

Ultrasonic Osteotome Assisted Posterior Endoscopic Cervical Foraminotomy in the Treatment of Cervical Spondylotic Radiculopathy Due to Osseous Foraminal Stenosis

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Objective : To investigate the efficacy and safety of the posterior endoscopic cervical foraminotomy (PECF) using ultrasonic osteotome for the treatment of cervical osseous foraminal stenosis, focusing on introduction of the advantages of ultrasonic osteotome in partial pediclectomy and ventral osteophyte resection in PECF.

Methods : Nineteen patients with cervical osseous foraminal stenosis who underwent PECF using ultrasonic osteotome in our institution between April 2018 and April 2021 were enrolled in this study. All the patients were followed up more than 12 months. The patients' medical data, as well as pre- and postoperative radiologic findings were thoroughly investigated. The visual analogue score (VAS), Japanese Orthopaedic Association (JOA) score, cervical dysfunction index (Neck disability index, NDI), and modified MacNab criteria were used to assess the surgical efficacy.

Results : All the patients were successfully treated with PECF using ultrasonic osteotome. The pre- and postoperative VAS, NDI, and JOA scores were significantly improved ($p < 0.05$). According to the modified MacNab criteria, 17 patients were assessed as "excellent", two patients were assessed as "good" at the last follow-up. There was no dura tear, nerve root damage, incision infection, neck deformity, or other complications.

Conclusion : Adequate nerve root decompression can be accomplished successfully with the help of ultrasonic osteotome in PECF, which has the advantage of reducing the probability of damage to the nerve root and dura mater, in addition to the original merits of endoscopic surgery.

Key Words : Ultrasonic osteotome · Cervical osseous foraminal stenosis · Percutaneous · Posterior endoscopic cervical foraminotomy · Minimally invasive surgery.

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INTRODUCTION

Cervical spondylotic radiculopathy (CSR) is a common disease resulted from cervical degenerative changes. The common cause of damage to cervical nerve root is either lateral disc herniation or osseous nerve root canal stenosis^{4,25)} (Fig. 1). Conservative therapy is recommended for at least 2 months in

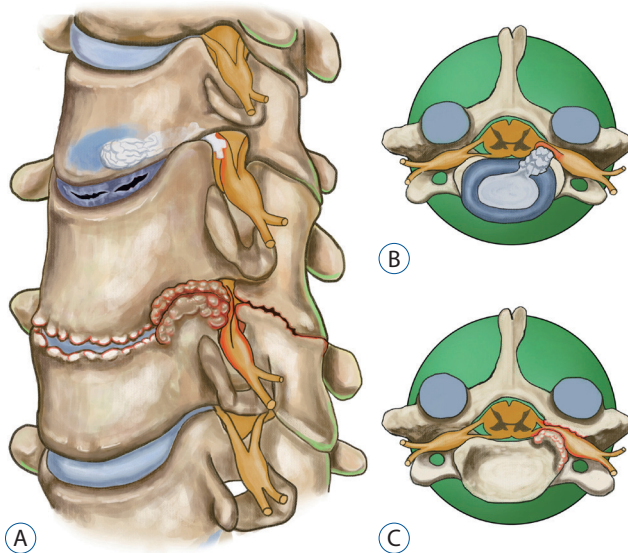


Fig. 1. Illustration showing the causes of cervical spondylotic radiculopathy. A : Indicating disc collapse, disc herniation and osteophyte hyperplasia with osseous foraminal stenosis respectively. B : Cervical disc herniation extruding the nerve root. C : Cervical nerve root compressed by osseous foraminal stenosis.

the treatment of CSR without myelopathy. Surgical decompression should be considered if conservative therapy fails¹¹⁾.

Microscopic anterior cervical discectomy and fusion (ACDF) has been considered as the golden standard treatment for CSR¹⁶⁾. However, the complications attributed to ACDF cannot be ignored although the overall incidence is not high, including symptomatic adjacent disc disease, pseudoarthrosis, instrumentation failure, and ventral approach-related complications, etc.^{5,6,8,15,21)}. Posterior cervical foraminotomy (PCF) with or without discectomy is another classic operation for the treatment of CSR and serves as an alternative to anterior cervical surgery. It has good therapeutic effect similar to that of anterior surgery with the added characteristics, such as avoiding the trouble related to the approach, instrumentation and fusion, preserving motor function and decreasing the incidence of adjacent level degeneration^{1,13,18,20)}.

With the great improvement of percutaneous endoscopic spine surgery during the past several decades, the posterior endoscopic cervical foraminotomy (PECF) has gradually got popular for the treatment of CSR^{7,26,28)}. More and more studies have demonstrated PECF provides equivalent outcomes to microsurgical PCF with better visualization, less soft tissue injury, shorter rehabilitation time and less hospital length of stay^{7,10,19,24,26,28)}.

Endoscopic high-speed drill is the mostly used tool for grinding bone in PECF. Posterior endoscopic cervical discectomy can be performed on the basis of PECF when the ventral

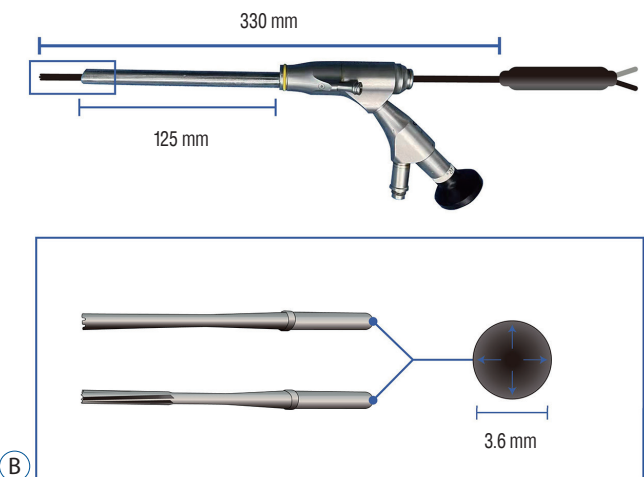
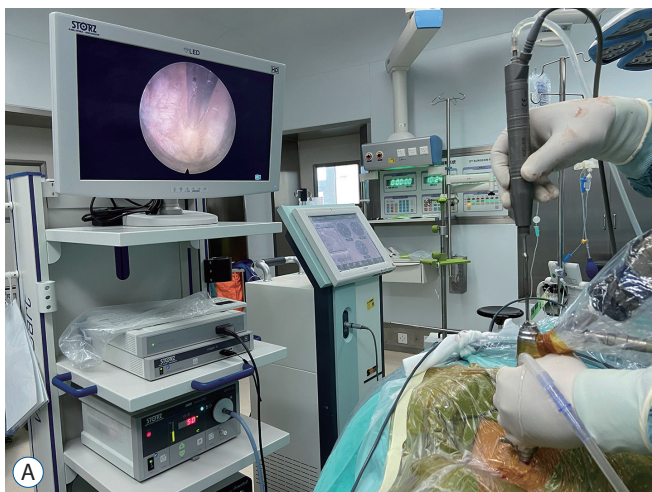


Fig. 2. A : Illustration showing the operating room layout. The host machine of the ultrasonic osteotome is next to endoscopic workstation. The operator is using endoscopic ultrasonic osteotome compatible with endoscopic working channel in PECF. B : Illustration showing ultrasonic osteotome (XD860A SMTP Technology, Beijing, China) profile, including diameter, length, and shape.

compression to the nerve root comes from lateral soft disc herniation (Fig. 1B)²³⁾. It is an ideal model because the surgical decompression to the affected nerve root is direct decompression. However, osseous nerve root canal stenosis is a different condition, usually resulted from hyperplasia of Luschka joint, calcified discs, hyperplastic ligaments and loss of the intervertebral height (Fig. 1A and C); using a high-speed drill to grind these hard lesions in the ventral region of the nerve root and dura is a relatively high-risk manipulation. For this reason, the currently mainstream is dorsal decompression without ventral bony resection. Most of the time, this kind of indirect decompression is enough to alleviate clinical symptoms. However, this method which is less attractive sometime will not achieve famous performance due to insufficient decompression^{22,29)}.

In recent years, the emergence of endoscopic ultrasound osteotome gives a better choice for these cases suffered from osseous nerve root canal stenosis. Ultrasound osteotome is the safest bone cutting tool. It has the property of selective bone-cutting without rotating, bouncing or rolling which can result

in entangling the surrounding soft tissue and injury to surrounding nerve tissue^{2,3,9,14)}. It has been suggested in the literature that ultrasonic osteotome is safer and more accurate and efficient than abrasive drilling^{2,3,9,14,27)}.

From April 2018 and April 2021, we performed PECF using ultrasonic osteotome in 19 patients with cervical osseous nerve root canal stenosis. To the best of our knowledge, this is the first report about ultrasonic osteotome involving PECF (Fig. 2). The purpose of this report is to investigate the efficacy and safety of the PECF using ultrasonic osteotome for the treatment of cervical osseous foraminal stenosis, focusing on introduction of the advantages of ultrasonic osteotome in partial pediculectomy and ventral osteophyte resection in PECF.

MATERIALS AND METHODS

This study complied with the principles of the Declaration of Helsinki. Patients and their guardians have signed in-

Table 1. Characteristics of patients

Case	Sex	Age (years)	Level	Operation time (months)	Bleeding volume (mL)	Incision length (mm)	Hospital stay (days)	Complication
1	M	47	C5/6	55	5	10	2	/
2	M	67	C3/4	45	5	10	2	/
3	M	47	C6/7	50	5	10	3	/
4	F	62	C5/6	70	5	10	3	/
5	F	42	C5/6	60	10	10	2	/
6	F	54	C4/5	48	10	10	3	/
7	M	67	C5/6	53	5	10	2	/
8	F	49	C5/6	50	10	10	3	/
9	F	65	C5/6	60	10	10	3	/
10	F	72	C5/6	55	10	10	2	/
11	M	78	C5/6	58	5	10	3	/
12	M	65	C4/5	70	5	10	3	/
13	F	55	C3/4	60	10	10	3	/
14	M	59	C5/6	50	5	10	3	/
15	F	62	C6/7	48	10	10	2	/
16	M	51	C6/7	42	5	10	2	/
17	F	42	C5/6	50	5	10	2	/
18	F	45	C5/6	51	5	10	2	/
19	M	62	C6/7	45	5	10	3	/

M : male, F : female

formed consent forms for surgery. The study has been approved by the Ethics Committee of Zhongshan Hospital, Fudan University (Institutional Review Board [IRB] approval number 2021-042), as well as Minhang Hospital, Fudan University (IRB approval number 2021-037-01X).

Patient population

Between April 2018 and April 2021, 19 patients with cervical osseous nerve root canal stenosis in our institutions were enrolled in this prospective clinical study. Among the 19 patients, nine were male, and 10 were female; with a mean age of 57.4 years (range, 42–78); there were two cases (10.5%) of C3–4 lesions, two cases (10.5%) of C4–5, 11 cases (57.9%) of C5–6, and four cases (21.1%) of C6–7 (Table 1). All operations were performed by the same senior author, who has specialized training in spinal neurosurgery and robust experience in full-

endoscopic spine surgery.

Inclusion criteria were as follows : 1) single-level CSR, unilateral radiculopathy with arm, neck or shoulder pain consistent with preoperative magnetic resonance imaging (MRI) and computed tomography (CT); preoperative cervical CT reconstruction imaging revealing osseous foraminal stenosis. 2) single-level CSR with unilateral osseous foraminal stenosis who has undergone ACDF surgery. And 3) failure of standard conservative treatment for at least 2 months.

Exclusion criteria were : 1) clear segmental instability or deformities; 2) myelopathy; 3) lateral and medial localization of disc herniation; and 4) more than two-level or bilateral osseous foraminal stenosis.

Endoscopic instruments

The full endoscopic surgical system iLESSYS® Delta (Joimax

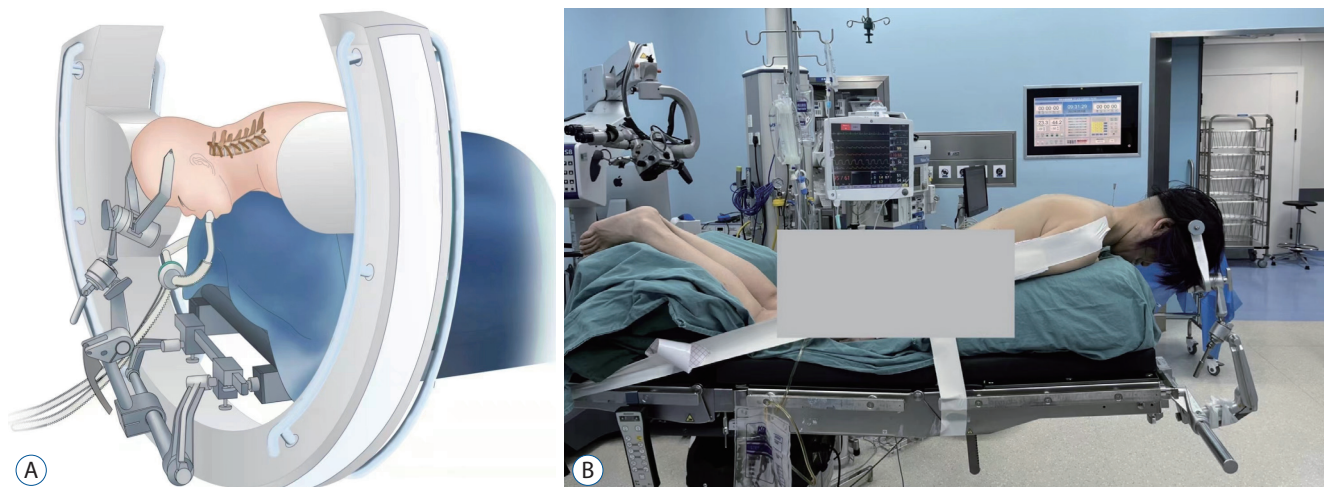


Fig. 3. A : Schematic diagram showing the position of the patient under movable C-arm fluoroscope. B : The patient was placed in the prone position with head fixed in the Mayfield clamp under general anesthesia.

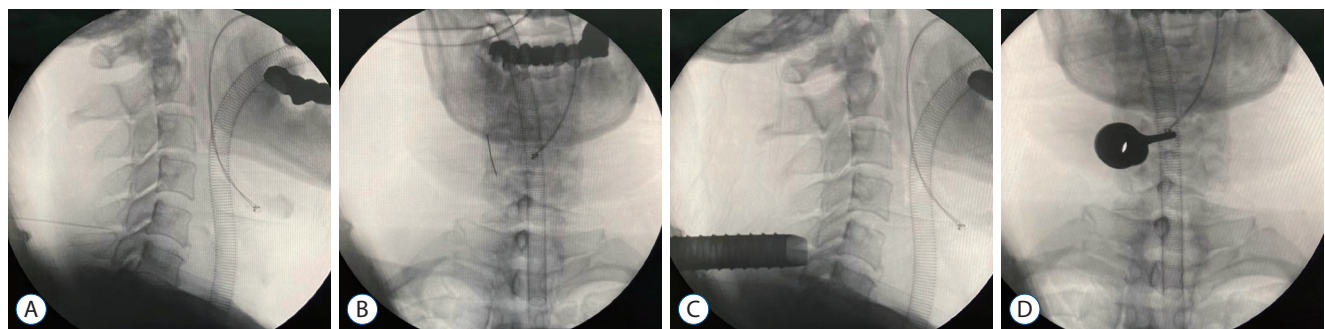


Fig. 4. A : Lateral fluoroscopy showing the spinal needle was introduced to touch the bone, which is C5-6 facet joint. B : Anteroposterior fluoroscopy showing the tip of needle was located in projection of pedicle. C and D : The position of the working cannula was controlled radiologically in anteroposterior and lateral position; (C) lateral view and (D) anteroposterior view.

GmbH, Karlsruhe, Germany) and ultrasonic osteotome device (XD860A; SMTP Technology, Beijing, China) was applied to perform the surgery. The Delta system includes an endoscope, endoscopic sheaths, nucleus pulposus clamp, and laminectomy rongeurs. The radiofrequency probe (Trigger-Flex® Bipolar System; Elliquance LLC, Baldwin, NY, USA) was utilized to control bleeding and ablate.

The ultrasonic osteotome device is made by SMTP Technology Co., Ltd located in Beijing Zhongguancun National Independent innovation demonstration center. The diameter of the ultrasonic osteotome is 3.6 mm, and the length of the ultrasonic osteotome is 330 mm. It can be matched with the spinal endoscope system which has working channel more than 3.6 mm in diameter (Fig. 2B).

Clinical evaluation

Operative time, hospitalization time, and complications were recorded. Visual analog scale scores for neck and arm pain, Japanese Orthopaedic Association (JOA) scores and Neck disability index (NDI) scores were evaluated preoperatively and on the second day, 3, 6, and 12 months postoperatively. MacNab criteria was used to evaluate surgical effectiveness.

Statistical analysis

SPSS ver. 23.0 (IBM SPSS Statistics, Chicago, IL, USA) was used to study data for statistical analysis. For continuous variables that conform to the normal distribution, the visual analogue score (VAS) score, JOA score and NDI are expressed as mean±standard deviation; the VAS score, JOA score and NDI

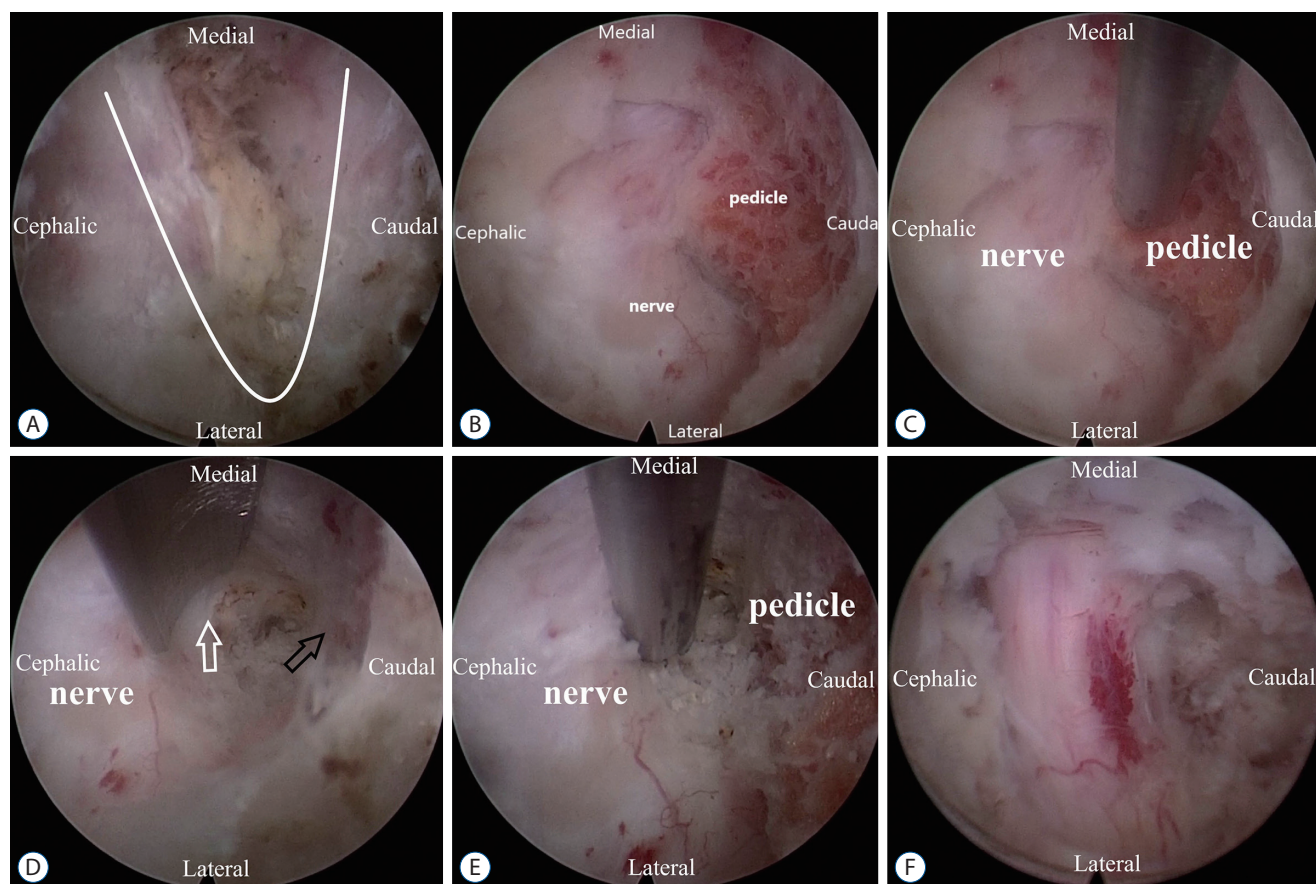


Fig. 5. Intraoperative endoscopic view of representative case 1. A : The “V-point” structure was identified. B : The C7 pedicle was identified which located inferior of the left C7 nerve root. The pedicle was close and at same level to root and dura. Using high-speed drill here was dangerous. C : Endoscopic ultrasound osteotome was used to perform partial pediculectomy. D : The ventral osteophyte was exposed after partial pediculectomy (white arrow represented hyperplasia of Luschka joint, black arrow represented the space which the original position of the pedicle located and now be removed). E : The ventral osteophyte was handled by ultrasonic osteotome without significant neural retraction. F : The C7 nerve root was fully decompressed and freed.

at different time points were compared using repeated-measures analysis of variance. $p < 0.05$ was considered to be statistically significant.

Surgical procedure

General anesthesia was used for all the patients. The patient was placed in a prone position with head fixed with Mayfield clamp. The neck was slightly flexed, and the shoulders were pulled downward with wide tape for intraoperative lateral fluoroscopy (Fig. 3).

The patient was routinely sterilized and draped. Under fluoroscopic guidance, an 18-gauge spinal needle was introduced to touch the bone, which is lateral facet joint on the lesion side of the target segment (Fig. 4A and B). Then the spinal needle was replaced with a guidewire. A 10-mm stab wound was made centered the guide wire in the skin. The paravertebral muscles and fascia were dilated gradually by soft-tissue-dila-

tors. The dilator could be used to slightly strip the muscles from laminar. Then the 10 mm delta working cannula with oblique mouth was inserted. The final position of working cannula was controlled radiologically in anteroposterior and lateral position (Fig. 4C and D). Finally, the endoscopic surgical system was introduced and all the subsequent steps were performed under constant irrigation with excellent endoscopic visualization.

After the soft tissues overlying the facet joint and laminae was cleaned using the tissue forceps and a bipolar radiofrequency probe, the “V-point” structure was identified, which is formed by two adjacent laminae and the affected facet joint (Fig. 5A). The endoscopic ultrasound osteotome was applied to resect bone tissue including partial lamina and medial half of the facet joint. The ligamentum flavum and affected nerve root was identified (Fig. 5B). In this step, the ligamentum flavum was kept *in situ* to prevent bleeding and protect dura.

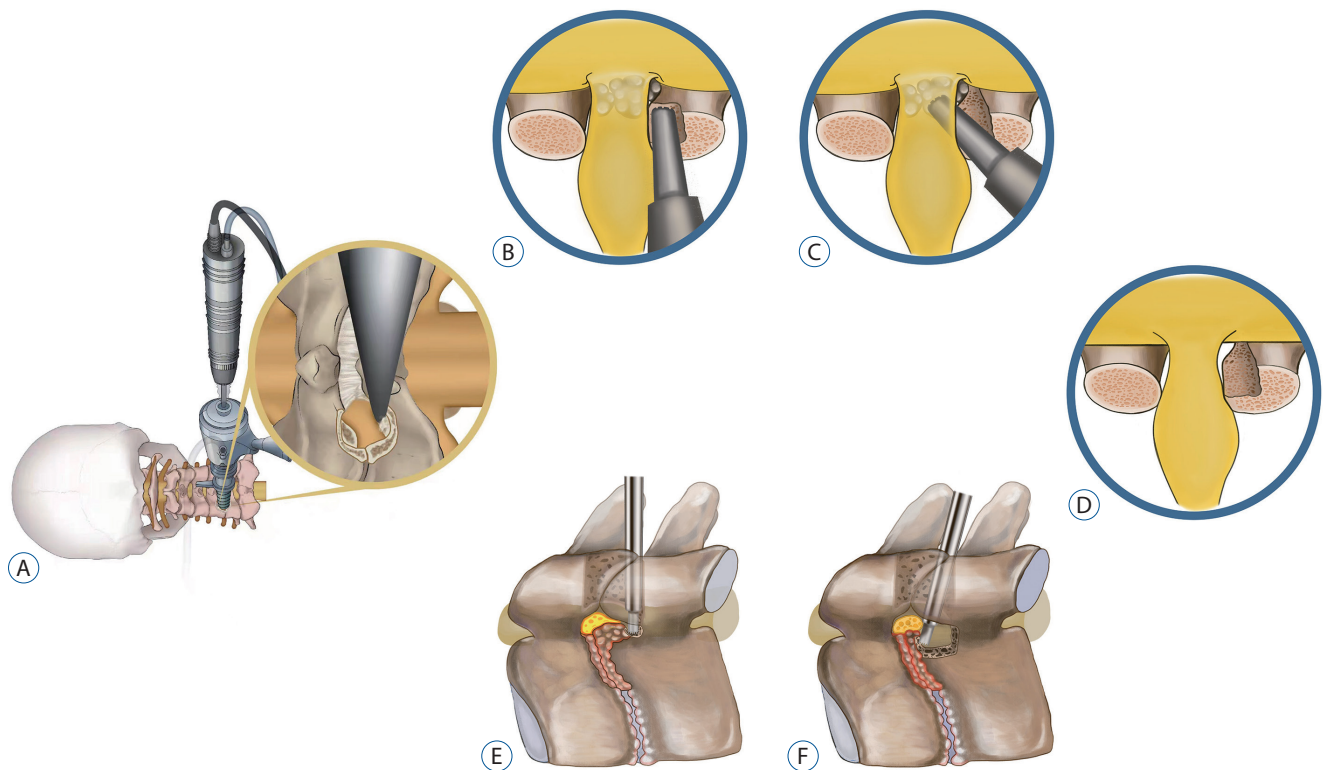


Fig. 6. Illustrations showing the application of endoscopic ultrasonic osteotome in posterior endoscopic cervical foraminotomy. A : Showing the application of endoscopic ultrasonic osteotome compatible with endoscopic working channel and the “key hole”. B-D : Illustrations showing the top view of application of ultrasonic osteotome. B : Endoscopic ultrasound osteotome was used to perform partial pediclectomy to enlarge the operation space. C : The ventral osteophyte could be handled by ultrasonic osteotome. D : The affected nerve root was 360° decompressed safely. E and F : Illustrations showing the side view of application of ultrasonic osteotome. E : After resection of medial half of the facet joint, endoscopic ultrasound osteotome was used to perform partial pediclectomy to enlarge the operation space. F : The ventral osteophyte could be handled by ultrasonic osteotome.

Endoscopic ultrasound osteotome was continue used to perform partial pediculectomy to enlarge the operation space (Figs. 5C, 6B and E), especially in the condition that the intervertebral height was lost and the distance between the upper and lower pedicle was significantly reduced (Fig. 7B and C). The working cannula was shifted toward the subneural working space (Fig. 5D). The ventral osteophyte could be handled by ultrasonic osteotome without significant neural retraction

(Figs. 5E, 6A, C, and F). After the completion of bony decompression, the ligamentum flavum and bands around neural elements were removed. The full decompression was confirmed with free mobilization of the nerve root (Figs. 5F, 6D, and 7D). Then, the endoscopic operation system was removed and the skin was closed with a single stitch. There was no drainage was needed.

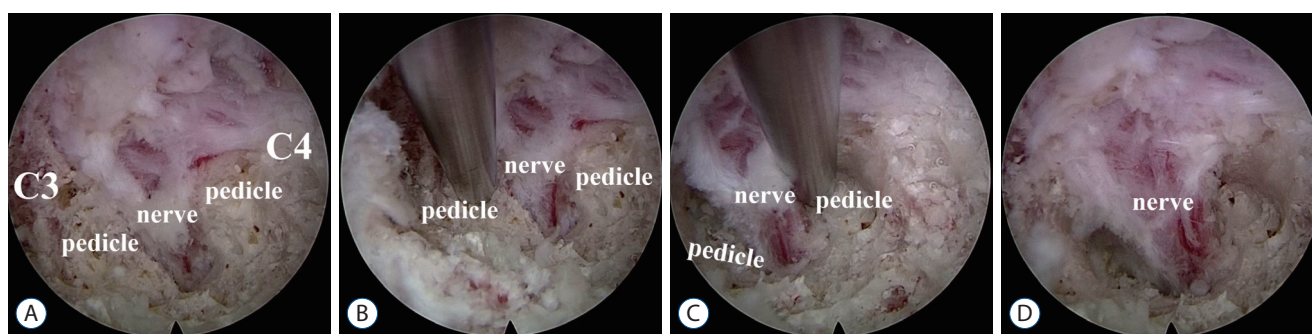


Fig. 7. Intraoperative endoscopic view of representative case 2. A : Left C4 nerve root was exposed which located within narrowed C3-C4 intervertebral foramen. The distance between the upper and lower pedicle was significantly reduced. B : Endoscopic ultrasound osteotome was used to perform partial C3 pediculectomy (at the same level with C4 nerve root). C : Endoscopic ultrasound osteotome was used to perform partial C4 pediculectomy and partial vertebral body resection (this location is below the level of the nerve root). D : The left C4 nerve root was fully decompressed and freed.

Table 2. Preoperative and postoperative scores of 19 patients with cervical osseous nerve root canal stenosis

Time	Neck and arm VAS scores	JOA scores	NDI (%)
Preoperative	7.1±1.1	12.68±1.49	58.6±8.3
Postoperative			
2 days	2.2±0.8	17.21±1.47	32.8±6.7
3 months	2.1±0.8	17.42±1.64	31.7±6.3
6 months	1.8±1.0	17.74±1.97	31.0±7.8
12 months	1.6±0.7	19.37±2.27	30.7±7.4
F value	133.00	67.53	168.57
p-value	<0.001	<0.001	<0.001

Values are presented as mean±standard deviation. VAS : visual analogue score, JOA : Japanese Orthopaedic Association, NDI : Neck disability index

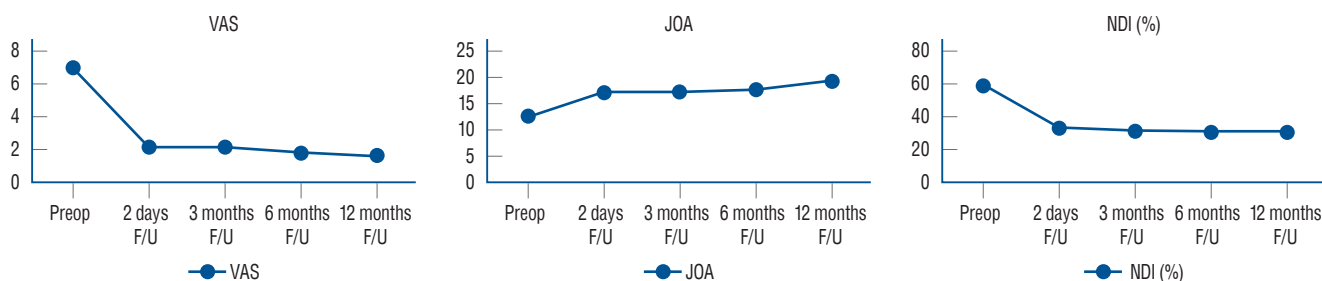


Fig. 8. During the follow-up time, the neck and arm VAS scores, JOA scores and the NDI improved significantly. VAS : visual analogue score, preop : preoperative, F/U : follow-up, JOA : Japanese Orthopaedic Association, NDI : Neck disability index.

RESULTS

Demographic data

The patient's basic information and operative characteristics are summarized in Table 1. The average operative time was 54 minutes (range, 42–70). The average hospital stay was 2.55 days (range, 2–3). Among the 19 patients, there were no surgery-related complications, such as nerve injury, cerebrospinal fluid (CSF) leakage, and wound infection.

Clinical outcomes

All 19 patients underwent successful surgery and completed

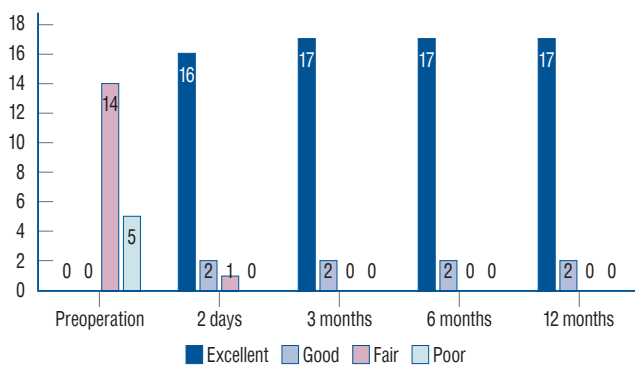


Fig. 9. Clinical results according to the modified MacNab criteria.

the follow-up visits for up to 12 months. As time went by, the change of the VAS score, the JOA and the NDI was shown in Table 2 (F values were 133.003, 67.529, 168.568, respectively; all $p < 0.001$). The differences in the scores before and after surgery were statistically significant ($p < 0.001$; Table 2 and Fig. 8). All 19 patients showed satisfactory effects according to the modified MacNab criteria at the last follow-up visit (Fig. 9).

Postoperative management

The patients were allowed to ambulate with neck brace after 8 hours of bed rest. Symptomatic medication treatments, aiming to eliminate swelling and pain, were routinely applied postoperatively. The patients were instructed in rehabilitation training and followed regularly. In our institution, patients would be advised to wear neck braces for 1 week and participate in normal activities 2 weeks postoperatively.

Perioperative complications

There were no severe surgery-related complications, such as nerve root injury, dura tears, hematoma, CSF leakage, or wound infections were observed. Two cases had transient paresthesia after surgery, which disappeared in 2 to 3 weeks. There were no cases of cervical instability, cervical pedicle fracture and further recurrence at the time of the final follow-up.

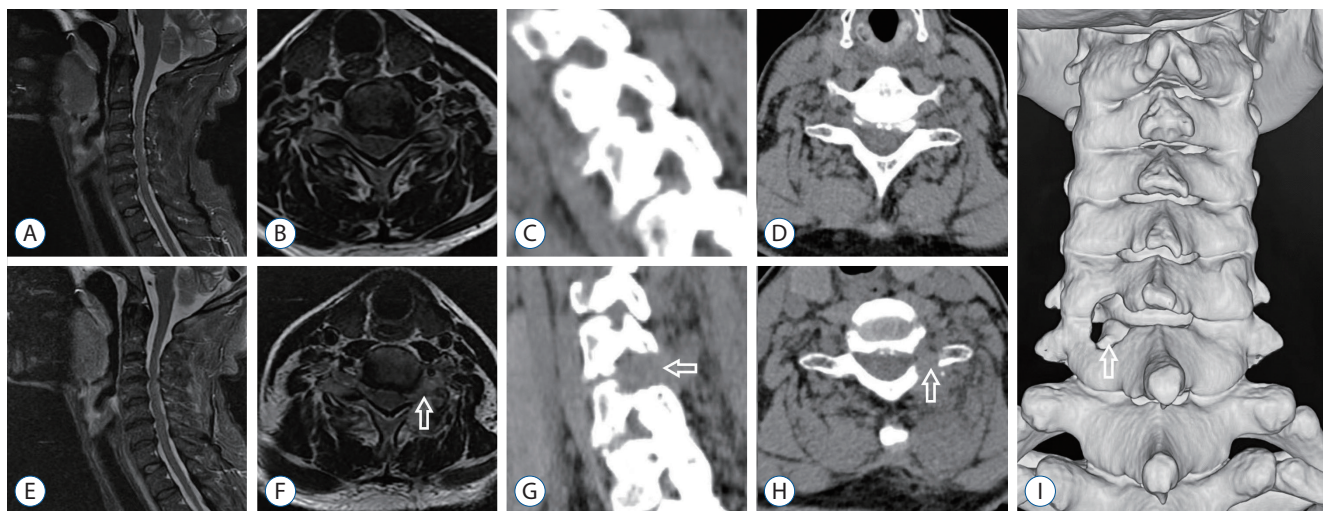


Fig. 10. The preoperative and postoperative imaging data of representative case 1. A, C, and G : Preoperative magnetic resonance imaging (MRI) and computed tomography (CT) studies showed osseous foraminal stenosis at the left side of the C6/7 level. B, D, and H : Postoperative MRI and CT image showed removal of the ventral osseous and decompression of the nerve root (arrow in D and H represented the intervertebral foramen has been enlarged). E : Preoperative CT reconstruction scan showed severe hyperplasia of Luschka joint with narrowing of the left C6-C7 foramen. F : Postoperative sagittal CT reconstruction showed the enlargement of C6-C7 intervertebral foramen (arrow) with partial pediclectomy and ventral osseous removal. I : The 3D reconstruction showed the keyhole (arrow) decompression range, which preserved the facet joint more than 50%.

Representative cases

Case 1

A 62-year-old woman presented with neck, shoulder and left arm pain radiating to the two fingers on the ulnar side about 3 months. She received several conservative treatment measures during the 3 months include medication, physical therapy, Chinese acupuncture and local anesthetic injection. However, her daily activities were seriously disturbed due to the pain had not been controlled effectively. When hospitalization, she rated the pain 9/10 on VAS scale. Preoperative MRI and CT revealed osseous foraminal stenosis at the left side of the C6/7 level. The patient underwent PECF using ultrasonic osteotome to remove part of facet joint, part of pedicle and ventral osteophyte. After the direct and sufficient C7 nerve root decompression, the pain was effectively relieved, with a VAS score of 1/10. Postoperative MRI demonstrated removal of the ventral osseous and decompression of the nerve root. Postoperative CT 3D reconstruction showed the keyhole decompression range, which preserved the facet joint more than 50% (Figs. 5 and 10).

Case 2

A 67-year-old man presented with left neck and shoulder pain 3 years combined with left arm pain and numbness. He had undergone ACDF surgery two times by other surgeons. One was C3-4 and the other was C5-6. He rated the pain 9/10 on VAS scale and his daily activities were seriously disturbed. Physical examination showed the decreased cervical motive range, left C3-C4 paravertebral tenderness and pain spreading to the left arm. Huffman sign was negative in bilateral hand. Preoperative MRI and CT 3D reconstruction images revealed osseous foraminal stenosis at the left side of the C3/4 level due to cage subsidence and insufficient decompression. For this complicated case, selective nerve root block (SNRB) to the C4 nerve root was performed to further clarify the diagnosis. The pain decreased more than 70% after SNRB, and the duration was about 4 hours. Hence, the patient underwent PECT using ultrasonic osteotome to remove part of facet joint, part of pedicle and ventral osteophyte at the left C3/4 level. After the procedure, the pain decreased sufficiently, with a VAS score of 2/10. Intraoperative endoscopic photos showed the 360° decompression of C4 nerve root. Postoperative MRI scans and CT 3D reconstruction demonstrated removal of the osseous

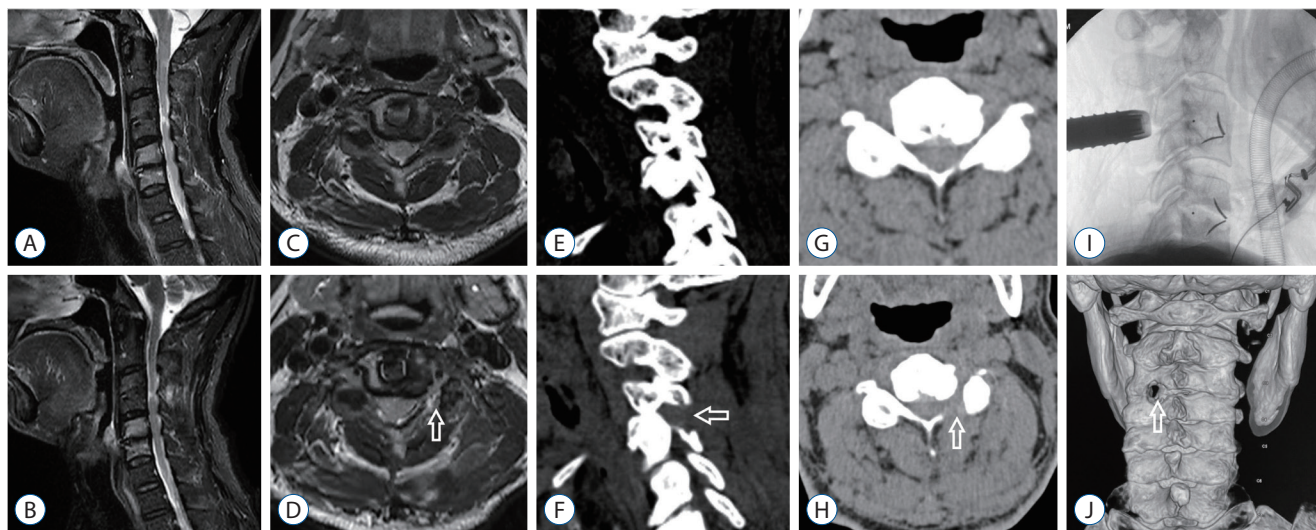


Fig. 11. The preoperative and postoperative imaging data of representative case 2. A, C and G : Preoperative magnetic resonance imaging (MRI) and computed tomography (CT) reconstruction images showing osseous foraminal stenosis at the left side of the C3/4 level due to cage subsidence and insufficient decompression. B, D, and H : Postoperative MRI and CT image showed removal of the osseous and decompression of the nerve root (arrow in D and H represented the intervertebral foramen has been enlarged). E : Preoperative sagittal CT reconstruction scan showing intervertebral height was lost and the distance between the upper and lower pedicle was significantly reduced with narrowing of the left C3-C4 foramen. F : Postoperative sagittal CT reconstruction shows the left C3-C4 intervertebral foramen (arrow) was enlarged with partial pediclectomy and ventral osteophyte removal. I : The position of the working cannula was controlled radiologically in the lateral position. J : The 3D reconstruction showed the keyhole decompression range, which preserved the facet joint more than 50%.

and decompression of the nerve root (Figs. 7 and 11).

DISCUSSION

Ultrasonic osteotome is a new type of bone-cutting tool based on piezoelectric high-frequency mechanical vibration, which utilizes a back and forth micromotion rather than high-speed rotation to allow precise removal of bone tissue without entangling the surrounding soft tissue¹⁴⁾. The energy can be preferentially transmitted to bone from the cutting edges of ultrasound osteotome. Hence, it has the property of selective bone-cutting without damaging adjacent soft tissue^{2,3,9,14,27)}. Ultrasonic osteotome has been applied in open spine surgery for some time, as well as in the fields of skull base surgery, otolaryngology, maxillofacial surgery, etc.^{14,27)}. In addition, the ultrasonic osteotome is stable and not easy to slip during operation without resulting in accidental injury to the surrounding tissue. At this point, it is superior to high-speed drill, which relies on a high-speed rotating bit to grind bone tissue. However, endoscopic ultrasound osteotome need to be specially designed to be slim and long enough to match the channel requirements of percutaneous endoscopic spine surgery. Fortunately, we now have this excellent weapon, which has been verified in our case series.

In PECF, bone tissues need to be resected may include lamina, facet process, pedicle and uncinat process, which are located on the dorsal, horizontal and ventral sides of nerve ele-

ments respectively. In terms of dorsal-located lamina and facet process resection, we believe that the high-speed drill is fully competent in the hands of experienced surgeons^{10,12,19,23,24,26)}. As for the pedicle and uncinat process, which are horizontal located and ventral located respectively relative to the nerve root and dura sac, it is dangerous to grind the hard bony structure (Fig. 12). Inadvertent slippage of high-speed rotating drill bit and involvement of nerve elements will be a great disaster. Just because of this, the current mainstream is dorsal indirect decompression without ventral bony resection for cervical osseous nerve root canal stenosis, which is a less attractive choice to avoid above risks^{12,29)}.

Thanks to the property of endoscopic ultrasound osteotome, we can securely resect part of the pedicle which is very close to the nerve root without worrying about to damage it (Fig. 6B and E). Partial pediculectomy can provide sufficient space to reach the posterior wall of the vertebral body. We can further remove part of vertebral if necessary to create more space. Partial pediculectomy enable us to have adequate space and get an appropriate angle to the ventral side of nerve root and lateral dura sac through the axillary or shoulder of the root without need of excessive root traction^{10,24)} (Fig. 6C and F). In our case series, postoperative images demonstrated ventral bony decompression had been achieved successfully in all the patients using ultrasound osteotome. The representative case 2 in this report is difficult to handle. The patient had severe C3-4 osseous foraminal stenosis after ACDF surgery two times because of cage subsiding and unsuccessful decompres-

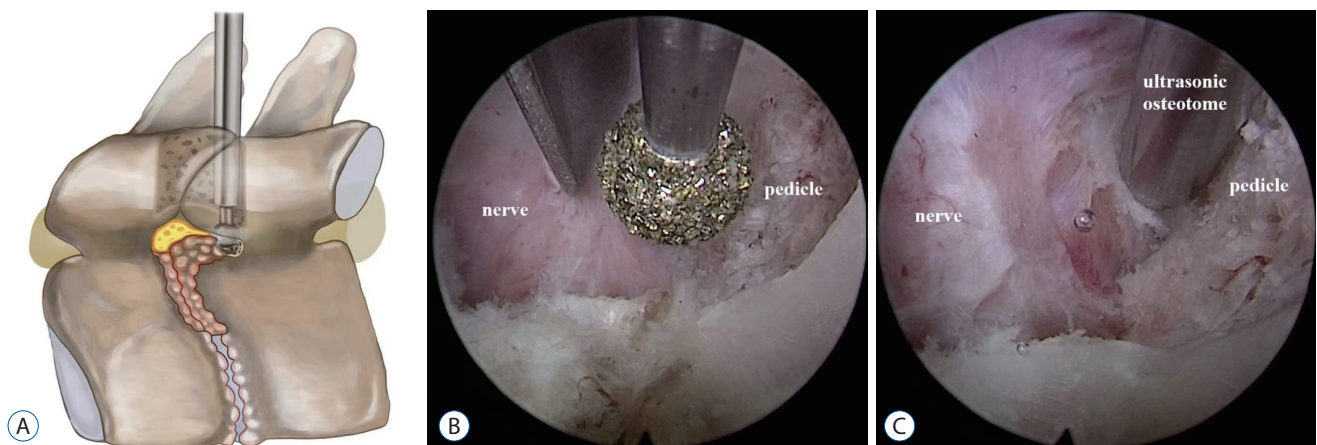


Fig. 12. Illustration showing the pedicle and the nerve root are in the same level. It is dangerous when the high-speed rotating bit bounce or slip, resulting involvement of nerve elements. A : So, the nerve root and dural sac should be pushed away. Even so, the risk remains. Moreover, excessive pushing will also cause damage to the nerves. B : On the contrary, endoscopic ultrasound osteotome has advantages in this respect. It can help us securely resect part of the pedicle without worrying about to involve nerve elements (C).

sion (Fig. 7A). The osseous stenosis is 360° surrounding the nerve root. Using ultrasonic osteotome, we achieved 360° decompression of the affected nerve root safely. Moreover, it is worth mentioning there was no dura and nerve root injury associated with bone cutting in our cases. It has been reported in the literature that nerve structures injury occurred in the resection procedure of pedicle and/or ventral bony lesion^{10,24,29}.

Some scholars may query that the ventral bony lesions do not need to be removed in the treatment to CSR. Oh et al.¹⁷ reported that 12 of 101 CSR patients (11.9%) experienced poor surgical effect who underwent PECF which is indirect dorsal decompression. Among them, seven patients had to undergo anterior revision surgery to remove nerve ventral osteophytes. Tong et al.²² retrospectively compared the surgical effect of indirect dorsal decompression group and direct ventral bone decompression group in the treatment of CSR caused by osseous intervertebral foramen stenosis. The clinical excellent and good rates were 60.87% in the former and 91.29% in the latter. These experiences indicated that adequate ventral decompression was still necessary. The clinical excellent rates in our series were 90% (17/19), which is corresponded to the reported conclusion. Furthermore, there were no surgery-related complications in our series. There were no cases of cervical instability, cervical pedicle fracture and further recurrence during follow-up.

The main disadvantage of endoscopic ultrasonic osteotome is that the price is too expensive nowadays. The main reason is that there are not many manufacturers of endoscopic ultrasonic osteotome. In addition, endoscopic ultrasonic osteotome with different tip shapes should be designed to meet the needs of different clinical operations. We believe these problems will be solved with the development of science and technology.

Limitations

To the best of our knowledge, this is the first report about endoscopic ultrasonic osteotome involving PECF. The limitation of this article is obvious, which is a prospective observational cohort study without large sample size and long follow-up time enough. However, the purpose of this report is to introduce the feasibility of endoscopic ultrasonic osteotome in partial pediculectomy and ventral osteophyte resection in PECF. We believe that it can be used as a reference for other

doctors who are going to employ this technique.

CONCLUSION

Adequate nerve root decompression can be accomplished successfully with the help of ultrasonic osteotome in PECF, which has the advantage of reducing the probability of damage to the nerve root and dura mater, in addition to the original merits of endoscopic surgery.

AUTHORS' DECLARATION

Conflicts of interest

No potential conflict of interest relevant to this article was reported.

Informed consent

Informed consent was obtained from all individual participants included in this study.

Author contributions

Conceptualization : YY, YJ; Data curation : YJ, CL; Formal analysis : CL; Funding acquisition : LY; Methodology : YJ; Project administration : YM; Visualization : YJ, CL; Writing - original draft : YJ, CL; Writing - review & editing : YY, YJ

Data sharing

None

Preprint

None

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