Full Endoscopic Approach with Foraminoplasty

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Introduction

Transforaminal endoscopic lumbar discectomy (TELD) gives results comparable to those of conventional open surgery for treatment of herniated discs (HDs). Since the introduction of contemporary endoscopic discectomy by Kambin and Sampson [1], remarkable advances in techniques and instruments have expanded its surgical application for various types of HDs. [2, 3] Nevertheless, the inability to place a working cannula near the disc fragment because of an anatomical barrier can lead to surgical failure and to the need for revision open surgery. The superior articular process (SAP) should be the chief obstacle to transforaminal endoscopic access to the dural sac and nerve root in the spinal canal. To overcome this hurdle, foraminoplasty can be considered, as it allows the working cannula to access the herniated disc. In this chapter, we describe our experience using foraminoplasty for HDs and propose indications for its use. [4]

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Indications

- Decreased disc height.
- High-grade up/down migration.
- Sequestration.
- Recurrent disc herniation.
- Central disc herniation with wide lamina angle.
- Huge (large) disc herniation.
- L5-S1 disc herniation with high iliac crest.
- Disc herniation with foraminal stenosis & lateral recess stenosis.

Anesthesia and Position

- **Local**/regional/general anesthesia.
- **Prone position**/lateral decubitus.

Special Surgical Instruments (Fig. 1)

- Manual bone drills.
- Endoscopic drill.
- Endoscopic Kerrison punch.
- Curved semi-flexible forceps/probe.

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Fig. 1 Endoscopic instruments for foraminoplasty. Manual bone drills, endoscopic diamond drill, endoscopic Kerrison punch, semi-flexible forceps and probe

Surgical Steps

Initial Targeting

TELD was performed under local anesthesia with patients in the prone position. The entry point on the skin was generally 8–14 cm from the midline, with consideration of both body size and disc location (Fig. 2a). After infiltration of the entry point with local anesthetics, an 18-gauge spinal needle was introduced under the guidance of fluoroscopic imaging. Subsequently, an epidurography was performed using contrast media to confirm the location of the exiting and traversing roots (Fig. 2b). Then, 1–2 cc of 1% lidocaine was injected on the outer surface of the annulus. After inserting the spinal needle into the disc, the nucleus pulposus was stained blue with 1 mL of contrast media (Telebrix, Guerbet, France) and indigo carmine solution (Carmine, Korea United Pharmaceutical, Yoenki, Korea) for discography (Figs. 2c, d). The location of the spinal needle was checked at the medial pedicular line on the AP view and the posterior vertebral line on the lateral view. The final target point depended on the disc location and surgical level. In paramedian disc herniation, the final target point of the spinal needle was the medial pedicular line on the anteroposterior (AP) view and the posterior vertebral line on the lateral view. For central disc herniation, the spinal needle was targeted between the medial pedicle line and midline in the AP view and on the posterior vertebral line on the lateral view. For downward migrated disc herniation, the needle was located on the superior vertebral notch of the lower vertebra with a cranio-caudal inclinatory 20–30° angle (Fig. 2e). However, when the spinal needle was located close to the target point in the AP view and the needle tip was located within the disc space in the lateral view, foraminoplasty should be performed; using a bone reamer or endoscopic drill, the SAP was partially removed.

Foraminoplasty

Serial manual bone drills were advanced to the medial pedicular line under fluoroscopy in ascending order of size (Figs. 3a, b). After using the largest reamer, needle placement was re-attempted.

Final PELD Procedure

After foraminoplasty, a tapered cannulated obturator was inserted along the guidewire; after touching the annulus, an obturator was inserted into the disc using hammering; a bevel-ended and oval-shaped working cannula was inserted into the disc along the obturator, and the obturator was removed. Next, an endoscope (Vertebris system; Richard Wolf GmbH, Germany) was inserted through the cannula (Fig. 3c). The facet joint was partially removed using an endoscopic drill, cutting forceps, and endoscopic Kerrison punch, while engaging the

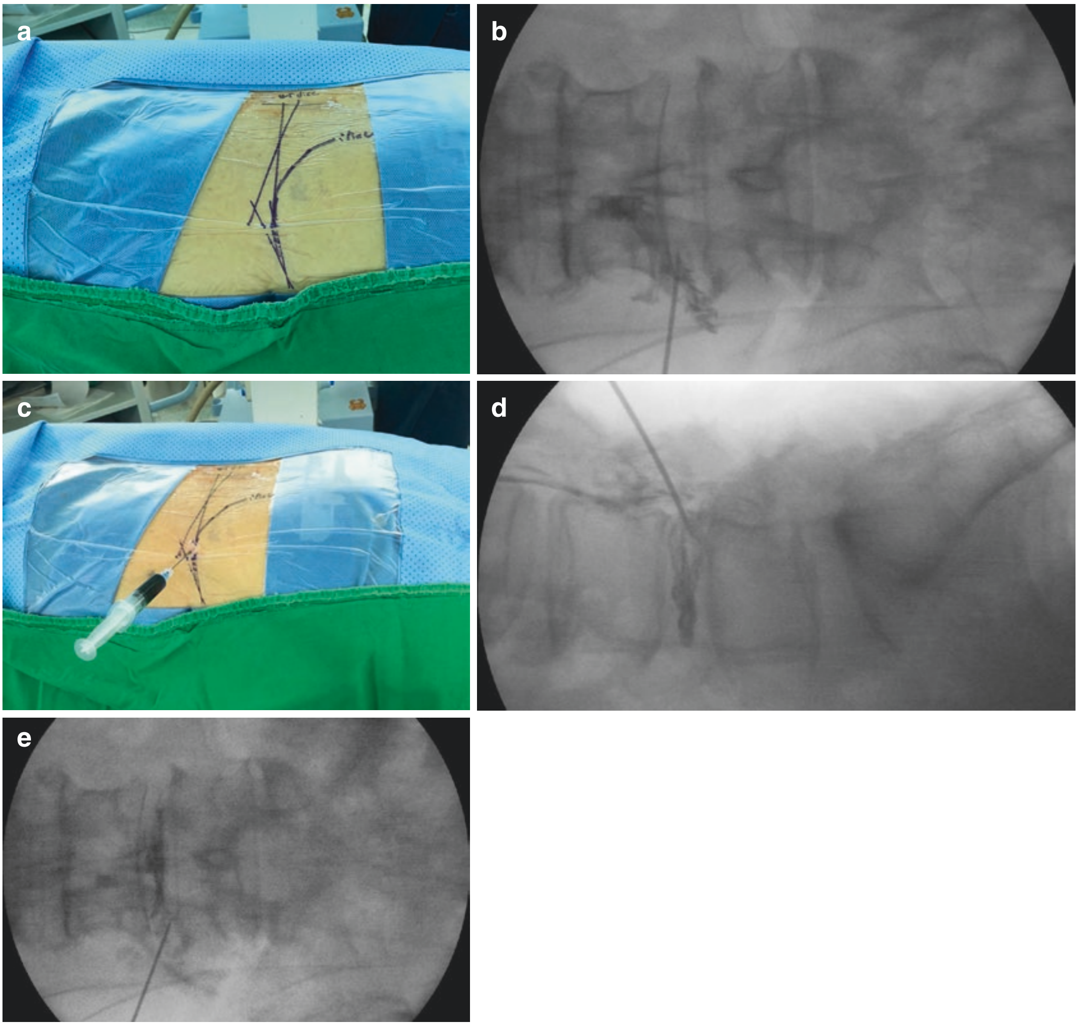

Fig. 2 Surgical steps (**a**) skin entry point, (**b**) epidurogram, (**c**, **d**) discography, and (**e**) intraoperative radiography revealing initial targeting for downward migrated disc herniation

working cannula. The yellow ligament was removed, and the traversing nerve root was exposed. Generally, the fragment is hidden under the traversing nerve root. Under endoscopic view, the disc fragment was pulled out with a curved probe and curved forceps. After removal of the fragment, the traversing nerve root became mobile. If disc protrusion was found in the disc space, the subannular disc was removed using the conventional method. After the herniated fragment was completely removed, the endoscope was removed.

High-Grade Migration/Downward Sequestration

Conventional TELD techniques may present difficulties in removing migrated HDs. Rigid instrumentation, poor visualization, and inability to reach or grasp herniated fragments render migrated discs inaccessible in conventional TELD. In particular, a rigid endoscope cannot be used to visualize the whole fragment for large migrated HDs. However, an inclinatory approach from the cranio-caudal or caudo-cra-

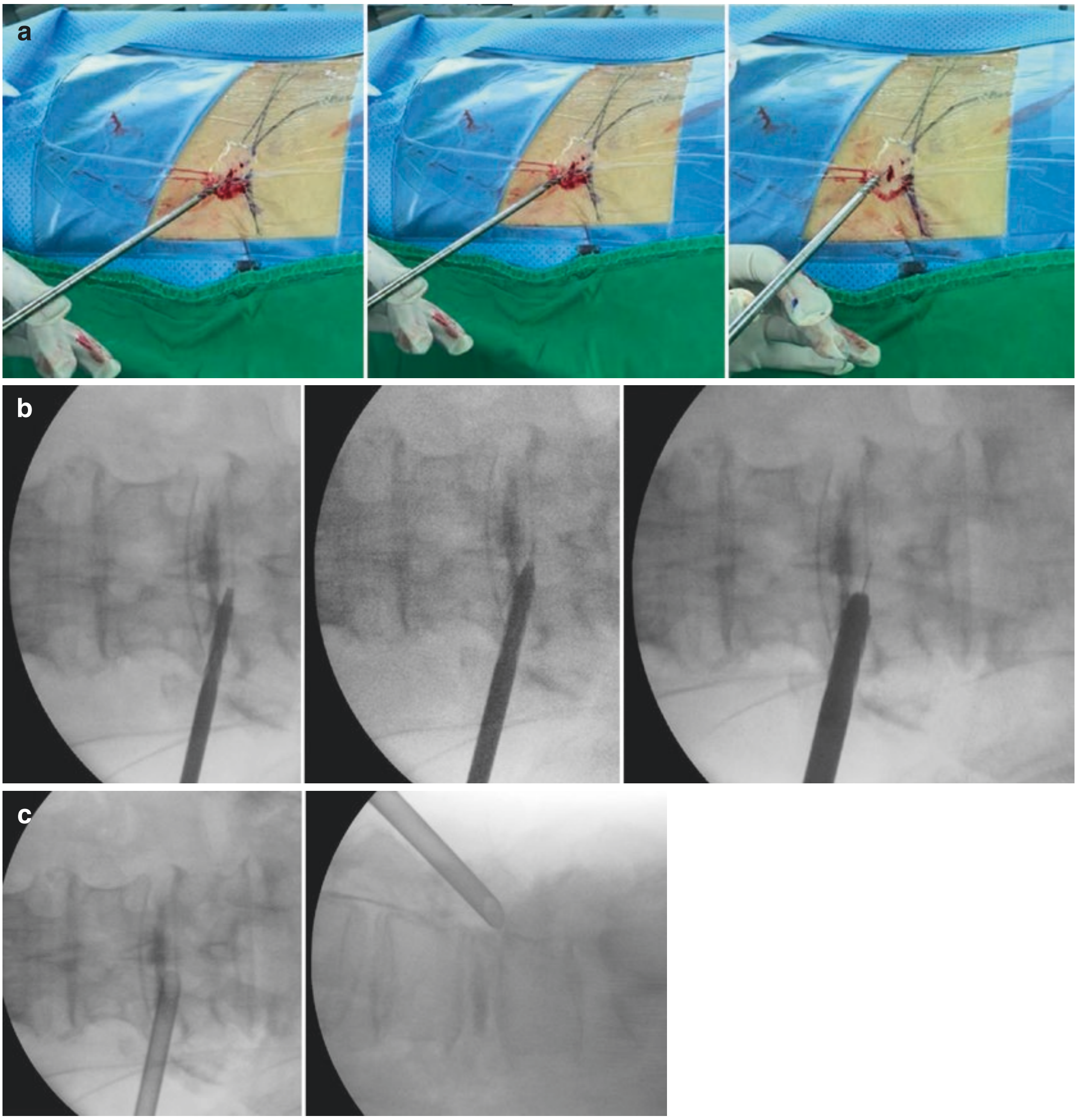

Fig. 3 Sequential reaming (**a**) intraoperative photos, (**b**) intraoperative radiographies and (**c**) the location of working cannula on the target point

nial direction can help extract and grasp the disc fragment using flexible curved forceps. For high-grade down migration or down-migrated sequestration, resection of the base of the superior facet and upper pedicle can aid in the visualization of hidden disc fragments in the anterior epidural space.

Illustrative Case

A 71-year-old woman had undergone microscopic discectomy at L4-L5 level 3 years prior. She complained of left leg pain and buttock pain. MR images revealed a large disc fragment that had migrated inferior to the level (Fig. 4a, b). The

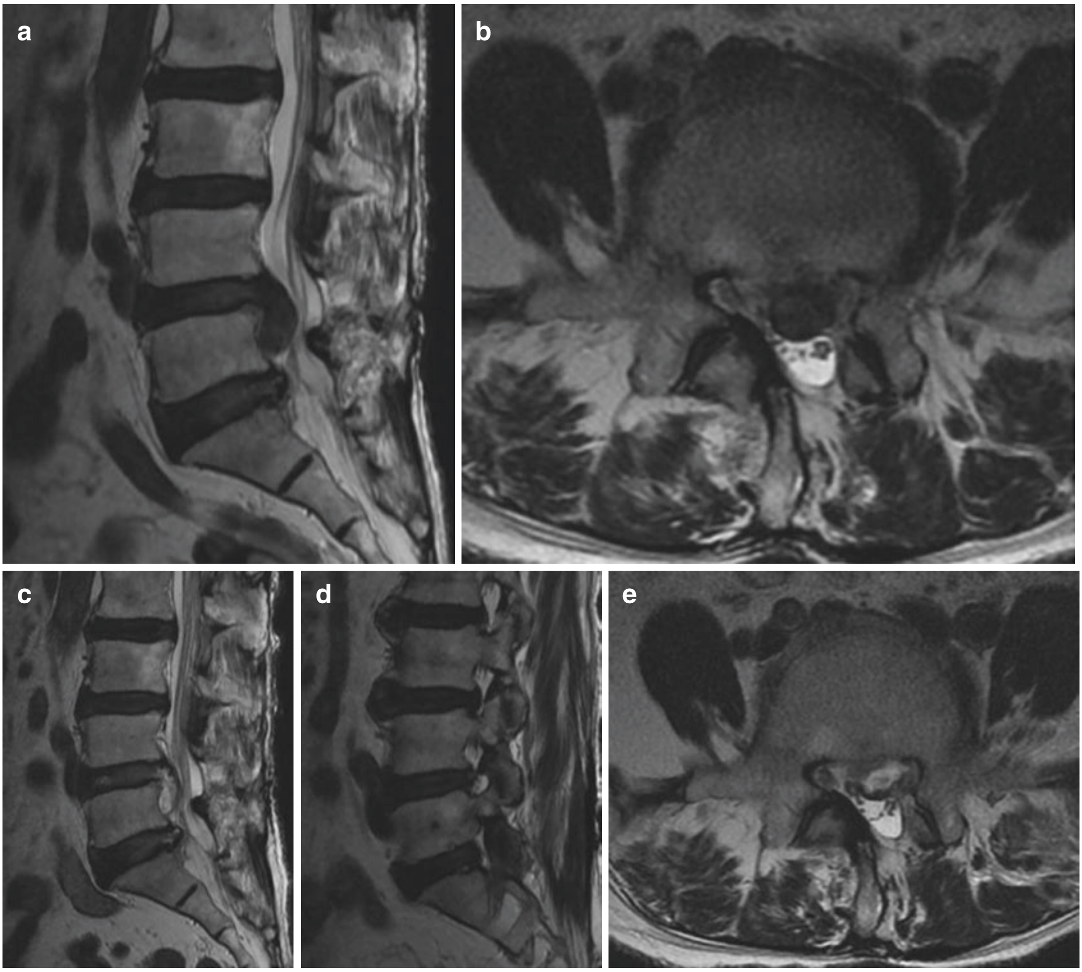

Fig. 4 Recurrent disc herniation with downward migration (**a**) Preoperative MR sagittal image revealing the HD extending downwardly at L4–5, (**b**) MR axial image, (**c**) postoperative MR sagittal image showing complete removal of HD, (**d**) MR sagittal image showing partial removal of the superior articular process (SAP) at the foraminal zone and (**e**) MR axial image

pain did not diminish after two epidural steroid injections. After endoscopic foraminoplasty, the disc fragment was removed using TELD (Video 1). MR images (Fig. 4c–d) showed complete removal of the HD and partial resection of the facet joint.

Recurrent Disc Herniation

TELD via the transforaminal route is effective for recurrent disc herniation and can reduce surgery-related complications and operation time. It can also facilitate rapid recovery using a virgin trajectory. After lumbar discectomy, disc height (DH) is significantly decreased and disc degeneration and facet arthropathy might progress. These changes can lead to foraminal narrowing, making it difficult for transforaminal endoscopic access to the epidural space and increasing the possibility of exiting nerve injury. If the working cannula is located far from the HD fragment due to facet hypertrophy, a disc fragment in the epidural space might remain if only the subannular disc or nucleus pulposus within the disc space is removed. Removing the middle part of the SAP

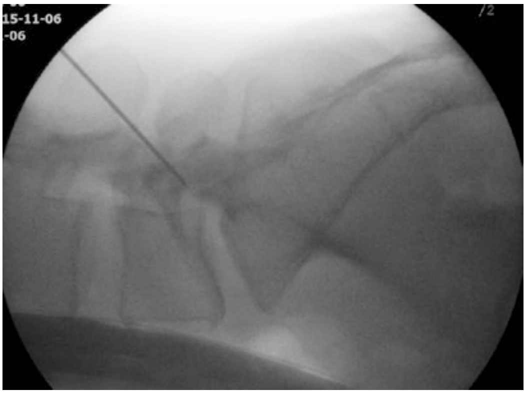

Fig. 5 For L5-S1 disc herniation, the trajectoy of the needle is cranio-caudal

can reduce the trajectory angle and facilitate working cannula access to the epidural space.

L5-S1 Intracanal Disc Herniation with a High Iliac Crest

The foraminal dimension decreases as the spinal level decreases; the L5-S1 level has a relatively shorter DH with larger facet joints than those of the other levels. These anatomical characteristics are barriers to performing TELD. Suprailiac entry, a cranio-caudal oblique trajectory, and widening of the posterior border (SAP) of the working zone can overcome anatomical barriers, allowing access near the epidural space (Fig. 5a). If the highest point of the iliac crest is located above the upper margin of the L5 pedicle in lateral radiography, foraminoplasty will be required [5].

Illustrative Case

A 36-year-old woman suffered from left posterior leg pain. The deep tendon reflex of ankle was diminished. Although she took medications and underwent physical therapy, the pain remained. A large central disc herniation compressed the thecal sac and left S1 nerve root (Fig. 6a, b). The iliac crest overlapped the intervertebral foramen of L5-S1 (Fig. 6c). To access near the HD, foraminoplasty was required. MR images (Fig. 6d, e) showed complete removal of HD and partial removal of SAP.

Central Disc Herniation with a Wide Lamina Angle

A conventional "inside-out technique" has an approach angle of approximately 25° and involves an intradiscal working channel that utilizes a cavity via an annulotomy opening using biting forceps. However, this technique is limited with respect to the removal of epidural disc fragments in the central portion of an HD. In cases of centrally located HDs, a bevel-ended cannula should be placed in the midline on the AP view and between the epidural space and intra-annular portion on the lateral view under intraoperative fluoroscopic guidance. The entry point is further from the midline than for a paramedian disc herniation, and the approach angle is shallower. When a central disc herniation is accompanied by a wide lamina angle (>100°), the working cannula will be far from the disc herniation with a steep approach angle (Fig. 7a) [4]. Partial removal of the superior facet joint (Fig. 7b) can reduce the approach angle, allowing the working cannula to be placed below the disc fragment (Fig. 7c).

Complications and their Management

TELD under local anesthesia potentially limits neural injury, although some authors perform PELD safely under general anesthesia [6]. The exiting nerve root (ENR) should be protected during the procedure. Irritation of the ENR and dorsal root ganglion can cause severe leg pain. In this situation, if irritation symptoms develop, the surgeon should try to adjust the entry point and trajectory, and then stop the procedure if the pain persists. Postoperative dysesthesia is one of the significant sequelae that negatively affects the quality of life. Considering the safety triangle, far from the ENR, a more caudal approach along the superior border of the inferior pedicle may be safe. Serial dilation and sequential reaming procedures

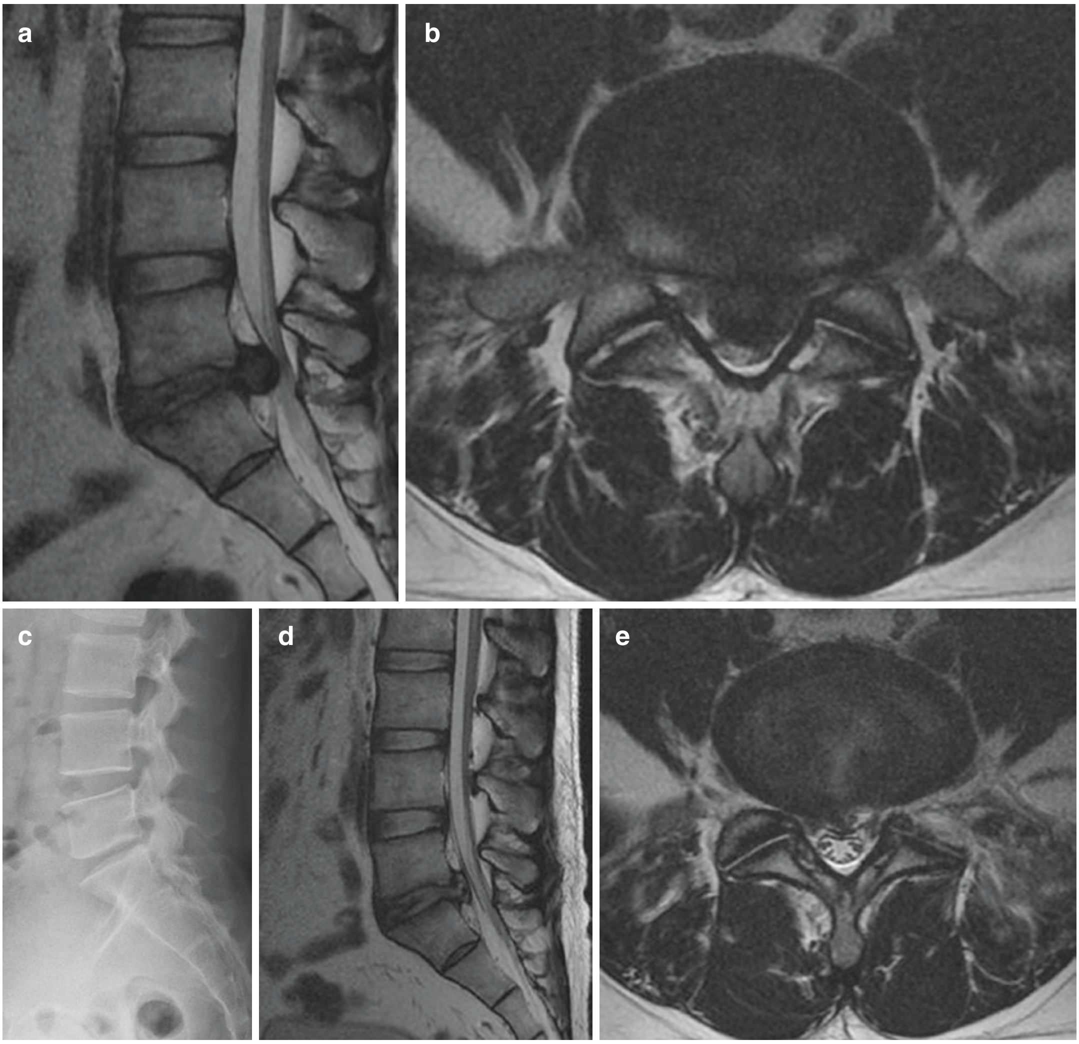

Fig. 6 L5-S1 disc herniation (**a**) preoperative MR sagittal image, (**b**) MR axial image showing large disc herniation compressed thecal sac and left S1 nerve root, (**c**) lateral radiography showing iliac crest overlapped the intervertebral foramen of L5-S1, (**d**) postoperative MR sagittal image and (**e**) MR axial image showing complete removal of HD with partial removal of the SAP

can reduce injury to the ENR. In severe foraminal stenosis, endoscopic foraminotomy using an endoscopic diamond drill from outside foramen to inside foramen is safer and more effective than using a manual bone drill. Reaming with too steep an approach angle, the disc space could be directly violated. Using fluoroscopic lateral imaging, the procedure can proceed appropriately.

Concomitant persistent pain is commonly caused by surgically unappreciated disc fragments, concurrent lateral recess stenosis, nerve root injury, epidural hematoma, and nerve root edema regardless of the appearance of complete removal of the herniated disc on postoperative MR. Concurrent lateral recess stenosis (Fig. 8a) is associated with poor prognosis. Lateral recess bony stenosis can be addressed with a separate decompression procedure. This requires partial removal of the SAP and ligamentum flavum (Fig. 8b).

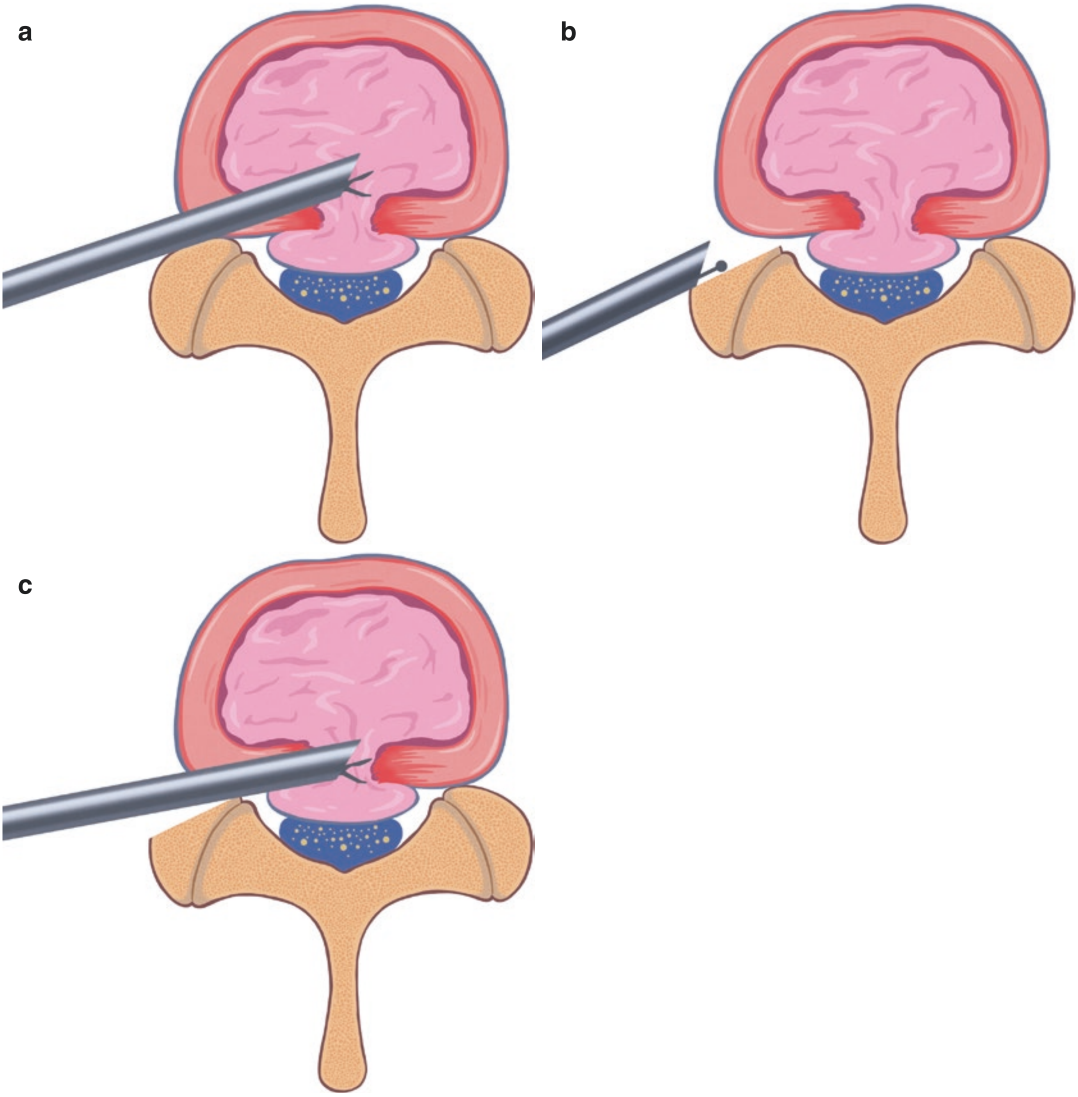

Fig. 7 Schematic illustration of transforaminal endoscopic lumbar discectomy (TELD) facilitated by endoscopic foraminoplasty for central disc herniation. (**a**) Conventional posterolateral TELD technique is shown with a herniated disc fragment in the epidural space inaccessible to the working cannula. (**b**) Removal of a SAP with an endoscopic drill is shown. (**c**) After foraminoplasty, the working cannula is located near the herniated disc fragment

Brief Discussion: Surgical Tip and Pitfall

Endoscopic foraminoplasty was first introduced by Knight et al. [7] Using a Holmium-Yag side-firing laser, undercutting of the facet joint, discectomy, mobilization of the exiting and traversing nerve roots, and ablation of osteophytes could be performed. Foraminal widening techniques, called "foraminoplasty," help surgeons access the epidural space, allowing visualization of hidden disc fragments and decompression of foraminal or lateral recess stenosis. Advances in endoscopic instruments, bone

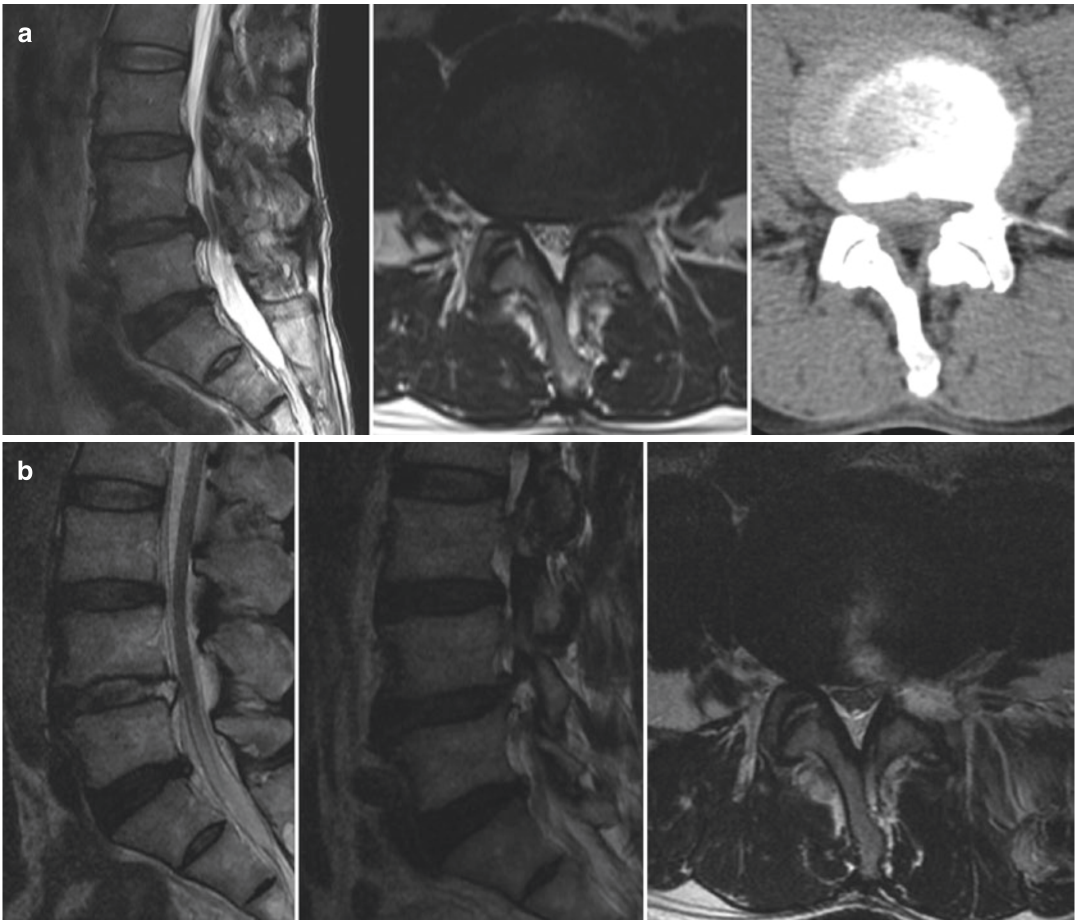

Fig. 8 HD with lateral recess stenosis (**a**) MR images and CT scan showing disc herniation with lateral recess stenosis at L4–5. (**b**) Postop MR images showing removal of HD and the SAP

Table 1 Clinical results of endoscopic foraminoplasty

Authors	No. of patients	Disease	Technique	Aim	Instruments	Success rate	Complication	Publication year
Knight et al. [7]	250	Foraminal stenosis	Endoscopic foraminoplasty	Decompression of exiting nerve root and traversing nerve root	Laser	73%	1 foot drop, 5% revision	1998
Schubert and Hoogland [8]	558	Disc herniation	Endoscopic foraminoplasty	Widening of foraminal zone	Reamer	95%	0.5% transient paresthesia, 3.6% revision	2005
Choi et al. [2]	59	Migrated disc herniation	Endoscopic foraminoplasty	Widening of foraminal zone and partial pediculectomy	Endoscopic drill	91%	8.5% revision	2008
Ahn et al. [9]	33	Foraminal stenosis	Endoscopic foraminotomy	Decompression of exiting nerve root	Endoscopic drill, laser, micropunch	82%	6.1% dysesthesia, 3% revision	2014
Choi and Park [5]	100	Disc herniation at L5–S1	Endoscopic foraminoplasty	Widening of foraminal zone	Reamer	92%	2% revision	2016

trephines, reamers, and endoscopic drills have occurred (Table 1). For example, an endoscopic diamond drill was used to undercut the superior facet in a study by Choi et al. [2] By contrast, a bone reamer under fluoroscopic guidance was used by Schubert and Hoogland. [8] Choi and Park also used reamers to engage the L5-S1 foramen [5]. Ahn et al. described a technique called "endoscopic foraminotomy" that achieves full decompression of the exiting nerve root in a foraminal stenosis using an endoscopic drill, side-firing laser, and endoscopic Kerrison punch. An endoscopic reamer or endoscopic drill was used for foraminal widening [9]. Sequential reaming using bone reamers or trephines is not a time-consuming technique and only depends on fluoroscopy. Nevertheless, sequential reaming can lead to neural injury and difficulties in controlling bone bleeding. To prevent neural injury, the reamer should not be advanced over the medial pedicular line, as suggested by Lee et al. [10] Furthermore, reaming is limited in terms of removal of a large portion of a large facet joint or hypertrophied facet joint. By contrast, an endoscopic drill can minimize neural injury under vision and a large amount of the facet joint can be removed. Finally, a diamond burr rarely causes bone bleeding. The downside of this procedure is that it is time-consuming.

The foraminoplasty target (Fig. 9) should be individualized for each situation. For a L5-S1 disc herniation in the spinal canal, removal of the cranial tip of the SAP through an oblique trajectory in the cranio-caudal direction can facilitate access to the disc fragment. For large central disc and recurrent disc herniation, the trajectory angle can be reduced by removing the mid-portion of the SAP at the mid-disc space level. For a downward-migrated disc, removing the base of the SAP and partially removing the upper pedicle can provide good visualization of a hidden disc.

Endoscopic lumbar foraminoplasty may be effective for small DH, high-grade downward migration, downward sequestration, recurrent HD, HD in L5-S1 with a high iliac crest, central HD with a wide lamina angle, and HD with lateral recess stenosis.

Fig. 9 Foraminoplasty target. For a L5-S1 disc herniation, the cranial tip (★) of the SAP through an oblique trajectory in the cranio-caudal direction. For large central disc and recurrent disc herniation, the mid portion (◆) of the SAP at the mid-disc space level. For a down-migrated disc, removing the base (▼) of the SAP and partially removing the upper pedicle

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