this approach in outpatient spinal surgery.

Methods

Study Design and Patient Selection

This prospective, randomized, single-surgeon, single-center comparative study evaluated the clinical and radiologic outcomes of percutaneous extraforaminal technique through Kambin's triangle versus midline CBT-based arthrodesis for the treatment of lumbar DDD. Institutional Review Board (IRB) approval was obtained, and written informed consent was secured from all participants. Data were collected from medical records and operative notes between 2010 and 2013.

Patients presenting with chronic low back pain with or without radiculopathy secondary to single-level or two-level degenerative disc and facet disease, low-grade spondylolisthesis, or central/foraminal stenosis were considered eligible. Diagnoses were confirmed through clinical evaluation, provocative injections, and radiographic imaging, including magnetic resonance imaging (MRI) and dynamic flexion–extension radiographs.

Inclusion criteria consisted of symptomatic degenerative pathology refractory to at least six months of nonoperative therapy, including physical therapy, anti-inflammatory medications, epidural or facet injections, and, where indicated, radiofrequency rhizotomy for facet-mediated axial pain. Additional criteria included segmental instability or foraminal stenosis correlating with clinical findings and preserved facet integrity on preoperative imaging. Exclusion criteria included severe spinal deformity or spondylolisthesis greater than Grade II, active infection, tumor, or prior fusion at the index level, as well as morbid obesity (BMI > 40 kg/m^2) or systemic conditions precluding operative intervention.

The decision to proceed with surgical intervention and the choice of approach were determined by the operating spine surgeon based on clinical judgment and patient preference after detailed counseling on the available fusion options. Eligible patients were randomized using a computer-generated sequence to undergo either an extraforaminal interbody approach or midline cortical bone trajectory based interbody arthrodesis at the L4–L5 or L5–S1 levels, with all procedures performed by the same surgeon at a single institution under standardized operative protocols.

Surgical Technique: Endoscopic Lumbar Interbody Fusion via Kambin's Triangle

All procedures were performed by a single surgeon using a standardized technique. Patients were placed prone on a Wilson frame under general anesthesia, and the lumbar spine was prepped and draped in the standard sterile fashion. The operative level was localized in both anteroposterior and lateral fluoroscopic planes. Using an oblique Ferguson view, a percutaneous extraforaminal trajectory was planned to access Kambin's triangle, bordered superiorly by the exiting nerve root, medially by the traversing nerve root, and inferiorly by the superior endplate of the caudal vertebra (Figure 1).

A spinal needle was advanced under fluoroscopic control to the disc space via a retroperitoneal approach approximately 4 cm lateral to the midline. A blunt guidewire was inserted after confirming disc entry, with continuous neuromonitoring to ensure neural safety (Figure 2). Sequential dilation was then performed over the guidewire to establish a safe working corridor (Figure 3), and the working cannula for endoscopic visualization was introduced.

Under direct visualization, an annulotomy was performed, followed by thorough discectomy and endplate preparation using pituitary rongeurs, curettes, and shavers. A polyetheretherketone (PEEK) cage, prefilled with a composite graft of autologous bone, demineralized bone matrix (DBM), and allograft cancellous bone, was inserted obliquely into the prepared disc space under

fluoroscopic guidance (Figure 4). The cage was positioned to restore disc height and achieve indirect foraminal decompression while avoiding endplate violation.

Following interbody placement, the Wilson frame was readjusted from kyphosis to a neutral position to restore physiological lordosis. Through a mini-open midline incision, bilateral transfacet pedicle screws were placed percutaneously at the operative level for supplemental fixation. Each screw was directed from the inferior articular process toward the superior articular process and pedicle base, providing rigid stabilization while preserving facet capsule integrity. The facet joints were decorticated, and DBM with allograft chips was packed into the posterior elements before layered closure (Figure 5).

Surgical Technique: Cortical Bone Trajectory- Based Arthrodesis

In the CBT group, patients were positioned prone on a radiolucent table. A midline incision was made to expose the posterior elements. Screws were inserted bilaterally under fluoroscopic guidance, following a medial-to-lateral and caudal-to-cephalad trajectory to maximize cortical bone engagement. After a unilateral facetectomy, standard discectomy and endplate preparation were performed. A PEEK cage packed with DBM and cancellous allograft was inserted into the interbody space, and compression across the screws was applied to facilitate arthrodesis. The wound was irrigated and closed in layers. All cases were performed in an outpatient surgical center.

Radiologic and Clinical Evaluation

Clinical outcomes were assessed using the VAS for back and leg pain and the ODI at baseline and at 6, 12, and 24 months postoperatively. All assessments were performed by independent evaluators blinded to surgical techniques. Radiologic evaluation included dynamic flexion–extension radiographs at each follow-up and computed tomography (CT) scans (slice thickness ≤1 mm) when indicated. Fusion was defined by the presence of bridging trabecular bone across the disc and facet joints, absence of radiolucent lines or screw loosening, and less than 1 mm translation or 3° angular motion between endplates on dynamic imaging.

Complications and Follow-Up

All intraoperative and postoperative complications were prospectively recorded and categorized as intraoperative (e.g., nerve irritation, dural tear, cage malposition) or postoperative (e.g., infection, pseudarthrosis, hardware loosening, or reoperation). Complications were adjudicated by independent reviewers using standardized definitions. Patients were followed at 2 weeks, 3 months, 6 months, 12 months, and 24 months, with additional visits as clinically required. Time to symptom resolution, return to activity, and reoperation rates were documented.

Statistical Analysis

Statistical analyses were conducted using standard descriptive and inferential methods. Continuous variables, including VAS, ODI, and fusion rates, were analyzed using the Student's t-test or Mann–Whitney U test as appropriate. Categorical variables, including complication and reoperation rates, were compared using the chi-square or Fisher's exact test. A p-value < 0.05 was considered statistically significant. Missing data were managed using the last observation carried forward method.

Results

Patient Demographics

Forty patients were included in the study: ten patients underwent an percutaneous extraformainal interbody approach, and thirty underwent midline cortical bone trajectory-based arthrodesis. The overall mean age at surgery was 58 ± 3 years, and the mean body mass index (BMI) was 29 ± 1.15 kg/m². The cohort comprised 33 males (82.5%) and seven females (17.5%). In the Kambin group, the mean age was 47.5 years, with females representing 90% of the patients. The mean BMI in this group was 29.8 kg/m². Three patients reported a prior history of smoking, with one patient continuing to smoke at final follow-up.

Operative and Functional Outcomes

Three spinal levels were addressed in the ELIFT group: L3–L4 (n=1), L4–L5 (n=9), and L5–S1 (n=1). One patient underwent a two-level procedure (L4–L5 and L5–S1). The mean operative time for ELIFT was 1.8 hours (range, 0.9–2.4 hours), and mean blood loss was 64.6 mL (range, 25–115 mL). The mean follow-up duration was 18 months. In the CBT group, operative data and perioperative parameters were comparable, with no significant intraoperative complications reported.

Clinical Outcomes

In the ELIFT group, all patients presented with both lower back and leg pain preoperatively. The mean VAS score for lower back pain improved from 7.8 preoperatively to 4.8 at 18 months ($p = 0.001$). The mean ODI score improved from 53% preoperatively to 24.4% postoperatively ($p = 0.02$). In the CBT group, there was significant improvement in VAS and ODI scores at final follow-up compared with preoperative values, though differences between CBT and ELIFT groups were not statistically significant.

Radiographic Evaluation

Sagittal and axial CT images were reviewed to assess implant position, graft subsidence, and osseous consolidation. Successful segmental unions were defined by the presence of continuous trabecular bone across the operative segment and the absence of radiolucency surrounding the implant. Solid union was achieved in 60% of patients in the extraforaminal cohort. No cases of implant failure or pseudarthrosis were observed. In the CBT group, rates of solid union were comparable, with stable instrumentation and no evidence of hardware failure.

Complications

Five patients (50%) in the Kambin group experienced complications directly related to surgery. Three developed postoperative nerve-related symptoms. One patient experienced pain and dysesthesia from impaction at the L5 nerve root, which was managed nonoperatively. Another required removal of a prominent cage with decompression of the affected nerve, after which solid osseous union was observed. A third patient underwent additional decompression of the L4 nerve root for persistent postoperative symptoms, though fusion was confirmed intraoperatively and symptoms were later attributed to possible intraneural fibrosis. The CBT group reported fewer postoperative complications, with no intraoperative dural tears or neural injuries observed.

Discussion

Overview

The present prospective randomized single-surgeon study compared outcomes of a novel endoscopic extraforaminal interbody approach performed through Kambin's triangle with the established CBT fusion technique. Both approaches achieved significant postoperative improvement in pain and disability scores with comparable radiographic evidence of solid union at two years. This extraforaminal method was associated with shorter operative time, reduced intraoperative blood loss, and earlier discharge, although it showed a higher incidence of transient nerve-related complications attributable to the initial learning phase.

Evolution of Lumbar Interbody Techniques and Rationale for the Extraforaminal Approach

Spinal stabilization procedures have progressed from open operations to minimally invasive and, more recently, visualization-assisted methods, reflecting ongoing efforts to reduce tissue disruption while maintaining biomechanical stability and reliable osseous consolidation. Early transforaminal endoscopic lumbar interbody fusion (Endo-TLIF) and percutaneous endoscopic lumbar interbody fusion (PELIF) have shown outcomes comparable to MIS-TLIF, with added benefits of less blood loss, shorter hospitalization, and faster recovery (Wu J –2018) (Haibier A-2024).

The extraforaminal method evaluated in this study advances these principles through a percutaneous, oblique extraforaminal approach via Kambin's triangle (Fanous AA,- 2020) (Tumialán LM-2019) (Humphreys SC- 2024) (Wang TY-2021). This trajectory provides access to the disc space without traversing the spinal canal, retracting the nerve root, or disrupting the facet joint. By restoring foraminal height and achieving indirect decompression through cage placement, this method parallels the goals of LLIF or OLIF while retaining a posterior, outpatient-friendly orientation.

The present findings mirror prior studies showing substantial VAS and ODI improvement following visualization-guided interbody procedures. The degree of symptomatic relief in the extraforaminal cohort aligns with reported average reductions of 3–4 points in VAS and 25–30% in ODI seen in contemporary series (Lewandrowski K-U –2022).

Comparison With Cortical Bone Trajectory Fixation

The CBT technique, first introduced by Santoni et al. (2009), achieves stable fixation by engaging the dense cortical bone of the pedicle isthmus while reducing muscle dissection (Santoni BG –2009) (Mullin JP -2016) (Delgado-Fernandez J-2017) (Cofano F-2020) . Multiple studies have demonstrated outcomes comparable to traditional pedicle screw constructs with respect to arthrodesis rates and functional recovery (Wu C –2024). In this study, midline cortical trajectory-based interbody arthrodesis produced favorable clinical and radiographic outcomes with a low complication profile, consistent with the established literature. When compared directly, the extraforaminal approach and CBT-based construct produced equivalent long-term pain relief and functional improvement. However, the percutaneous technique offered advantages in terms of reduced blood loss, shorter operative time, and faster mobilization demonstrating that a percutaneous, endoscopic corridor can achieve outcomes comparable to an established MIS fixation method while further limiting tissue disruption.

Facet Preservation and Biomechanical Considerations

A defining characteristic of this strategy is facet preservation combined with percutaneous bilateral transfacet screw fixation. Biomechanical studies have demonstrated that transfacet constructs provide posterior column stiffness comparable to traditional pedicle screw systems in single- level stabilization (Lang Z-2022) (Boucher HH –1959) (Magerl FP-1984) (Rajasekaran S-2005). Preservation of the facet capsule may promote secondary osseous bridging and contribute to maintenance of posterior column integrity.

By integrating facet preservation with intervertebral support, this construct balances the biomechanical strength of conventional instrumentation with the soft-tissue–sparing advantages of minimally invasive access. The resulting stabilization strategy appears well suited for outpatient spinal surgery and aligns with the broader shift toward less invasive, resource-efficient operative care (Chin KR –2024).

Complications and Learning Curve

Nerve-related complications were observed only in the extraforaminal group, presenting transient dysesthesia or irritation of the exiting nerve root (Ju CI –2023). Such events are recognized risks when accessing the intervertebral disc space through Kambin's triangle, given the close anatomical relationship to neural structures and the technical demands of visualization-assisted instrumentation. Importantly, no reoperations for hardware failure or persistent nonunion were required, highlighting the overall safety of both treatment strategies. As surgical experience with this technique advances, improvements in visualization and instrument control may further reduce the incidence of these complications.

Study Limitations

This study is limited by its modest sample size, single-center design, and single-surgeon experience, which may restrict generalizability. Although prospective and randomized, the extraforaminal group sample reflects the initial adoption phase of this technique. Radiographic assessment relied on qualitative CT evaluation without volumetric quantification. Longer-term follow-up is warranted to evaluate construct durability, adjacent segment degeneration, and cost –effectiveness across broader clinical settings. Future multicenter, randomized studies with larger cohorts and longer follow-up durations are necessary to validate these early outcomes. Quantitative imaging, patient-reported outcomes beyond two years, and biomechanical comparisons incorporating finite-element modeling could further define the relative advantages of ELIFT versus CBT. Integration of navigation, robotics, and advanced visualization technologies may represent the next step in improving procedural accuracy and safety in minimally invasive lumbar interbody surgery.

Clinical Takeaway

Both techniques provide effective, minimally invasive solutions for lumbar DDD. The endoscopic group expands the spectrum of outpatient-interbody arthrodesis by combining neural element preservation with transfacet stabilization, achieving a balance between decompression and soft-tissue preservation. CBT remains a dependable MIS option with predictable outcomes and robust fixation. Technique selection should ultimately be guided by patient anatomy, bone quality, and surgeon experience.

Conclusion

This visualization-assisted extraforaminal interbody technique represents an evolution in tissue-preserving spinal surgery by integrating direct disc access through Kambin's triangle with facet-sparing exposure and percutaneous transfacet fixation to achieve stable segmental arthrodesis while minimizing soft-tissue disruption. In this single-surgeon prospective series, the technique

demonstrated comparable improvements in pain, function, and fusion rates to the established cortical bone trajectory (CBT) technique, while offering significant advantages in operative time, blood loss, and hospitalization duration. The transient complications observed were primarily related to the learning curve rather than inherent limitations of the technique. These findings suggest that this method may serve as a safe, effective, and minimally invasive option for treating degenerative disc disease, particularly suited for outpatient and ambulatory spine surgery settings. Further multicenter studies with larger cohorts and longer follow-up are warranted to confirm its long-term biomechanical and clinical durability.

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Appendix

Figure Legend

Figure 1A/B: Sagittal & Axial MRI demonstrating herniated disc at L4-L5

Figure 2: Lateral fluoroscopy of guidewire in L4-L5 disc space

Figure 3A: Lateral fluoroscopy of guidewire and dilator at L4-L5

Figure 3B: Lateral fluoroscopy of final docking position of endoscope

Figure 4A: Anteroposterior fluoroscopy of PEEK cage placement

Figure 4B: Lateral fluoroscopy of PEEK cage placement

Figure 5: Lateral fluoroscopy of transfacet pedicle screw

Figure 6A: Sagittal CT demonstrating fusion at L4-L5

Figure 6B: Axial CT demonstrating fusion within PEEK cage.

Figure 1AB

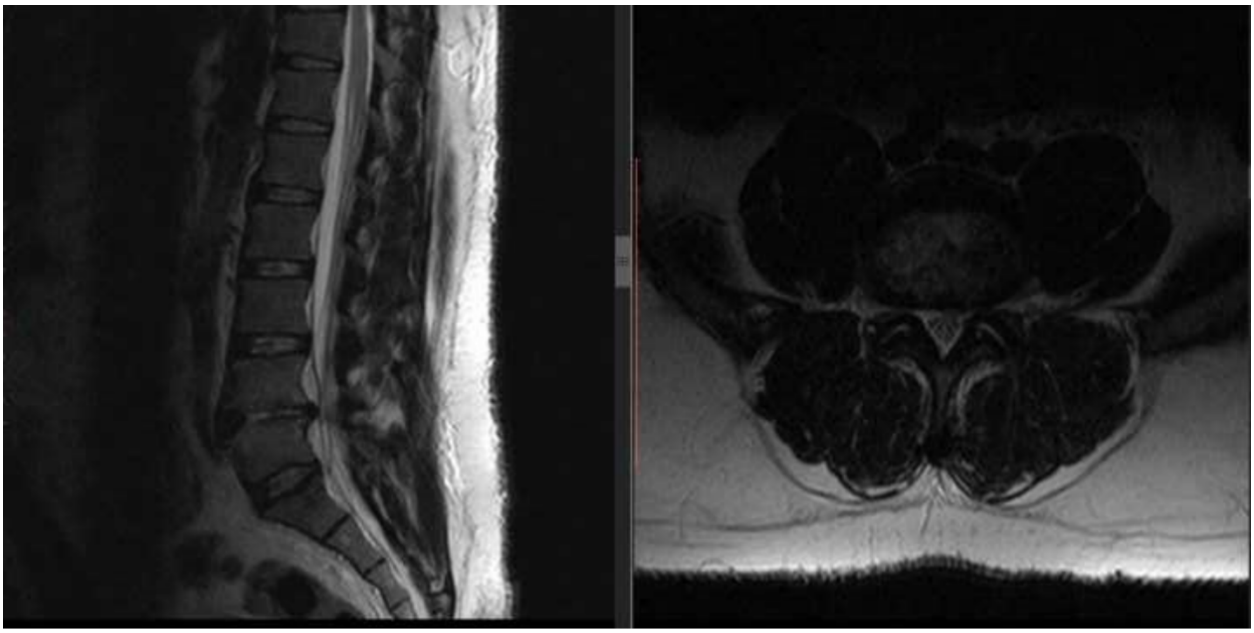

Figure 2

Figure 3A

Figure 3B

Figure 4A

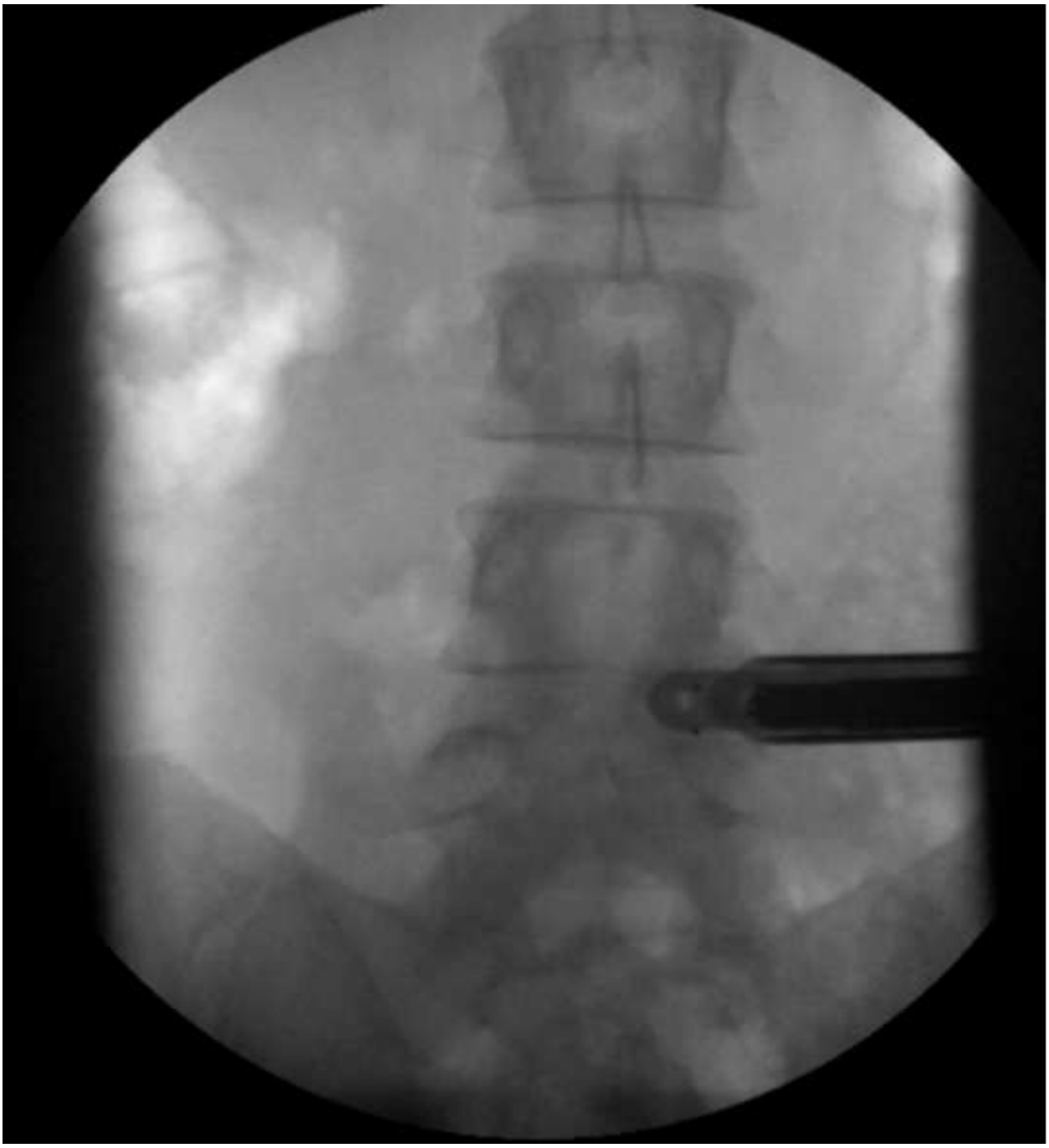

Figure 4B

Figure 5

Figure 6A

Figure 6B

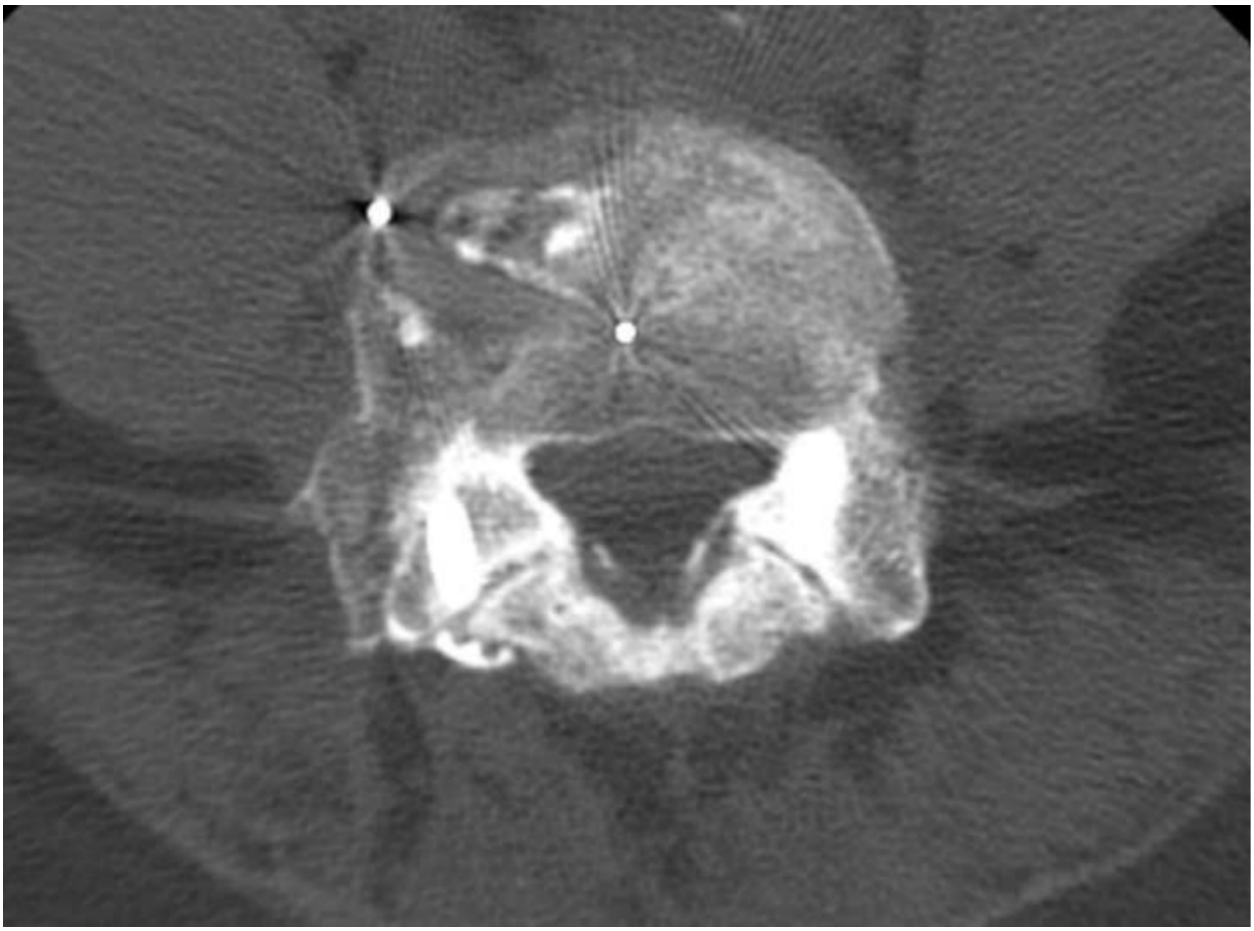

Table Legend

Table 1: Comparison of clinical outcomes between CBT and ELIFT groups

Parameter	CBT Fusion (n = 30)	ELIFT (n = 10)	p-value
Mean age (years)	58 ± 3	47.5 ± 4	0.04
BMI (kg/m²)	29 ± 1.15	29.8 ± 1.2	0.62
Operative time (minutes)	136 ± 22	102 ± 18	< 0.05
Estimated blood loss (mL)	168 ± 46	78 ± 24	< 0.01
Hospital stay (days)	2.1 ± 0.6	0.9 ± 0.3	< 0.05
VAS (pre → post)	7.8 → 2.5	7.8 → 4.0	0.13
ODI (pre → post)	54% → 23%	53% → 24.4%	0.18
Fusion rate (%)	90	90	0.855
Complication rate (%)	3.3	50	0.02

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