Foraminal Stenosis

Sang-Ha Shin and Junseok Bae

1 Foraminal Stenosis Ventral Decompression

Sang-Ha Shin

Abstract Open foraminal decompression with/without fusion has been performed as a standard surgical treatment for lumbar foraminal stenosis. Recently reported endoscopic approach through extraforaminal landing enables working mobility after partial removal of superior articular process. After that, it was possible to approach the foraminal zone safely and to treat decompression for foraminal stenosis. After access to the foramen, full scale foraminal decompression along the exiting nerve root can be performed using a variety of surgical instruments. Instruments such as endoscopic burrs, bone reamers, punches, forceps, and lasers can be used for selective decompression under high resolution endoscopic vision. We conclude that transforaminal endoscopic decompression could be an effective treatment method for selected groups of patients with foraminal stenosis. It can be performed under local anesthesia and has a short operative time and less blood loss.

Keywords Lumbar; Stenosis; Foraminal; Endoscopic; Transforaminal

1.1 Presentation of the Patient and Illustrated Cases

Case 1
A 54-year-old female patient presented with left leg pain. Preoperative magnetic resonance (MR) image demonstrated dorso-ventral foraminal stenosis caused by hypertrophied facet joint and ventral osteophytic spur (Fig. 1a). After endoscopic foraminotomy, the patient's symptom improved and postoperative MR image showed complete decompression of foramen (Fig. 1b) (Video 1).

Case 2
A 58-year-old male patient presented with right leg pain. Preoperative magnetic resonance (MR) image demonstrated ventral foraminal stenosis caused by osteophytic spur (Fig. 2a). After endoscopic foraminotomy, the patient's symptom improved and postoperative MR and CT images showed complete decompression of foramen (Fig. 2b) (Video 2).

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Fig. 1 (**a**) Preoperative magnetic resonance (MR) image showing dorso-ventral foraminal stenosis caused by hypertrophied facet joint and ventral osteophytic spur. (**b**) Postoperative MR image showed complete decompression of foramen

1.2 Preoperative Planning

Preoperative MRI should be carefully checked to determine the appropriate skin entry point and approaching angle. The distance from the midline to the skin entry point can be calculated in the axial image of the MRI, usually 6–13 cm. The appropriate approach angle is determined by the location of the lesion. An angle of about 15 degrees is recommended for the decompression of the subarticular zone and an angle of about 30–45 for the decompression of the foraminal or extraforaminal zone.

1.3 Surgical Steps

Endoscopic foraminal decompression can be performed under local anesthesia. Midazolam or fentanyl may be given intravenously to relieve pain and sedation during procedure. The degree of sedation is controlled to respond to the physician's verbal command during the procedure. The patient is placed in the prone position after flexion of the knee and hip on the radiolucent table with fluoroscopic guidance. Knee and hip flexion postures provide foraminal widening to provide a wider working space during decompression.

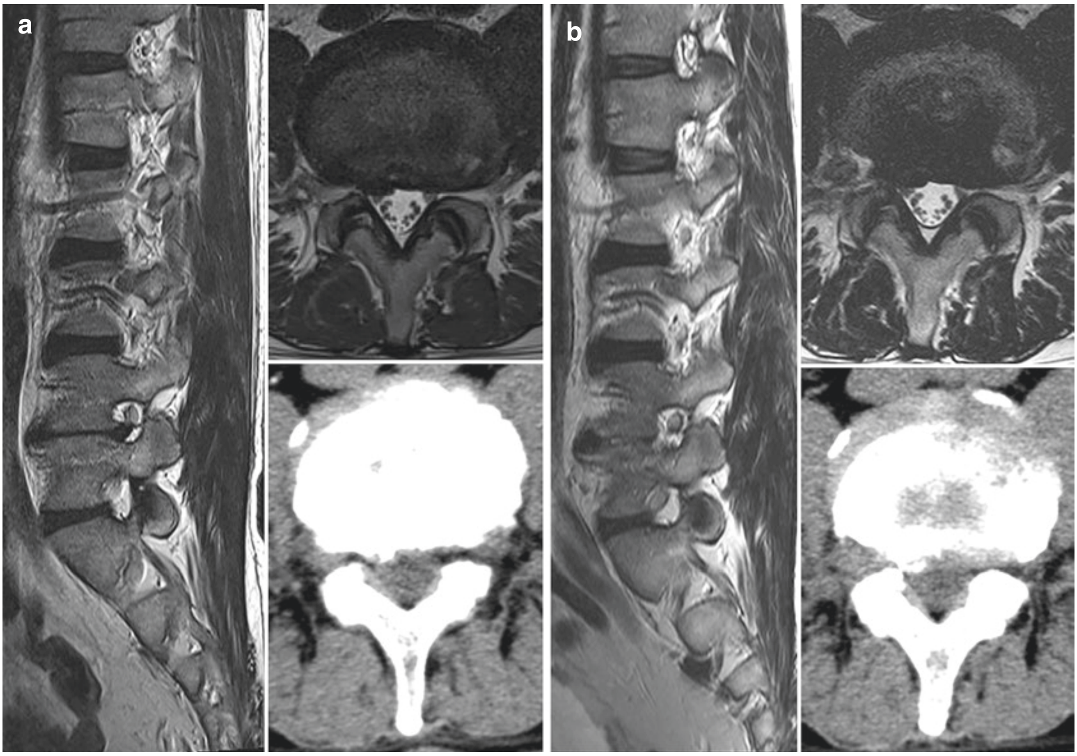

Fig. 2 (**a**) Preoperative MR image showing ventral foraminal stenosis caused by osteophytic spur. (**b**) Postoperative MR and computed tomography images showing complete decompression of foramen

Unlike disc herniation, in patients with foraminal stenosis, the target of removal is not a soft cartilage but a bony structure or thickened foraminal ligament. Endoscopic drills, bone reamers, shavers, etc. can be used to remove bony structures (Fig. 3). And endoscopic punches or lasers are useful for the removal of thickened ligamentum flavum. Also, endoscopic scissor or endoscopic probe may be useful for dissection between the exiting nerve root and the surrounding tissue.

After determining the proper approach angle and skin entry point, insert an 18 gauge spinal needle under the superior articular process using a fluoroscope. Then insert the guide wire and place the obturator into the foramen. Along the obturator, the bevel-ended working cannula is introduced and placed on the undersurface of the facet joint. The obturator is removed and the ellipsoidal working channel endoscope is inserted. The surgeon can see the superior facet through endoscopic visualization. Hypertrophied part of facet joints can be safely removed using an endoscopic burr or bone reamer with both endoscopic and fluoroscopic guidance. The direction of the bone removal should be from the outside to the inside and from the inferior pedicle to the superior pedicle. If resistance is lost during facet joint undercutting, bone work can be stopped and then foraminal ligament can be observed. When the foraminal ligament is removed, the perineural fat, exiting nerve root, traction spur, and disc surface can be observed. While moving the working cannula, decompression may be selectively carried out to the desired area. Hypertrophied foraminal ligaments can be removed using endoscopic punches, grasper, or scissors, and extruded discs or soft tissues can be coagulated or ablation using bipolar radiofrequency. Holmium yttrium-aluminum-garnet (HO: YAG) lasers can provide clear vision by removing tissue debris. After decompression, the

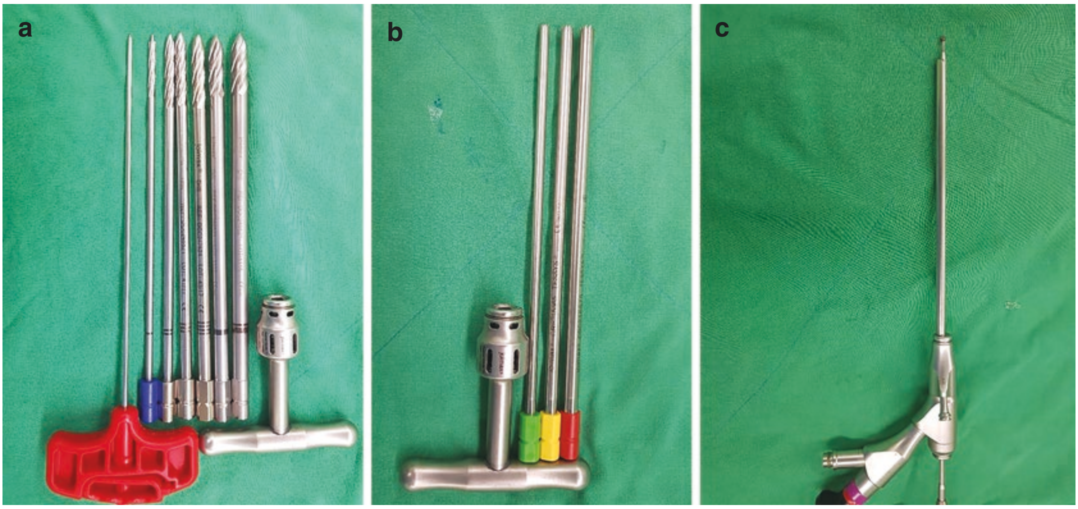

Fig. 3 Special surgical instrument used for endoscopic foraminotomy. (**a**) Manual bone drill. (**b**) Manual bone reamer. (**c**) Electrical endoscopic burr

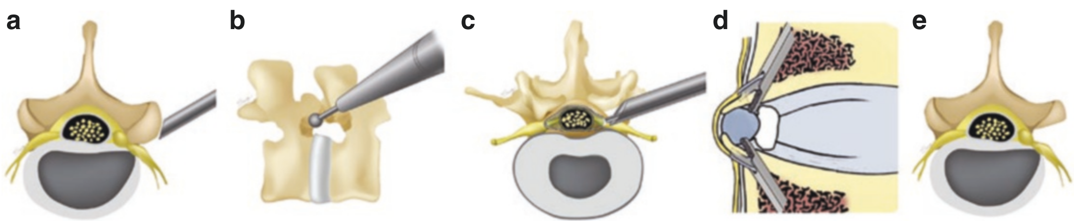

Fig. 4 Schematic illustrations of endoscopic foraminal decompression. (**a**) Extraforaminal landing of working cannula. (**b**) Undercutting of facet joint using endoscopic drill. (**c**) Selective foraminal decompression. (**d**) Removal of ventral osteophytic spur. (**e**) Confirmation of full decompression along the course of exiting nerve root

surgeon can fully observe the course of the exiting nerve root from the pedicle medial margin to the extraforaminal area through endoscopic vision. The endpoint of this procedure is when the exiting nerve root is observed free of the surrounding structure (Fig. 4). After complete decompression, the endoscope is removed and wound closure is performed. After several hours of observation the patient can be discharged.

1.4 Commentary

Open foraminal decompression with/without fusion has been performed as a standard surgical treatment for lumbar foraminal stenosis. Total facetectomy provides complete nerve decompression, but often leads to spinal instability and usually requires additional fixation [1–3]. Wiltse et al. [4] reported a paraspinal approach as a method for decompression of foraminal stenosis. Because this technique preserves much of the facet joint, it is now widely used as a standard surgical treatment for decompression in patients with foraminal stenosis.

The full endoscopic transforaminal approach has less muscle trauma and less blood loss than open decompression. It can also be done under local anesthesia. Thus, reduced hospital stay, early functional recovery, and better cosmesis are shown [5, 6]. With the desire of patients and the development of endoscopic instruments, the transforaminal approach is gaining in popularity. To date, endoscopic transforaminal decompression has been predominantly performed in patients with disc herniation. For spinal stenosis, endoscopic working mobility is limited due to foraminal bony structure and exiting nerve root [7–10]. Recently reported endoscopic approach through extraforaminal landing enables working mobility after partial removal of superior articular process. After that, it was possible to approach the foraminal zone safely and to treat decompression for foraminal stenosis. We will describe this technique in this chapter.

This technique can be applied to patients with foraminal stenosis who do not respond to preservation therapy and whose symptoms persist. It is appropriate to perform in patients with unilateral radicular symptom.

This technique is not appropriate in patients with segmental instability or spondylolisthesis. In these cases, fusion surgery should be considered. It is also difficult to apply to patients with profound motor weakness or revision surgery. Approach is also difficult in patients with high iliac crest at L5/S1 level. Coexisting pathological conditions such as acute inflammation, infection, or tumor can also be difficult to apply.

Excessive manipulation or irritation of the dorsal root ganglion during foraminal decompression can lead to postoperative dysesthesia. Postoperative dysesthesia can occur from 6.5% to 24% [1, 2]. Most patients improve gradually with conservative treatments such as nerve root blocks or medication therapy.

The posterior lateral transforaminal approach has limited working mobility and narrower vision than the open paraspinal approach. Thus incomplete decompression may occur. In patients with pain that persists after endoscopic decompression, fusion surgery is usually needed.

Postoperative hematoma can also occur after endoscopic decompression. This can be reduced by the use of meticulous bleeding control and hemostatic agents during the procedure. Bone bleeding may occur after bone resection, which is difficult to control using endoscopic instruments. If there is uncontrolled bone bleeding, a drainage tube can be inserted and removed when the volume of blood decreases during the postoperative period [7].

The main target of decompression of endoscopic foraminotomy is the structures that compress the exiting nerve root. Therefore, the surgeon needs to identify the exiting nerve root and proceed with decompression along its course. For safe foraminal decompression, it is important to approach the foramen after partial resection of the superior articular process after landing into the superior articular process of the extraforaminal area. In patients with foraminal stenosis, the working zone is very narrow, and there is a risk of nerve damage when the working cannula is inserted directly into the foramen without partial decompression of the facet. When working on the bone, use a drill or reamer to fully expose the lower margin of the upper pedicle and the upper margin of the lower pedicle under the guidance of fluoroscope and endoscope. Partial resection of the superior articular process only at the discal level may be insufficient to expose the proximal part of the exiting nerve root.

After access to the foramen, full scale foraminal decompression along the exiting nerve root can be performed using a variety of surgical instruments. Instruments such as endoscopic burrs, bone reamers, punches, forceps, and lasers can be used for selective decompression under high resolution endoscopic vision.

2 Dorsal Decompression

Junseok Bae

Abstract Foraminal stenosis by hypertrophied foraminal ligament or impingement of superior articular process is compressing the exiting nerve root by cranial-to-caudal compression or dorsal portion of the neural foramen. This type of foraminal stenosis is often caused by disc height narrowing. Instead of height restoration with interbody fusion, resection of the superior articular process and foraminal ligament also can decompress exiting nerve root compression. In this chapter, the authors describe the transforaminal endoscopic decompression technique for dorsal foraminal decompression.

Keywords Foraminal stenosis; Foraminal ligament; Superior articular process; Dorsal root ganglion; Transforaminal endoscopic approach

2.1 Introduction

In the aged population, degenerative lumbar scoliosis (DLS) is commonly present [11–13]. It is often related to low back pain due to additional degenerative spondylolisthesis and rotatory olisthesis. Lumbar stenosis is also a common problem in the combination of ligamentum flavum hypertrophy, facet arthropathy, disc collapse, and olisthesis. Patients with DLS frequently present with foraminal stenosis (FS) on the concavity side that causes severe disabling radiculopathy [12, 14, 15]. Decompression and fusion surgery are recommended if the pain is refractory to non-operative treatment. However, fusion surgery is not favorable for patients with aged osteoporotic bone and medical comorbidities. Endoscopic foraminotomy has been proved to be effective and safe in foraminal decompression while minimizing post-decompression instability [16–24]. Transforaminal endoscopic foraminotomy has an advantage in treating radiculopathy in FS in DLS.

2.2 Indications

Indicated patients are those who have symptomatic foraminal compression of dorsal root ganglion by hypertrophied foraminal ligament or impingement of superior articular process. A diagnostic injection is necessary to confirm symptomatic relief. Surgical decompression is considered when intensive conservative treatment fails to improve pain.

In patients with DLS, decompression without fusion is indicated for lateral listhesis <2 mm, Cobb's angle <25 degrees with coronal balance [12, 14, 15]. Vacuum disc or coronal malalignment are factors of early collapse of neural foramen and recurrent stenosis. A preoperative CT scan is necessary to exclude the vacuum disc. Cases with the presence of segmental instability, grade II or above spondylolisthesis, and severe sagittal/coronal malalignment are excluded.

2.3 Surgical Technique

*Surgical Technique (*Figs. 5 and 6*)*

1. Patient position: Prone on a radiolucent operating table with knees flexed.
2. Anesthesia: Conscious sedation with IV fentanyl and midazolam.
3. Surface marking: Operating level, midline, and cranio-lateral extent of iliac crest under C-arm guidance.
4. Trajectory planning: An imaginary line is drawn from the skin surface to the intended annular puncture site using AP and lateral C-arm views. The trajectory should parallel to the disc space aiming at the lateral surface of SAP. The approach angle is between 10 and 15 degrees.
5. The planned needle pathway is infiltrated with 8–10 mL of 1% lidocaine.
6. 18G spinal needle is inserted along the planned trajectory under fluoroscopic guidance.
7. Once the needle touches the lateral facet joint, it is slightly withdrawn and advanced into the foramen, then an epidurography is performed to confirm the location of the exiting root.
8. The needle is replaced with a 0.8 mm guide wire.
9. Skin is incised and a blunt cannulated obturator is passed over the guide wire under fluoroscopic control until its tip reaches the lateral surface of the facet.
10. Finally, a 7 mm beveled working cannula is placed over the obturator, and an endoscope is introduced (Tessys, Joimax GmbH, Karlsruhe, Germany) (Fig. 5a, b).
11. The superior articular process is resected at this point using a high-speed drill (Shrill®, Joimax GmbH, Karlsruhe, Germany) (Figs. 5c, d and 6a, b), with side-firing Ho:YAG laser (Lumenis, Israel) and endoscopic Kerrison and forceps (Fig. 6c–e).

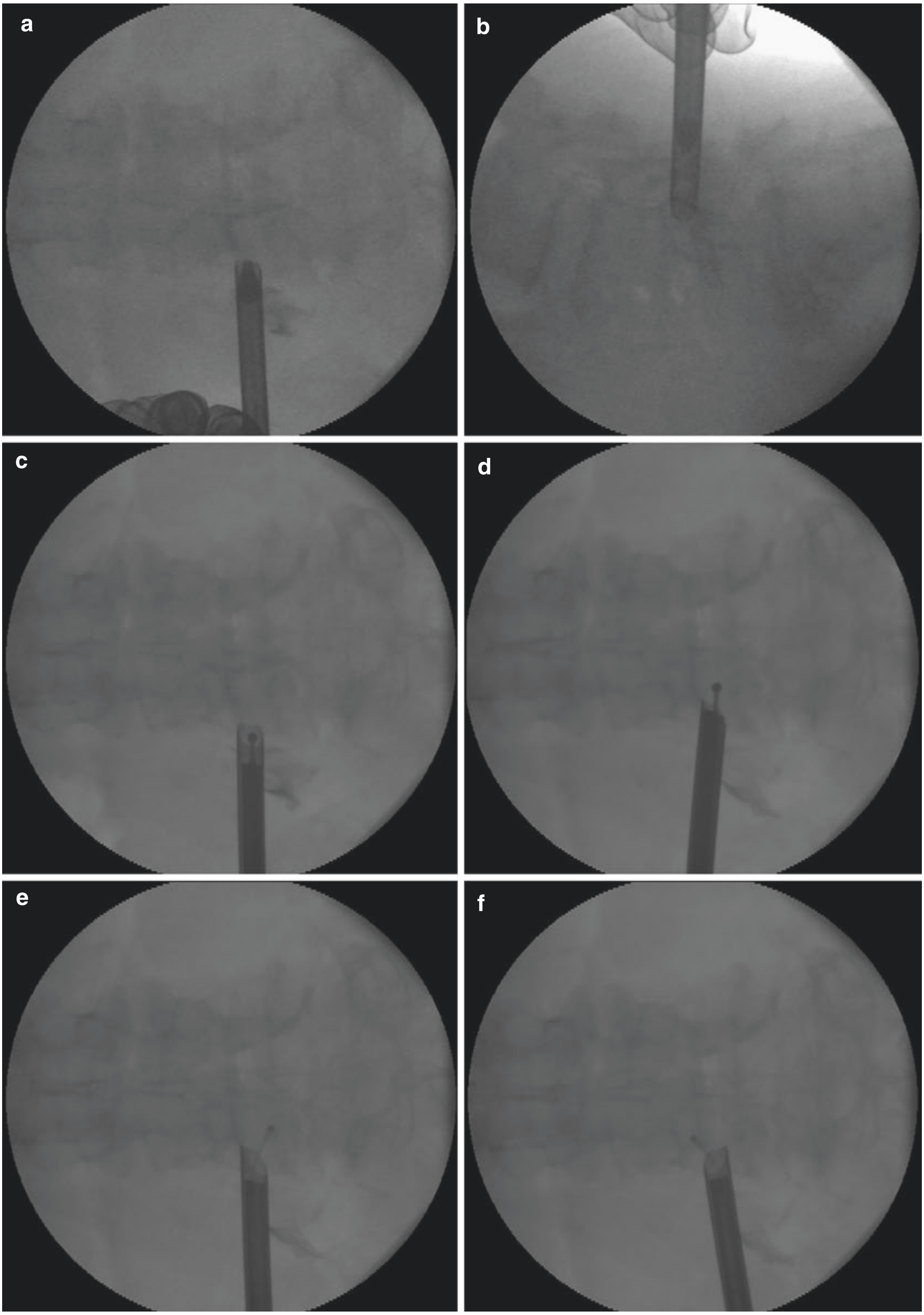

Fig. 5 Surgical technique: Beveled working cannula is placed over the obturator and an endoscope is introduced (**a**, **b**). The superior articular process is resected at this point using a high-speed drill (**c**, **d**). The radiofrequency probe is indicating the amount of foraminal decompression (**e**, **f**)

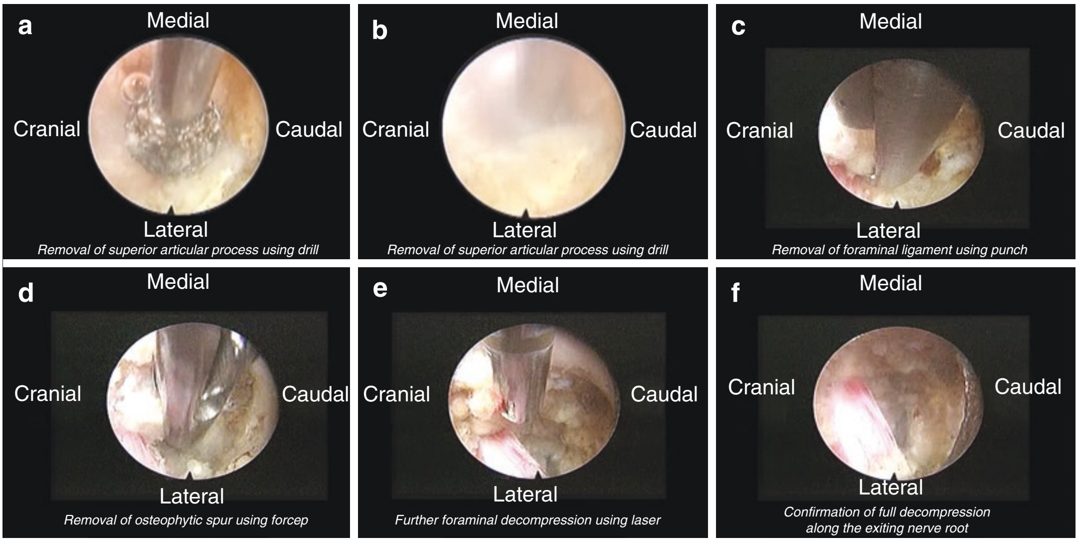

Fig. 6 Endoscopic view of surgical steps. (**a**) A high-speed drill is resecting the lateral surface of the superior articular process. (**b**) Drill tip is penetrating SAP as seen in Fig. 5D. (**c**) Foraminal ligament is resected with endoscopic Kerrison punch. (**d**) Osteophytic spur is removed with endoscopic forceps. (**e**) Residual foraminal ligament is evaporated with side-firing Ho:YAG laser. (**f**) Final inspection of exiting nerve root decompression

12. Throughout the procedure, continuous feedback from the patient is utilized to avoid any neural injury.
13. Direct endoscopic visualization of a free nerve root is used to confirm adequate decompression. (Fig. 6f).
14. Skin is closed in standard fashion.

2.4 Case Illustration

A 72-year-old female patient was complaining of severe radiating pain on the left side. The pain was radiating from the buttock to the anterior thigh. She was suffering from chronic low back pain for more than 10 years. She had a lot of medical comorbidities such as hypertension, uncontrolled diabetes, history of angina with 3 cardiac stents. Standing X-ray showed segmental scoliosis and multilevel disc degeneration, degenerative spondylolisthesis at the L3-4, L4-5 levels, and isthmic spondylolisthesis at the L5-S1 level (Fig. 7a, b). MRI showed foraminal stenosis at the L3-4, L4-5, and L5-S1 levels with significant impingement of the L4 nerve root by L5 SAP (Fig. 7d). Diagnostic block at left L4 root confirmed symptom relief (Fig. 7c). Endoscopic transforaminal foraminotomy was done. Postoperative sagittal MRI shows resection of the tip of SAP and well-decompressed L4 root (Fig. 8a). A follow-up X-ray 1 year after surgery is showing a stable state (Fig. 8b, c).

2.5 Summary

Transforaminal endoscopic foraminotomy has an advantage over conventional open decompression or fusion surgery because all procedures can be performed under local anesthesia for elderly patients with medical problems and it avoids fusion-related complications such as implant failure or pseudarthrosis. Endoscopic foraminotomy is an effective and minimally invasive treatment option for treating severe radiculopathy caused by foraminal stenosis, especially in DLS patients.

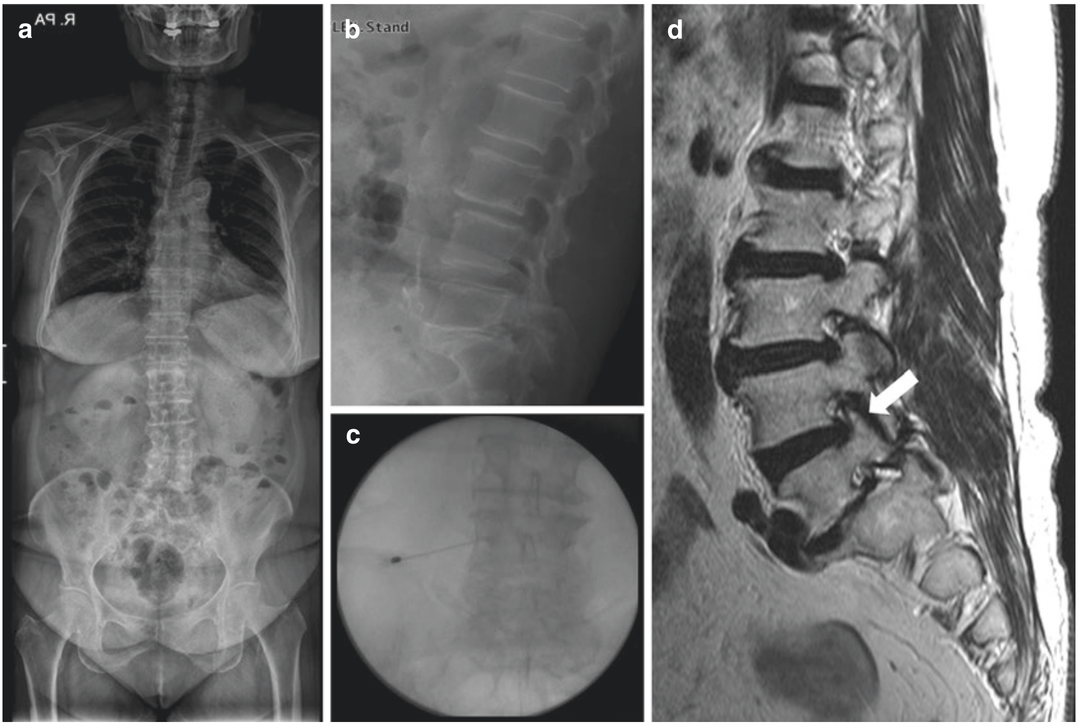

Fig. 7 Representative case of a 72-year-old female with degenerative scoliosis and foraminal stenosis at the L4-5 level. Symptomatic L5-S1 disc herniation: Preoperative X-ray AP and lateral (**a**, **b**) and MRI (**d**) showing segmental scoliosis and multilevel disc degeneration, degenerative spondylolisthesis at the L3-4, L4-5 levels, and isthmic spondylolisthesis at the L5-S1 level. Note the tip of the superior articular process (white arrow) is compressing the L4 nerve root. A diagnostic block at the left L4 root was done (**c**)

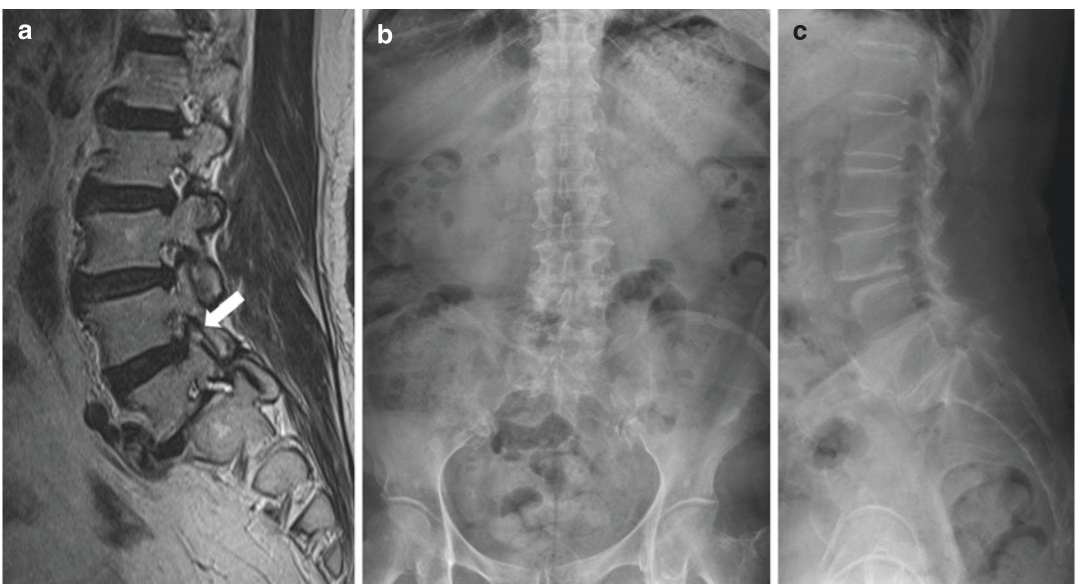

Fig. 8 Endoscopic transforaminal foraminotomy was done. Postoperative sagittal MRI shows resection of the tip of SAP (white arrow) and well-decompressed L4 root. (**a**) A Follow-up X-ray 1 year after surgery is showing a stable state (**b**, **c**)

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