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ORIGINAL ARTICLE

# Minimally invasive cervical foraminotomy and diskectomy for laterally located soft disk herniation

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**Abstract**

*Purpose* The posterior cervical foraminotomy and diskectomy (PCD) is a traditional surgical technique for patients with laterally located soft-disk herniation. Recently, tubular retractor-assisted posterior foraminotomy and diskectomy (MTPF) and posterior percutaneous endoscopic cervical foraminotomy and diskectomy (P-PECD) have been introduced, but a comparative study has not yet been performed.

*Methods* Patients with foraminal soft-disk herniation and a follow-up period of >2 years were retrospectively reviewed; 22 patients underwent a MTPF and 22 patients underwent a P-PECD. The primary end-point was an improvement of arm pain more than 4.3. The clinical parameters (age, sex, disability index, neck and arm pain), radiological parameters (cervical curvature, segmental angle, anterior-/posterior-disk height and amount of facet joint removal) preoperatively and at postoperative month 24 and the surgical methods were considered as co-variates.

*Results* Successful outcome was achieved in 19/22 (87 %) of the patients after both MTPF and a P-PECD. Preoperative SA showed trend ($P = 0.08$; OR 1.2; 95 % CI 0.98–1.4) and the cut-off SA was 1.45° (sensitivity 80 %, specificity 73 %). The length of the facet joint's removal was 0.02–2.49 mm (0.1–15.2 %) with no difference between the MTPF and P-PECD. The surgical method was not a significant factor.

*Conclusions* For patients with foraminal soft-disk herniation, either MTPF or P-PECD, may be regarded as an alternative options to open surgery. Preoperative kyphotic SA (cut-off value 1.45°) seemed to be associated with poor outcome and this may be considered in selecting surgical methods.

**Keywords** Cervical vertebrae · Disk · Percutaneous · Tubular retractor · Endoscopes

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## Introduction

The anterior cervical diskectomy and fusion (ACDF) is regarded as a standard surgical technique for cervical disk degenerative disease, but problems associated with the instrumentation and with fusion have led to the adoption of a motion preservation surgery. However, the use of artificial disks does not appear to address these issues because various problems, such as heterotopic ossification, mechanical failure and spontaneous fusion, have been reported [1–4]. Although it is not applicable for every case, a surgical technique without fusion or instrumentation,

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such as the anterior or posterior foraminotomy and diskectomy, may be another option for patients with foraminal soft-disk herniations [5–13]. The posterior cervical foraminotomy and diskectomy (PCD) is a well-known traditional surgical technique with successful outcomes in patients with radicular pain due to a laterally located herniated disk [12, 14–18]. Recently, a minimally invasive surgery that uses a tubular retractor or a full-endoscopic system has been introduced [7, 10, 14, 19–22]. Retrospective comparative studies have shown outcomes after the microscopic tubular retractor-assisted posterior microforaminotomy (MTPF) that are comparable to the outcomes for the conventional PCD, but the duration of the hospital stay, blood loss, postoperative analgesic use and postoperative neck pain were lower after the MTPF [10, 16]. Another minimally invasive technique, the posterior percutaneous endoscopic cervical foraminotomy and diskectomy (P-PECD), has now been introduced, with acceptable outcomes [7, 19, 21, 22]. However, a comparative study between MTPF and P-PECD has not yet been performed. Theoretically, the trauma to the soft tissue may be minimized with a P-PECD with the assistance of magnification and fine endoscopic instruments, but the effectiveness was questionable [7, 16]. The objective of the present study was to analyze the clinical outcomes after either an MTPF or P-PECD.

## Materials and methods

### Patients

After obtaining permission from the Institutional Review Board, the medical records of 24 consecutive patients who underwent a posterior percutaneous endoscopic cervical foraminotomy and diskectomy (P-PECD) between May 2010 and August 2012 were retrospectively reviewed. The P-PECD was performed for patients with a single-level cervical foraminal soft-disk herniation without spinal cord compression and facet joint degeneration [23]. The degree of the degeneration of the disk was evaluated with T2-weighted sagittal magnetic resonance (MR) imaging as described by Pfirrmann et al. [24], and grades of I, II and III (inhomogeneous structure of the disk with an intermediate, gray signal intensity with a preserved disk height) were considered to be acceptable for a posterior-PECD, if indicated [16, 23]. The patients with pure neck pain, gross cervical instability, symptomatic central disk herniation and ossification of the posterior longitudinal ligament were excluded [12, 23]. For the comparison, consecutive patients who underwent a microscopic tubular retractor-assisted posterior foraminotomy and diskectomy (MTPF) between March 2005 and August 2011 with the same indications were located, and 34 of these patients met the criteria. The P-PECD and MTPF were each performed by a different surgeon in separate hospitals. Other surgeries, such as anterior discectomy or artificial disk replacement, were not performed for the same indication within the same period (24 P-PECDs in Seoul National University Hospital by CHK, and 34 MTPFs in Kyungpook National University Hospital by KTK). Of the patients included in the present study, 22/24 (92 %) of the patients who underwent a P-PECD and 22/34 (65 %) of the patients who underwent an MTPF were followed-up for at least 2 years.

Preoperatively, magnetic resonance (MR) imaging and plain radiographs (standing anterior–posterior, lateral neutral, flexion and extension) were obtained. The patients were asked to stand and look straight ahead during the neutral radiography. All of the patients completed a questionnaire to determine their neck disability index (NDI /50) [25] and the visual analogue pain score for the neck (Neck-VAS /10) and arm (Arm-VAS /10). The characteristics of the patients are shown in Table 1.

All of the patients who underwent a P-PECD were discharged the day following the operation, and the patients who underwent an MTPF were discharged 2–3 days after the operation. Neck collars were not used in any of the patients, and free neck motion was encouraged. The patients were scheduled to visit the outpatient clinic at 1, 3, 6 and 12 months postoperatively, as well as yearly thereafter. At each visit, the patients were asked to complete the same questionnaire described previously, and plain radiographs, including dynamic images, were obtained at 6, 12 months, and yearly thereafter following the same protocol. To assess the functional outcomes, the minimal clinically important change of the Arm-VAS was set at 4.3, and that of the NDI 10.5, in accordance with the previous literature [26].

## Surgical methods

### MTPF

The surgical technique for the MTPF was the same as previously reported [11, 16, 27]. All of the operations were performed under general anesthesia with the patient in a prone position using three-point pin fixation devices with a table-mounted holder (Mayfield® system, Intergra, Painsboro, JN). The tubular muscle dilators were placed serially after making 2 cm skin incision. A final working channel (either a 16-mm or an 18-mm tubular retractor) was placed over the dilators and fixed over the lamina-facet junction with a table-mounted flexible retractor arm, and the dilators were removed. All procedures were performed with the fluoroscopic guidance. Under the surgical microscope, a

**Table 1** Characteristics of patients

| | MTPF ($N = 22$) | P-PECD ($N = 22$) | Total | $P$ value |
|---|---|---|---|---|
| Sex (M:F) | 16:6 | 15:7 | 31:13 | |
| Age | 56.3 ± 8.2 | 44.7 ± 10.6 | 48.3 ± 15.0 | <0.01 |
| Level | | | | |
| C4–5 | 1 | 1 | 2 | |
| C5–6 | 9 | 10 | 19 | |
| C6–7 | 9 | 10 | 19 | |
| C7–T1 | 3 | 1 | 4 | |
| Side (R:L) | 12:10 | 16:6 | 28:16 | |
| NDI | 22.6 ± 6.5 | 23.8 ± 9.5 | 22.2 ± 9.2 | 0.99 |
| Neck-VAS | 7.3 ± 1.4 | 5.8 ± 1.8 | 6.5 ± 1.7 | 0.003 |
| Arm-VAS | 7.7 ± 1.1 | 6.9 ± 1.8 | 7.3 ± 1.5 | 0.07 |

*MTPF* microscopic tubular retractor-assisted posterior microforaminotomy, *P-PECD* posterior percutaneous endoscopic cervical foraminotomy and discectomy, *Arm-VAS* arm visual analogue pain score of arm, *Neck-VAS* visual analogue pain score of neck

partial hemilaminectomy and foraminotomy with a partial facetectomy of the target level was performed using high-speed drills. The ruptured fragments were removed from the axilla (22/22) of the nerve root. After the operation, a closed suction drain was inserted through the working channel, and the wound was closed in a layer-by-layer fashion. The drain was removed 1-2 days after the surgery.

## P-PECD

The surgical techniques used were similar to those previously reported [7, 21–23]. All of the operations were performed under general anesthesia with the patient in a prone position using three-point pin fixation devices with a table-mounted holder (Mayfield® system, Intergra, Painsboro, JN) or in craniocervical traction using a Gardner-Wells tong skeletal fixation system. After a skin incision of 8 mm was made above the medial junction of the inferior and superior facet joints with an intraoperative orthogonal fluoroscopic image, the oblique-type working channel (7.9 mm outer diameter) was introduced on the obturator, and the endoscope (Vertebris®, Richard Wolf GmbH, Knittlingen, Germany) was introduced. After identifying the margin of the superior laminar, inferior laminar and medial point of the facet joint (V-point) [23], the inferior lamina, superior lamina and facet joint were drilled with full-endoscopic instruments [7, 22]. The size of the bony drilling was dependent on the size and location of the herniated disk material, and it was usually within a 3–4 mm radius around the V-point. The ruptured fragments were identified from the axilla (21/22) or shoulder (1/22) of the nerve root. After the operation, a closed suction drain was inserted through the working channel and the wound was closed with two sutures. The drain was removed the following day.

## Radiological evaluation

The radiological parameters obtained at preoperation and postoperative 2 years were measured; including the cervical curvature (CA, C2–7, tangential method), the segmental Cobb's angle at the operative level (SA) and the actual anterior/posterior height from the superior endplate of the cephalic vertebra to the inferior endplate of the caudal vertebra (AH and PH) (Fig. 1) [23, 28, 29]. The negative angles indicated lordosis. The actual AH and PH lengths were calculated using CT scans or MR images (Fig. 1). The range of motion (ROM) of the CA and SA was calculated from the extension and flexion lateral radiographs, and the change between the values preoperatively and at 24 months postoperatively was compared. The amount of facet removal was assessed using either the computed tomography (CT) scan or MR images that were taken within postoperative month 1 (Fig. 2). All of the measurements were performed by a research nurse who was blinded to the clinical outcome.

## Statistical analysis

The present study focused on the clinical outcomes after each surgical method, and the primary end-point was an improvement of Arm-VAS more than 4.3 at 24 months [26]. The clinical parameters (age, sex, NDI, Neck-VAS and Arm-VAS), radiological parameters (CA, SA, AH/PH and ROM of CA/SA) at preoperation and at postoperative month 24, the amount of facet joint removal, and the surgical method (MTPF or P-PECD) were considered as co-variates. Mann–Whitney's $U$ test and the Chi square test were used for the univariate analysis. The significant factors obtained from the univariate analysis were put into a multi-variate analysis with a linear logistic regression

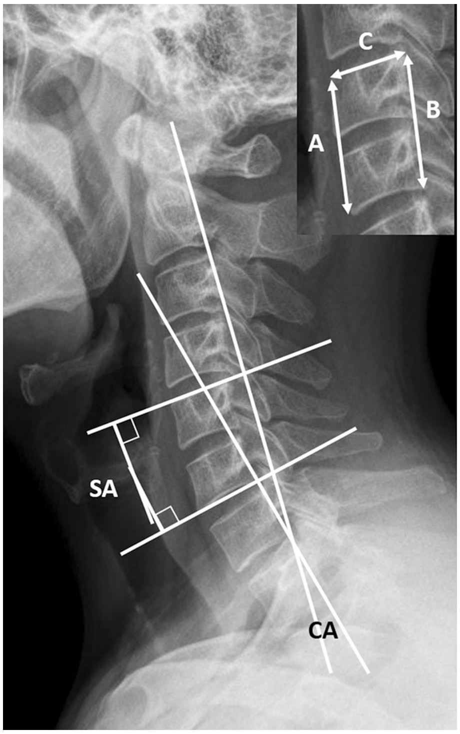


**Fig. 1** Radiological measurements. The cervical curvature is measured using the tangential method from C2 to C7. The segmental angle (*SA*) is measured from the superior endplate to the inferior endplate of the cephalic and caudal vertebra using Cobb's method. To calculate the anterior (AH) and posterior height (PH) between the cephalic and caudal vertebra, the length between the anterior/superior corner and anterior/inferior corner of the cephalic and caudal vertebrae was measured (*A*) using plain radiographs. Similarly, the length from the posterior/superior to the posterior/inferior corner of the vertebrae was measured (*B*) using plain radiographs. The length of the superior endplate of the cephalic vertebra was measured using plain radiographs (*C*) and computed tomography scans (actual *C*). The actual lengths of *A* (AH) and *B* (PH) were measured using the following formula: $AH = A \times (\text{actual } C/C)$; $PH = B \times (\text{actual } C/C)$

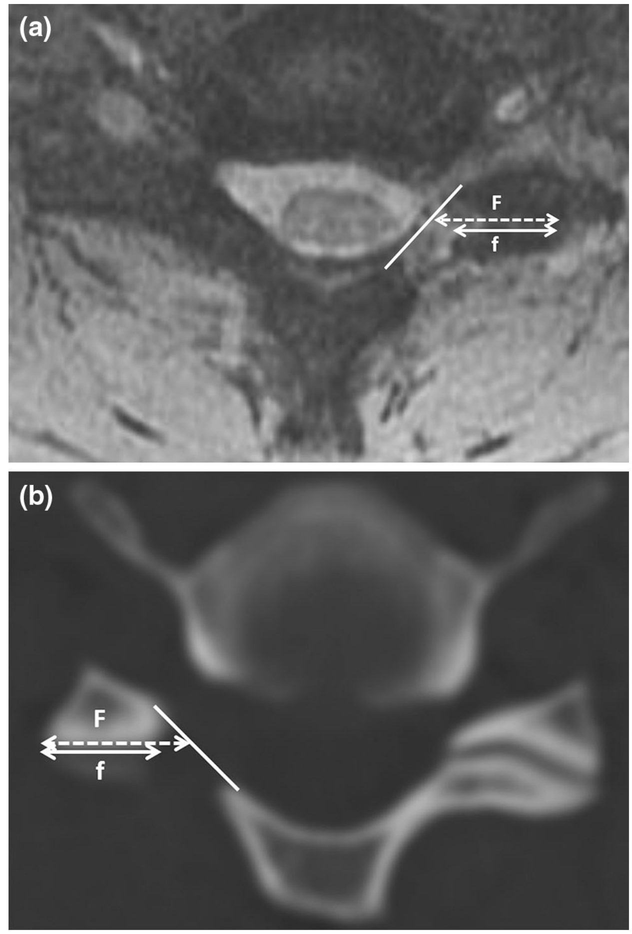


**Fig. 2** Measurement of the foraminotomy. **a** The length of the facet joint was measured from the lateral margin to the medial margin of an imaginary line. The amount of the facet joint removal was calculated as $F - f$, and the percentage of removal was calculated as $100 \times (F - f)/F$. **b** The same method was applied for the MR image

analysis. All of the statistical analyses were performed using SPSS (version 17.0, SPSS, Chicago, IL, USA), and the statistical significance was defined as $P < 0.05$ (two-sided).

## Results

The clinical outcomes are described in Table 2. The NDI was decreased by more than 10.5 in 21/22 (95 %) of the patients after the MTPF and in 20/22 (91 %) of the patients after the P-PECD ($P = 1.00$). The primary end-point (decrease of Arm-VAS ≥4.3) was achieved in 19/22 (87 %) patients after MTPF and 19/22 (87 %) patients after P-PECD ($P = 1.0$). The mean NDI and Neck-VAS were lower after the P-PECD than after the MTPF ($P < 0.05$) (Table 2).

The radiological results are shown in Table 3. The SA became more lordotic after the P-PECD and the PH decreased less after the P-PECD than after the MTPF ($P < 0.05$). The preoperative SA was kyphotic in 8/22 of the patients and the postoperative SA was kyphotic in 5/22 of the patients after the P-PECD at 24 months (Table 4). However, the SA was kyphotic in 8/22 of the patients and in 14/22 of the patients after the MTPF at 24 months (Table 4).

The amount of the facet joint removed was 0.78 ± 0.51 mm (range 0.14–2.49) after the MTPF and 0.98 ± 0.60 mm (range 0.02–2.30) after the PECD ($P = 0.20$), and the percentage was 5.4 ± 3.2 % (range 1.07–15.24) and 6.4 ± 3.9 % (range 0.11–14.38) ($P = 0.31$), respectively.

On the univariate analysis, there was no significant factor for the successful improvement of an arm pain, but preoperative SA showed trend ($P = 0.08$; OR 1.2; 95 % CI 0.98–1.4). Preoperative mean SA of patients with improved

**Table 2** Clinical outcomes

| | Pre | 1 month | 12 months | 24 months | *P* value* |
|---|---|---|---|---|---|
| MTPF | | | | | |
| NDI | 22.6 ± 6.5 | 5.7 ± 2.7 | 4.8 ± 2.1 | 3.1 ± 1.7 | |
| Neck-VAS | 7.3 ± 1.4 | 2.2 ± 1.5 | 1.1 ± 0.9 | 1.0 ± 1.0 | |
| Arm-VAS | 7.7 ± 1.1 | 2.5 ± 1.6 | 1.1 ± 1.2 | 1.0 ± 1.1 | |
| P-PECD | | | | | |
| NDI | 23.8 ± 9.5 | 7.7 ± 6.7 | 3.4 ± 4.3 | 1.9 ± 3.8 | 0.003 |
| Neck-VAS | 5.7 ± 1.8 | 2.3 ± 1.9 | 1.1 ± 1.8 | 0.8 ± 1.5 | 0.047 |
| Arm-VAS | 6.4 ± 2.2 | 2.5 ± 2.1 | 1.8 ± 2.5 | 0.9 ± 1.7 | 0.09 |

*MTPF* microscopic tubular retractor-assisted posterior microforaminotomy, *P-PECD* posterior percutaneous endoscopic cervical foraminotomy and discectomy, *Arm-VAS* arm visual analogue pain score of arm, *Neck-VAS* visual analogue pain score of neck

* Between each values of MTPF and P-PECD at 24 months

**Table 3** Radiological outcomes

| | Pre | 24 months | *P* value[†] | Change[a] |
|---|---|---|---|---|
| MTPF_CA (°) | 3.1 ± 10.8 | −1.6 ± 15.1 | 0.03 | −4.7 ± 9.1 |
| P-PECD_CA (°) | −9.0 ± 12.9 | −15.0 ± 12.0 | <0.01 | −6.1 ± 7.4 |
| *P* value* | 0.001 | 0.003 | | 0.27 |
| MTPF_CA_ROM (°) | 25.5 ± 14.7 | 30.2 ± 15.1 | 0.03 | 5.0 ± 9.4 |
| P-PECD_CA_ROM (°) | 33.8 ± 15.6 | 43.4 ± 12.4 | <0.01 | 5.6 ± 12.5 |
| *P* value* | 0.06 | 0.006 | | 0.91 |
| MTPF_SA (°) | −0.7 ± 5.2 | 1.3 ± 5.3 | 0.09 | 2.0 ± 5.3 |
| P-PECD_SA (°) | 0.01 ± 5.62 | −3.0 ± 4.9 | <0.01 | −3.1 ± 3.1 |
| *P* value* | 1.00 | 0.009 | | <0.01 |
| MTPF_SA_ROM (°) | 5.8 ± 6.5 | 5.3 ± 3.4 | 0.92 | −0.6 ± 7.3 |
| P-PECD_SA_ROM (°) | 13.0 ± 7.1 | 10.8 ± 6.1 | 0.1 | −2.2 ± 5.7 |
| *P* value* | 0.001 | 0.004 | | 0.13 |
| MTPF_AH (mm) | 39.0 ± 4.1 | 38.1 ± 3.8 | 0.22 | −0.9 ± 2.1 |
| P-PECD_AH (mm) | 34.3 ± 3.6 | 34.2 ± 3.6 | 0.41 | −0.2 ± 0.6 |
| *P* value* | 0.001 | 0.004 | | 0.69 |
| MTPF_PH (mm) | 38.1 ± 3.9 | 35.9 ± 3.8 | <0.01 | −2.2 ± 2.3 |
| P-PECD_PH (mm) | 35.0 ± 3.5 | 34.4 ± 3.2 | 0.14 | −0.5 ± 1.1 |
| *P* value* | 0.02 | 0.26 | | 0.02 |

*AH* actual anterior height, *CA* cervical curvature, *MTPF* microscopic tubular retractor-assisted posterior microforaminotomy, *PH* actual posterior height, *P-PECD* posterior percutaneous endoscopic cervical foraminotomy and discectomy, *ROM* range of motion, *SA* segmental angle

* Between each values of MTPF and PECD at each period

[†] Between values obtained at preoperation and postoperative 24 months

[a] Change between preoperation and postoperative 24 months

Arm-VAS was −0.9 ± 5.3° and that of patients without improved Arm-VAS was 3.8 ± 4.5°. To determine the optimal cut-off value of the preoperative SA, the ROC curve was created (Fig. 3). The area under the curve (AUC) was 0.76 (95 % CI 0.57–0.98). The cut-off SA was 1.45° (sensitivity 80 %, specificity 73 %).

Complications occurred after surgery in one patient (a dural tear without sequel) after an MTPF and in two patients (two transient hypoesthesias due to a dural tear and a thermal injury without sequel) after a P-PECD [23]. During the follow-up, an epidural injection was administered in two patients after the MTPF and in one patient after a P-PECD due to increased arm pain at 12 months. Their symptoms were improved after the injection. Fusion surgery was performed in one patient 30 months after an MTPF due to increased neck pain.

**Table 4** Change of cervical and segmental kyphosis

| | MTPF | | | P-PECD | | |
|---|---|---|---|---|---|---|
| | CA_preoperation | | | CA_preoperation | | |
| | Lordosis | Kyphosis | Total | Lordosis | Kyphosis | Total |
| CA_24 months | | | | | | |
| Lordosis | 11 | 3 | 14 | 18 | 1 | 19 |
| Kyphosis | 0 | 8 | 8 | 0 | 3 | 3 |
| Total | 11 | 11 | 22 | 18 | 4 | 22 |
| | SA_preoperation | | | SA_preoperation | | |
| | Lordosis | Kyphosis | Total | Lordosis | Kyphosis | Total |
| SA_24 months | | | | | | |
| Lordosis | 6 | 2 | 8 | 14 | 3 | 17 |
| Kyphosis | 8 | 6 | 14 | 0 | 5 | 5 |
| Total | 14 | 8 | 22 | 14 | 8 | 22 |

*CA* cervical curvature, *MTPF* microscopic tubular retractor-assisted posterior microforaminotomy, *P-PECD* posterior percutaneous endoscopic cervical foraminotomy and discectomy, *SA* segmental angle

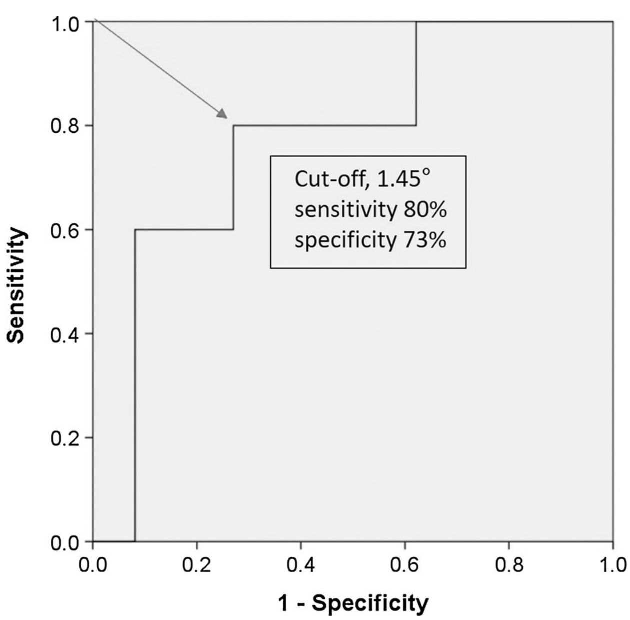


**Fig. 3** ROC curve for segmental angle. The area under the curve (AUC) was 0.76 (95 % CI 0.57–0.98). The cut-off SA was 1.45° (sensitivity 80 %, specificity 73 %)

## Discussion

The primary objective of the present study was to determine factors for the successful improvement of arm pain after either MTPF or P-PECD. The minimal detectable change of Arm-VAS was set as 4.3, to minimize inclusion of false-positive outcome [26]. The primary end-point was met in 87 % of patients in both groups. The NDI was improved in 96 and 91 % after MTPF and P-PECD, respectively. Preoperative SA was seemed to be associated with the Arm-VAS and cut-off value was 1.45°. Neither the surgical method nor the removal amount of the facet joint was significant factors.

### Clinical outcomes

The posterior cervical foraminotomy and diskectomy (PCD) is an alternative option for selected patients with predominant arm pain, and the clinical improvement and reoperation rates were comparable to those of the standard ACDF [10, 12–14, 16, 19, 21, 22, 30]. The preservation of a mobile segment is a great advantage of PCD over fusion surgery with respect to the cost, the progression of the adjacent segment pathology and an earlier return to work [12–14]. The MTPF or P-PECD may be considered as an alternative to the PCD. After the MTPF, a favorable outcome was obtained in 86–97 % of the patients, which was not inferior to the conventional PCD [12, 16, 31]. In addition, the blood loss, postoperative length of stay and postoperative medication use were decreased after the MTPF compared with the conventional PCD [12, 32]. The complication rate for MTPF has been reported to be 0–4.3 % [12, 16]. Reoperation after an MTPF was necessary in 7 % of the patients [12]. Another alternative method is the P-PECD. A favorable outcome was achieved in 97 % of the patients, the complication rate was 3–5 % and reoperation rate was 3 % [8, 19, 22].

The present study also showed that 87 % of the patients achieved successful improvement of arm pain with either method. The NDI was decreased more than 10.5 in 93 % (41/44) of patients. Complication rate was 7 % (3/44) and reoperation rate was 2 % (1/44), although symptomatic recurrences were relieved by epidural injections in three patients. However, the reoperation rate may increase with a longer follow-up, as a previous study has shown, in which the reoperation rate was 16.4 % for patients after a PCD with a more than 2-year follow-up [13]. Preoperative kyphotic SA (cut-off value 1.45°) seemed to be associated with poor outcome and this may be considered in selecting surgical methods.

### Violation of facet joint

The extent of the facet joint's removal was approximately 38 % with the microscopic technique, and the transverse length was an average of 13.5 mm [33]. Theoretically, the ruptured disk material could be removed through the axilla of a nerve root without violating the facet joint [34]. Anatomical studies have shown that the horizontal and vertical lengths from the medial point of the facet joint to the axilla of the nerve root was 3.8–7.1 mm from C3 to C7 [34, 35]. The present study included patients with soft-disk herniation, and violations of the facet joint were minimized with the use of magnification and micro-instruments; the length of the facet joint's removal was 0.02–2.49 mm (0.1–15.2 %) with no difference between the MTPF and P-PECD [12, 33, 36]. The extent of the foraminotomy was not limited by the small size of the skin incision in the PECD due to the use of the pivoting ability of the endoscope and the working channel [23, 37, 38].

## Limitations of the present study

This study was retrospective in design, and the inherent selection bias and limited statistical power should be considered. Because the P-PECD and the MTPF surgeries were performed in different hospitals by different surgeons, there was a selection bias. In addition, 35 % of patients after MTPF were lost to follow-up. Although the clinical and radiological parameters were evaluated by an independent research nurse blinded to the outcomes, the surgical outcome may be dependent on the expertise of the surgeon. Therefore, the present study had limitations in the generalizability of the result. Nevertheless, the present study showed that the clinical and radiological outcomes may not differ between the MTPF and P-PECD procedures, with a success rate comparable to the conventional PCD.

## Conclusion

For patients with foraminal soft-disk herniation, a minimally invasive posterior cervical foraminotomy and diskectomy, such as the MTPF or P-PECD, may be regarded as alternative options to open surgery. Preoperative kyphotic SA (cut-off value 1.45°) seemed to be associated with poor outcome and this may be considered in selecting surgical methods. It seemed that the violation of facet joint may be reduced with either MTPF or P-PECD, but a prospective study with a longer follow-up is required to observe a long-term consequence.

### Compliance with ethical standards

**Conflicts of interest** The first author (CHK) is a consultant of Richard Wolf GmbH. CKC and SBP are users of the endoscopic equipment of Richard Wolf GmbH. The other authors declares no conflict of interest concerning the materials or methods used in this study or the findings described in this paper.

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**Ethical approval** This study was approved by the institutional review board at the Seoul National University Hospital (H-1210-078-434).

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