SURGICAL APPROACHES IN MULTILEVEL CERVICAL DISC REPLACEMENT AND CERVICAL HYBRID SURGERY: A SERIES OF FOUR CASE REPORTS

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Background:

Multilevel artificial cervical disc replacement and anterior hybrid surgery have been established as effective treatments for multilevel cervical degenerative disc disease. Proper surgical techniques are essential to alleviate patient symptoms and ensure the optimal functioning of cervical implants. However, the use of incorrect surgical strategies may result in complications such as implant migration and neurological deficits. In this paper, we outline our surgical strategies for multilevel cervical disc replacement and hybrid surgery, summarized into five key points.

Case Summary:

We present four case reports to illustrate these surgical strategies. All patients were diagnosed with cervical degenerative disc disease accompanied by myelopathy or radiculopathy, necessitating multilevel cervical spine surgery. The first case highlights the importance of prioritizing decompression at levels with severe spinal cord compression. The second case emphasizes that disc replacement should precede fusion in cervical hybrid surgery. The third and fourth cases demonstrate the necessity of a top-down implantation sequence in two-level continuous cervical disc replacement. All patients experienced significant symptom relief following surgery.

Keywords: Cervical disc replacement, Cervical hybrid surgery, Multilevel cervical spine surgery, Surgical strategy, Implant migration, Case report.

Introduction

Multilevel cervical degenerative disc disease, a growing public health issue, occurs when two or more segments of the cervical spine degenerate, leading to significant disability and loss of productivity. The traditional treatment, anterior cervical discectomy and fusion (ACDF), remains widely used for multilevel cervical spondylosis but has limitations such as pseudarthrosis and the potential for adjacent segment degeneration. In recent years, the development of non-fusion techniques, particularly artificial cervical disc replacement (CDR), has been shown to be effective and safe for both single-level and multilevel cervical degenerative disc diseases, as demonstrated by multiple U.S. FDA studies and meta-analyses.

Compared to ACDF, CDR offers advantages such as preserving segmental range of motion (ROM) at the surgical level, reducing the risk of adjacent segment degeneration, and avoiding complications like nonunion or pseudoarthrosis. For two-level cervical spondylosis, studies have shown that two-level CDR provides comparable outcomes to two-level ACDF in terms of neurological recovery, with even better results in measures like the Neck Disability Index score.

A relatively newer approach, anterior hybrid surgery (HS), combines CDR and fusion at different levels during the same procedure to treat multilevel cervical degenerative disc disease. This technique is gaining recognition due to its ability to tailor treatment to the specific characteristics of each level, aiming to preserve segmental motion, avoid extensive fusions, and maintain sagittal alignment and stability.

However, the technical challenges of these procedures can deter some surgeons from adopting CDR or HS for multilevel cases. Based on our experience, improper implantation sequences during continuous two-level CDR can cause complications, such as migration of the artificial disc. Moreover, excessive tapping during CDR can exacerbate spinal cord compression or loosen the implanted prosthesis. To achieve optimal outcomes and maintain implant function, careful planning of each surgical step and executing the surgery in the correct sequence is essential. Even minor imperfections in the surgical strategy can lead to unnecessary complications.

In this paper, we outline our surgical strategies for multilevel CDR and HS, summarized into five key points, and illustrate these strategies through four case presentations. We hope our insights will enhance the performance and outcomes of multilevel CDR and HS, and we also discuss the most appropriate surgical techniques for these procedures.

Surgical Strategies for Multilevel CDR and HS

Over the past 15 years, we have performed more than 800 cervical disc replacement (CDR) and 300 hybrid surgery (HS) procedures, all conducted by the same senior surgeon (H.L.). This extensive experience has enabled us to develop well-considered implantation strategies for multilevel CDR and HS. The safety profile and clinical outcomes of multilevel cervical spine surgeries have been previously reported by our team.

Patients with multilevel cervical degenerative disc disease typically experience severe spinal cord compression, and the CDR procedure often requires multiple tapping processes. Without complete decompression of the affected levels, these tapping maneuvers can potentially worsen spinal cord compression. Additionally, excessive tapping may destabilize the implant or prosthesis by causing vibrations. Therefore, two guiding principles are crucial:

- Avoid aggravating spinal cord compression during the procedure.
- Ensure the stability of the inserted prosthesis is maintained.

To adhere to these principles, five key notes must be followed:

1. In multilevel CDR or HS, decompression of the disc spaces and preparation of the endplates at all surgical levels should be completed before implant insertion.
2. An appropriately sized implant trial or a rail punch should be used to maintain intervertebral disc height before prosthesis implantation.
3. Levels with severe spinal cord compression should be prioritized for decompression.
4. In HS procedures, the CDR should be performed before cervical fusion surgeries such as anterior cervical discectomy and fusion (ACDF) or anterior cervical corpectomy decompression and fusion (ACCF).
5. For continuous two-level CDR, all rasping, drilling, and cutting processes should be completed at both surgical segments before implanting the artificial disc, and the upper level should be prioritized for disc implantation.

The specific details of the surgical procedures are demonstrated through four representative case presentations outlined below.

Case Presentation

The four patients were all diagnosed with cervical degenerative disc disease and required surgical intervention to alleviate their symptoms.

Chief Complaints:

- **Case 1:** (Severe spinal cord compression at certain levels, requiring priority decompression): The patient experienced neck pain and numbness in both upper limbs for 8 months.
- **Case 2:** (Disc replacement performed prior to fusion in hybrid surgery): The patient reported numbness in both upper limbs for 1 year.
- **Case 3:** (Following a top-down implantation sequence in continuous two-level CDR): The patient suffered from neck pain and weakness in the right upper limb for 6 months.
- **Case 4:** (Migration of an inserted artificial disc during continuous two-level CDR due to improper implantation sequence): The patient experienced numbness in the left upper limb for 10 months.

History of Present Illness:

- **Case 1:** A 54-year-old man presented with neck pain and numbness in both upper limbs for 8 months. He sought conservative treatment 6 weeks ago, but his symptoms persisted.
- **Case 2:** A 51-year-old woman reported numbness in both upper limbs for 1 year. She underwent 4 weeks of conservative treatment at another facility, with no symptom relief.
- **Case 3:** A 41-year-old woman experienced neck pain and weakness in her right upper limb for 6 months. After 3 months of conservative treatment outside our hospital, her symptoms remained unchanged.
- **Case 4:** A 45-year-old woman presented with numbness in her left upper limb for 10 months, which progressively worsened. Over the last 6 months, she developed weakness in both upper limbs.

History of Past Illness:

- **Case 1:** No past medical abnormalities.
- **Case 2:** Physical examination revealed reduced muscle strength in the right upper limb.
- **Case 3:** Physical examination revealed decreased muscle strength in the right arm.
- **Case 4:** No past medical abnormalities.

Personal and Family History:

No abnormalities reported in any case.

Physical Examination:

- **Case 1:** Decreased sensation and muscle strength were observed in both upper limbs.
- **Case 4:** Muscle strength in both upper limbs was reduced upon examination.

Laboratory Examinations:

Preoperative laboratory tests showed no abnormalities in all cases.

Imaging Examinations:

- **Case 1:** A lateral radiograph revealed a straightened cervical alignment, which normalized during flexion-extension movement. The disc height and range of motion (ROM) at C4/5 were preserved. A computed tomography (CT) scan showed significant osteophyte formation at the posterior borders of C5/6 and C6/7, requiring extensive decompression. Magnetic resonance imaging (MRI) identified cervical disc herniation at C4/5 and C6/7, along with intervertebral foramen stenosis at C5/6 and C6/7 (Figure 1).

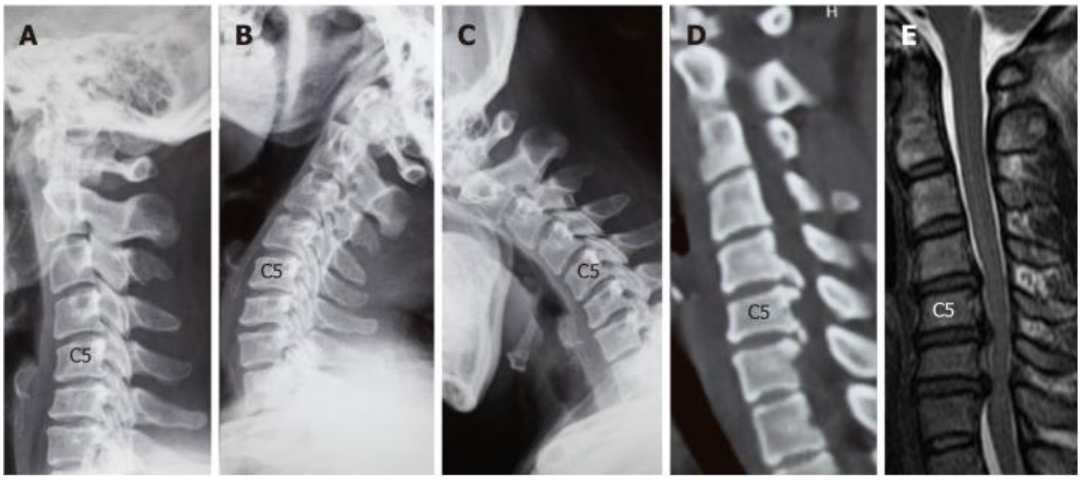

Figure 1
Computed tomography images of case 1. A-C: Lateral radiographs showing a straightened cervical alignment that returned during flexion-extension movement. The range of motion at C4/5, C5/6, and C6/7 was 11.3°, 14.53°, and 1.28°, respectively; D: Computed tomography image showing large numbers of osteophytes at the posterior border of C5/6 and C6/7; E: Magnetic resonance imaging revealed cervical disc herniation at C4/5 and C6/7.

- **Case 2:** Radiographs indicated that intervertebral disc height was preserved at C4/5, C5/6, and C6/7, but the range of motion (ROM) at C5/6 was noticeably reduced. A CT scan revealed a significant presence of osteophytes at the posterior-inferior borders of C5 and C6, which required extensive removal. MRI showed multilevel spinal cord compression at C4/5, C5/6, and C6/7, with the compression at C4/5 being caused by cervical disc herniation (Figure 2).

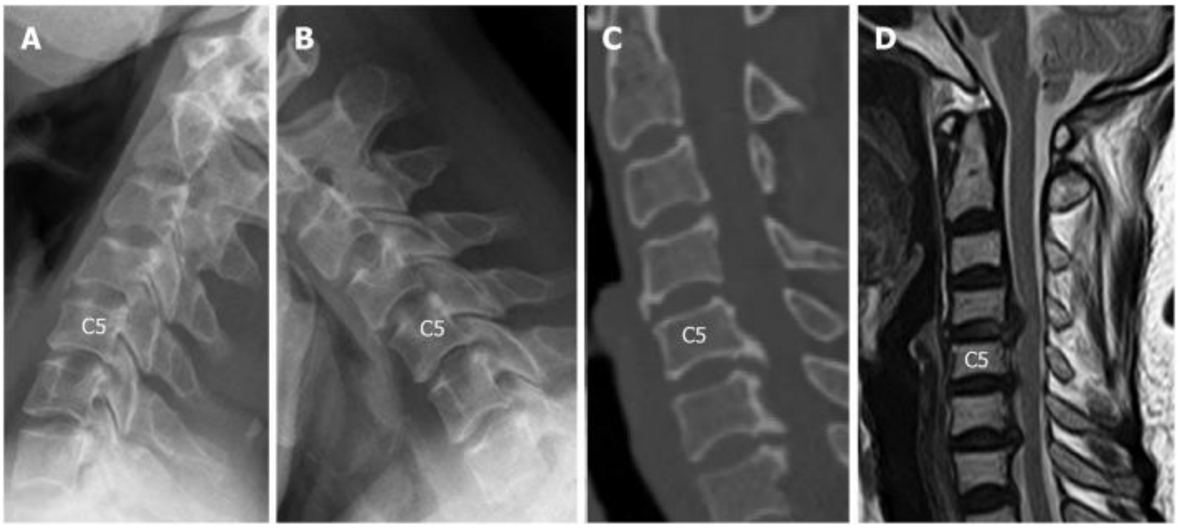

Figure 2
Computed tomography images of case 2. A and B: Lateral radiographs taken before surgery revealed that the range of motion at C5/6 was decreased (2.57°), while the range of motion at C4/5 and C6/7 was 9.34° and 6.05°, respectively. The intervertebral disc height at C4/5 was preserved; C: Large numbers of osteophytes were revealed at the posterior-inferior border of

C5 and C6; D: Magnetic resonance imaging indicated spinal cord compression at C4/5, C5/6, and C6/7, and compression at C4/5 was caused by disc herniation.

- **Case 3:** Lateral radiographs revealed that the intervertebral disc height at C5/6 and C6/7 was well maintained, with cervical alignment showing normal lordosis. The range of motion (ROM) at C5/6 and C6/7 was preserved. Spinal compression was primarily caused by disc herniation, and the facet joints appeared normal (Figure 3).

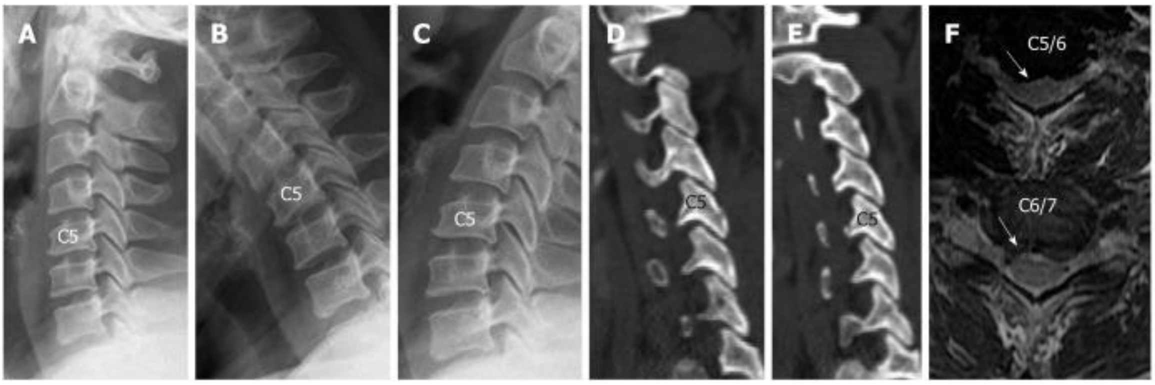

Figure 3
Spinal compression was mainly caused by disc herniation, and the facet joints were normal. A-C: Range of motion at C5/6 and C6/7 was 11.93° and 11.28°, respectively, and the intervertebral disc height at both levels was slightly decreased; D and E: There was no obvious degeneration of the facet joints; F: Magnetic resonance imaging revealed soft disc herniation at C5/6 and C6/7.

- **Case 4:** Lateral radiographs demonstrated that the range of motion (ROM) at C4/5 and C5/6 was preserved. A CT scan showed that the reduction in intervertebral disc height at both levels was less than 30%. MRI revealed soft disc herniation at the C4/5 and C5/6 levels (Figure 4).

Figure 4

Computed tomography images of case 4. A-C: Range of motion at C4/5 and C5/6 was 10.63° and 9.93°, respectively, and the intervertebral disc height at both levels was slightly decreased; D and E: There was no obvious degeneration of the facet joints; F: Magnetic resonance imaging revealed soft disc herniation at C4/5 and C5/6.

Final Diagnosis

- **Case 1:** C4/5 cervical disc herniation; C5/6 and C6/7 cervical spondylosis.
- **Case 2:** C4/5 cervical disc herniation; C5/6 and C6/7 cervical spondylosis.
- **Case 3:** C5/6 and C6/7 cervical disc herniation.
- **Case 4:** C4/5 and C5/6 cervical disc herniation.

Treatment

- **Case 1:**
  We opted to perform anterior cervical corpectomy and fusion (ACCF) at C6 to fully remove the osteophytes. At C4/5, cervical disc replacement (CDR) was performed to preserve range of motion (ROM) and avoid complications associated with long-segment fusion.

Surgical Procedure (Figure 5):

Due to severe compression at C5/6 and C6/7, decompression of the lower segments was prioritized. The C6 vertebral body was excised, and osteophytes at the posteroinferior border of C5 and the posterosuperior border of C7 were removed. Decompression of the intervertebral foramina at C5/6 and C6/7 was also performed. Decompression and endplate preparation were carried out at C4/5, followed by the implantation of the artificial disc using standard techniques at C4/5 (Figure 5A-D). Afterward, a titanium mesh was appropriately implanted, and the ACCF procedure was completed according to standard surgical protocols (Figure 5E-F).

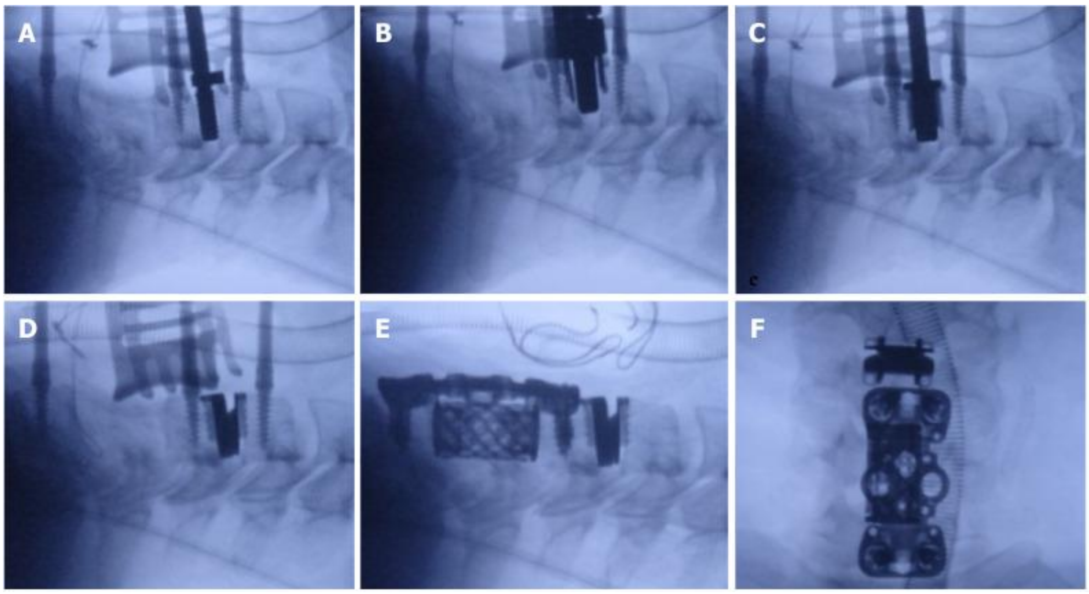

Figure 5

The surgical procedure used for the hybrid surgery combining cervical disc replacement with anterior cervical corpectomy decompression and fusion in case 1. A: The decompression at C5/6 and C6/7 was performed first, and then the decompression and endplate preparation were finished at C4/5. The C4/5 disc space was inserted with an appropriate sized implant trial; B and C: The drilling and cutting processes were performed following the standard procedure; D: An appropriately sized artificial disc was inserted at C4/5; E: Anterior cervical corpectomy decompression and fusion was completed at C5-7 level; F: Lateral radiograph was taken to confirm the implants in good position.

Case 2

We performed cervical disc replacement (CDR) at C4/5 using a Prestige-LP artificial disc, and multilevel anterior cervical discectomy and fusion (ACDF) at C5/6 and C6/7 using the Zero-P system (Depuy Synthes Companies, United States).

Surgical Procedure (Figure 6):

Decompression and endplate preparation were performed in a systematic order, prioritizing decompression at levels with severe spinal cord compression. An appropriately sized implant trial was used to maintain the disc space. While preparing the disc space at C4/5, the implant trial for C5/6 and C6/7 was kept in place (Figure 6A-B). The artificial disc at C4/5 was implanted following standard procedures (Figure 6C-D). Zero-P systems were then implanted at C5/6 and C6/7. Lateral and anterior-posterior radiographs confirmed that the prostheses were correctly positioned (Figure 6E-F).

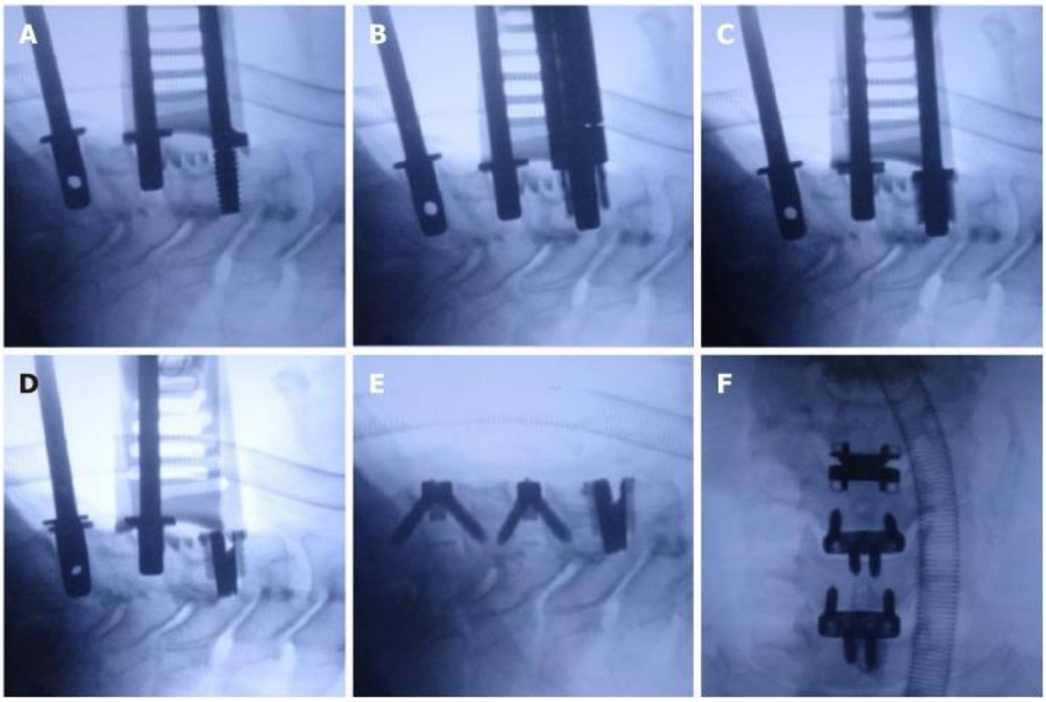

Figure 6

The surgical procedure of the hybrid surgery combining cervical disc replacement with ACDF in case 2. A: Decompression and endplate preparation were performed at C4/5, C5/6, and C6/7. Cervical disc replacement was performed before anterior cervical discectomy and fusion; B-D: Drilling, cutting, and implanting processes of cervical disc replacement were performed. The C5/6 and C6/7 disc spaces were supported by implant trails; E: Anterior cervical discectomy and fusion was performed at C5/6 and C6/7; F: Lateral radiograph was taken to confirm the implants in good position.

Case 3

The patient underwent two-level cervical disc replacement (CDR) at C5/6 and C6/7 using Prestige-LP artificial discs to preserve range of motion (ROM) at both levels.

Surgical Procedure (Figure 7):

Decompression was carried out at the C5/6 and C6/7 disc spaces. Implant trials of appropriate sizes were used to confirm the disc spaces (Figure 7A). Rasping, drilling, and cutting were performed at C5/6 following standard procedures, with the implant trial at C6/7 left in place to maintain disc height (Figure 7B-C). The same rasping, drilling, and cutting were then performed at C6/7, while the rail punch at C5/6 was kept in place to preserve intervertebral disc height (Figure 7D-F). The artificial discs were implanted in a top-down sequence: first, the rail punch at C5/6 was removed and an appropriately sized artificial disc was implanted; next, the rail punch at C6/7 was removed and an artificial disc of the correct size was implanted (Figure 7G-H).

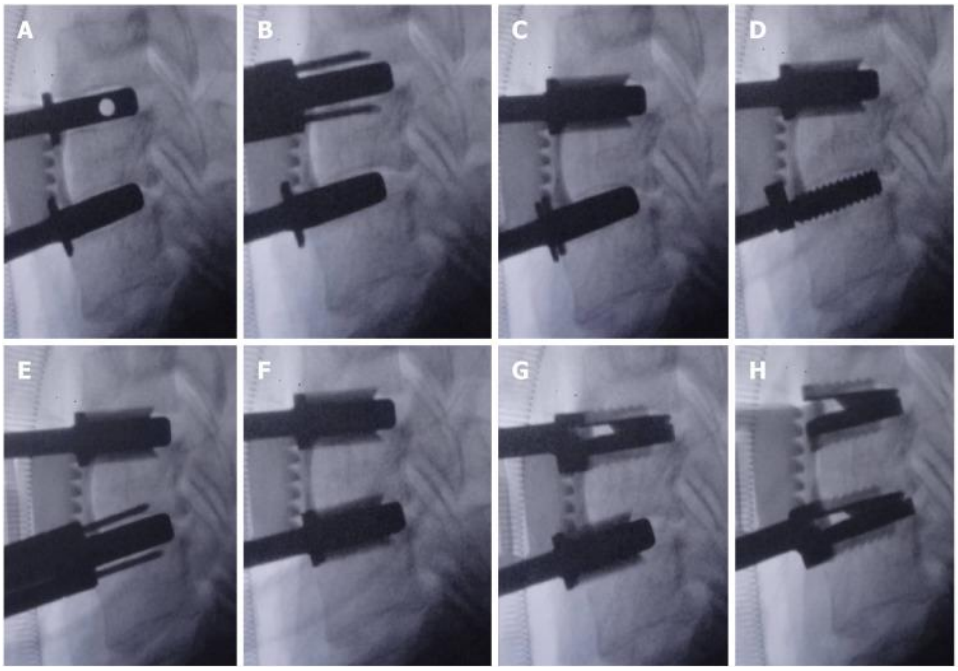

Figure 7
The surgical procedure of continuous two-level cervical disc replacement in case 3. A: The disc space was maintained with appropriately sized implant trails; B and C: Rasping, drilling, and cutting were performed at C5/6, and the implant trail at C6/7 was reserved; D-F: Rasping, drilling, and cutting were performed at C6/7, and the implant trail at C5/6 was reserved; G and H: Artificial discs were implanted at C5/6 and C6/7 following a top-down sequence.

Case 4

Examination findings indicated that the patient was suitable for two-level cervical disc replacement (CDR) at C4/5 and C5/6 using Prestige-LP artificial discs. However, during the implantation of the second disc, the upper tab of the previously inserted disc at C5/6 migrated forward due to an improper implantation sequence.

We followed standard procedures for decompression and implant size selection at both C4/5 and C5/6. Rasping, drilling, cutting, and disc implantation at C5/6 were completed according to standard protocols (Figure 8A), and a lateral radiograph confirmed that the artificial disc at C5/6 was properly positioned. Next, we began addressing the C4/5 disc space. After rasping, the upper tab of the C5/6 artificial disc migrated forward (Figure 8B). The migration continued during the drilling, cutting, and implantation of the disc at C4/5 (Figure 8C-E). To assess stability, flexion-extension intraoperative radiographs were taken, which showed that the migration of the C5/6 disc did not worsen during movement. Consequently, the upper tab of the C5/6 disc was tapped back into its correct position (Figure 8F).

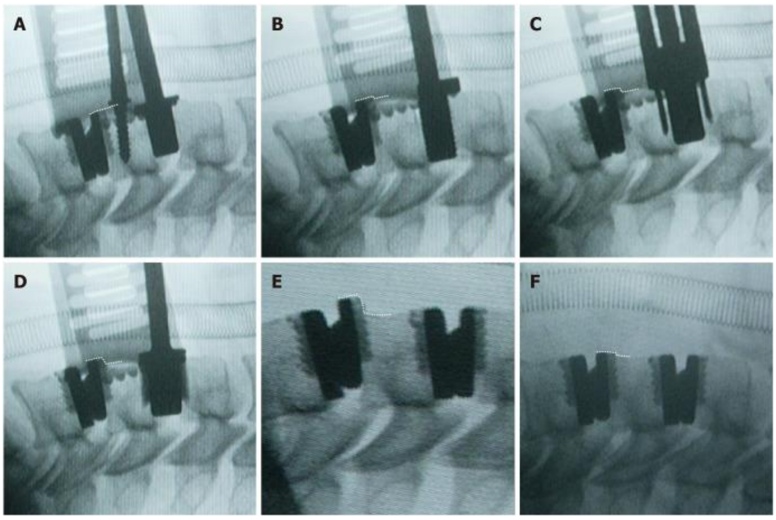

Figure 8
The surgical procedure of continuous two-level cervical disc replacement, which followed a bottom-up sequence in case 4. A-E: The upper tab of the prosthesis at C5/6 migrated forward during preparation of the disc space at C4/5. The degree of anterior migration of the artificial disc at C5/6 is denoted with dashed lines; F: We tapped the migrated tab back to the correct position.

Outcome and Follow-up

- **Case 1:**
  Complete decompression was achieved, leading to significant symptom relief after surgery.
- **Case 2:**
  Complete decompression was performed, and the patient showed noticeable recovery.
- **Case 3:**
  Following surgery, the patient's symptoms were greatly alleviated. Both prostheses remained stable, and the range of motion (ROM) at C5/6 and C6/7 was preserved during long-term follow-up.
- **Case 4:**
  One week post-surgery, no migration of the artificial disc at C5/6 was observed. The patient was followed for 8 years. While migration of the upper tab at C5/6 was detected 1 month after surgery, it did not progress during the 8-year follow-up period .

Discussion

Compared to multilevel fusion surgeries, multilevel cervical disc replacement (CDR) and hybrid surgery (HS) provide advantages such as preserving range of motion (ROM) and preventing accelerated degeneration in adjacent segments. Moreover, cervical HS offers a personalized treatment approach for multilevel cervical degenerative disc disease, addressing the specific degenerative features of each segment. While these techniques present certain technical challenges, they can be ideal options for well-selected patients. In this paper, we share our surgical strategies for multilevel CDR and HS, summarized in the following key points:

- **Note 1:** In multilevel CDR or HS, decompression of the disc spaces and preparation of the endplates at all surgical levels should be completed before implant insertion.
- **Note 2:** An appropriately sized implant trial or rail punch should be used to maintain disc height before prosthesis implantation.

- **Note 3:** Priority should be given to decompressing levels with severe spinal cord compression.
- **Note 4:** In HS, CDR should be performed before fusion surgeries, such as anterior cervical discectomy and fusion (ACDF) or anterior cervical corpectomy decompression and fusion (ACCF).
- **Note 5:** For continuous two-level CDR, rasping, drilling, and cutting processes at both surgical levels should be completed before disc implantation, and the upper level should be implanted first.

We illustrate these strategies through four typical cases and discuss key lessons learned from each.

Lessons from Case 1:

In this case, we prioritized decompressing the more severely compressed C5-7 segments, as outlined in Note 3. Literature suggests that intensive manipulation during surgery can lead to unwanted spinal cord damage. Given the severity of compression in multilevel cervical spondylosis, gentle and precise manipulation is essential, especially during anterior cervical surgeries. Many tapping processes are involved in CDR, and in cases where spinal cord compression could worsen, priority decompression at the most affected level is critical to avoid further injury during these procedures.

Lessons from Case 2:

This case demonstrates our implantation strategy for multilevel cervical HS. Decompression and endplate preparation for all segments were completed before prosthesis implantation, as noted in Note 1, minimizing manipulation under fluoroscopy. We maintained disc space integrity at other levels by using appropriately sized implant trials, as described in Note 2, to ensure stability during implantation. For example, by reserving the implant trial at C5/6, we stabilized the vertebrae and minimized rocking during procedures, ensuring optimal conditions for CDR.

Additionally, we performed CDR before the fusion procedure, following Note 4. Given that CDR involves tapping, vibrations from excessive tapping could loosen the fusion cage or screws if performed after fusion. Performing CDR first reduces tapping-related vibrations and ensures implant stability.

Lessons from Case 3:

In this case of continuous two-level CDR, we reserved an implant trial or rail punch in one disc space to maintain height while operating on the other, as outlined in Note 2. The key principle in Note 5 emphasizes completing rasping, drilling, and cutting at both levels before disc implantation. Had we implanted the C4/5 disc before performing these procedures at C5/6, the stability of the C4/5 disc could have been compromised by the tapping forces. Furthermore, by implanting the disc at C4/5 first, we avoided the risk of migration of the C5/6 disc during the upper-level procedure, a problem illustrated in Case 4.

Lessons from Case 4:

The migration of the previously inserted disc in this case is related to the design of the Prestige-LP cervical disc, which uses a ball-and-trough structure. The ball, located on the upper tab, allows some degree of transverse movement relative to the lower tab, with more forward than backward movement. This design feature contributed to the migration of the upper tab during the procedure (Figure 9).

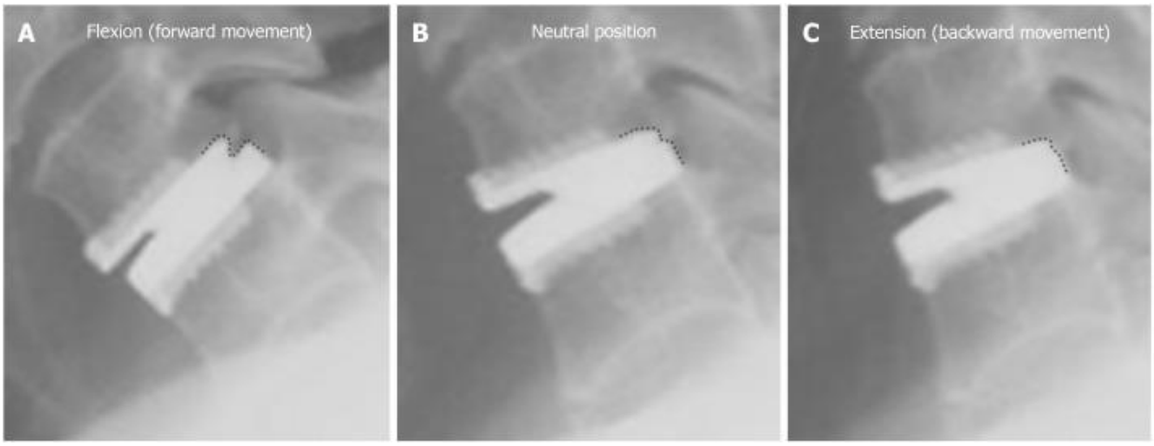

Figure 9
The position of the upper tab relative to the lower tab (denoted with dashed lines) of Prestige-LP in flexion (A), neutral position (B), and extension (C). The Prestige-LP cervical disc was designed with a ball and socket structure, with the ball to the rear of the upper tab and the socket on the lower tab. This design allowed the prosthesis to move transversely; the forward displacement was larger, and the prosthesis could move only slightly backward.

In **Case 4**, we followed a bottom-up sequence, first inserting the prosthesis at C5/6 before addressing the C4/5 disc space. As a result, the C5 vertebral body and the prosthesis at C5/6 were exposed to several unnecessary tapping processes. Each tap generated impact forces that caused the C5 vertebra and the upper tab of the prosthesis at C5/6 to move backward (Figure 10A and 10B). However, as noted earlier, the upper tab of the Prestige-LP cervical disc has very limited backward movement relative to the lower tab. Thus, when the C5 vertebral body moved backward due to the impact forces, while the upper tab remained in place, a shearing force was created between the C5 vertebra and the upper tab of the prosthesis at C5/6 (Figure 10B). This led to the forward migration of the upper tab of the C5/6 prosthesis.

Conversely, if we had followed a top-down sequence—starting with the C4/5 prosthesis before inserting the C5/6 prosthesis—this migration likely would not have occurred (Figure 10C and 10D). In such a sequence, when the prosthesis at C5/6 is inserted, the C5 vertebra and the lower tab of the C4/5 prosthesis would be subjected to the tapping forces (Figure 10C). Given that the upper tab of the C4/5 prosthesis is designed to move forward relative to the lower tab, the backward movement of the C5 vertebra and the lower tab at C4/5 would occur without generating a shearing force between the two components. As a result, the prosthesis at C4/5 would not experience migration (Figure 10D).

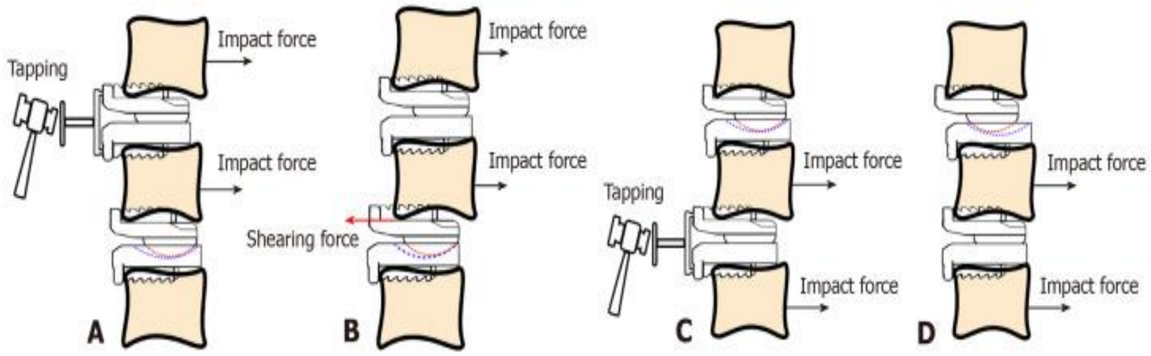

Figure 10

The mechanism underlying the condition occurring in case 4. A: The impact force generated by tapping processes allowed the C5 vertebra as well as the upper tab at C5/6 to move backward; B: While the posterior border of the ball continued to contact the posterior border of the socket at C5/6, the backward movement of the upper tab at C5/6 was restricted due to the design of the prosthesis. Therefore, a shearing force was generated between the C5 vertebral body and the upper tab at C5/6. Affected by this shearing force, the upper tab at C5/6 finally migrated forward; C and D: If we inserted the prosthesis using a top-down sequence, the anterior border of the socket on the lower tab at C4/5 would barely contact the ball on the upper tab at C4/5. Therefore, no shearing force would be generated between the lower tab at C4/5 and the C5 vertebral body, and the prosthesis would not migrate.

Limitations

One major limitation of this study is that we did not report the cumulative incidence of the effectiveness or complications of these procedures. Additionally, we did not compare our surgical techniques with alternative methods. Future research should address these gaps.

Conclusion

Using an inappropriate implantation sequence in multilevel cervical spine surgery can lead to complications such as the migration of a previously inserted artificial disc, worsening spinal cord compression, and implant loosening. Through extensive surgeries and careful case analysis, we have confirmed the rationality and safety of our strategies. We hope that these surgical approaches will contribute to improved outcomes in multilevel cervical spine surgeries. We believe that paying meticulous attention to surgical procedures can significantly enhance the performance and outcomes of both multilevel cervical disc replacement and hybrid surgery

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