Original Article

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Back To Basics at The Craniovertebral Junction: Occipito-Cervical Fusion for Basilar Invagination with Atlantoaxial Instability

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Learning Point of the Article:

Conventional occipitocervical fusion with foramen magnum decompression provides safe, effective stabilization for selected patients with complex or infective craniovertebral junction pathology when reduction is not feasible.

Abstract

Introduction: Basilar invagination (BI) with atlantoaxial instability is a complex craniovertebral junction disorder that causes progressive cervicomedullary compression and disabling myelopathy. Although reduction-based techniques such as distraction–compression–extension–reduction (DCER) have expanded surgical options, conventional occipitocervical fusion remains an important stabilization strategy in selected patients with rigid deformity, advanced neurological compromise, or infective craniovertebral junction pathology.

Materials and Methods: This retrospective case series included three patients with BI and atlantoaxial instability, including one with infective C1–C2 spondylodiscitis, who underwent posterior occipitocervical fusion with foramen magnum decompression between 2024 and 2025. Clinical outcomes were assessed using the Nurick grade, Visual Analog Scale (VAS), and Oswestry Disability Index (ODI). Radiographic evaluation included the atlantodental interval (ADI), clivo-axial angle (CXA), Chamberlain's line, and McRae's line. Perioperative complications and neurological outcomes were recorded. All patients completed 12 months of follow-up.

Results: All patients presented with advanced myelopathy (Nurick Grade III–V) and marked craniovertebral instability (ADI, 6.2–9.0 mm; CXA, 125°–132°). Posterior occipitocervical fusion with foramen magnum decompression was successfully completed in all patients without intraoperative neurological deterioration, implant-related complications, or revision surgery. Neurological status remained stable or improved throughout follow-up. The patient with infective spondylodiscitis demonstrated improvement in VAS (8 to 3) and ODI (64% to 38%), while all patients achieved radiographic construct stability at final follow-up.

Conclusions: Occipitocervical fusion with foramen magnum decompression provided satisfactory neurological stabilization, radiographic stability, and functional improvement in this small series of patients with complex BI and atlantoaxial instability. It remains a valuable stabilization strategy for selected patients when reduction-based techniques are not feasible.

Keywords: Basilar invagination, atlantoaxial instability, Occipitocervical fusion, craniovertebral junction, cervical myelopathy, spondylodiscitis, clivo-axial angle, Nurick grade.

Introduction

Basilar invagination (BI) with atlantoaxial instability is a complex craniovertebral junction (CVJ) disorder characterized by superior migration of the odontoid process into the foramen

Author's Photo Gallery

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magnum, resulting in progressive cervicomedullary compression and neurological deterioration [1,2]. Patients commonly present with cervical myelopathy, gait disturbance, neck pain, and long-tract signs secondary to chronic neural compression and instability [1,2].

The surgical management of BI has evolved from decompression-focused procedures to stabilization-based strategies aimed at restoring alignment and achieving durable fusion. Contemporary reduction techniques, such as distraction–compression–extension–reduction (DCER), have demonstrated favourable radiological and clinical outcomes in selected reducible deformities [1]. However, these techniques require specialized instrumentation and appropriate anatomical conditions, limiting their applicability in patients with rigid deformity, severe instability, poor bone quality, or infective craniovertebral junction pathology [3,4].

Conventional Occipitocervical fusion provides rigid stabilization of the craniovertebral junction and remains an established treatment option for complex BI, particularly when reduction-based techniques are not feasible [3-5]. In infective C1–C2 spondylodiscitis, progressive Osseo-ligamentous destruction further compromises stability, making robust posterior fixation essential for neural protection and spinal stability [6].

We present a retrospective three-patient case series of basilar invagination with atlantoaxial instability, including one patient with infective C1–C2 spondylodiscitis, managed with conventional occipitocervical fusion and foramen magnum decompression. This study highlights the clinical presentation, radiological characteristics, surgical management, and 12-month outcomes, emphasizing the continued role of conventional occipitocervical fusion as a reliable stabilization strategy in selected complex craniovertebral junction pathologies.

Materials And Methods

Study Design and Setting

This retrospective observational case series included three consecutive patients with basilar invagination (BI) associated with atlantoaxial (C1–C2) instability who underwent posterior Occipito-cervical fusion at a single tertiary referral spine center. One patient had concomitant infective C1–C2 spondylodiscitis with craniovertebral junction instability. Patients with traumatic craniovertebral injuries, neoplastic lesions, previous craniovertebral junction surgery, or incomplete clinical records were excluded. All procedures were performed by the same experienced spine surgery team using a standardized surgical protocol. Owing to the descriptive nature of the study and the small sample size, only descriptive analysis was performed.

Clinical Assessment

All patients underwent detailed neurological evaluation with emphasis on motor weakness, gait disturbance, and long tract signs such as hyperreflexia, Hoffmann's sign, Babinski sign, and finger escape phenomenon. Functional disability was assessed using the Oswestry Disability Index (ODI), while pain severity was quantified using the Visual Analog Scale (VAS). Neurological status was further graded using the Nurick grading system to assess the severity of myelopathy and functional impairment.

Radiological Assessment

Preoperative imaging included X-ray cervical spine with dynamic views, computed tomography (CT) of the craniovertebral junction for bony anatomy and instability assessment, and magnetic resonance imaging (MRI) for evaluation of corticomedullary compression and infective pathology. Radiological parameters assessed included atlantodental interval (ADI), Chamberlain's line, McRae's line, and clivo-axial angle (CXA) to quantify instability and basilar invagination severity. Immediate postoperative radiographs were reviewed to assess implant position, construct alignment, and maintenance of reduction.

Surgical Technique

All patients were counselled regarding disease severity and surgical risks, including neurological deterioration, vascular injury, and potential need for postoperative ventilatory support. After informed consent, patients were intubated with care to avoid excessive neck movement, and a video laryngoscope was used when difficult airway was anticipated.

Gardner-Wells tongs were applied for cranial stabilization. Intraoperative neuromonitoring with motor evoked potentials (MEPs) and somatosensory evoked potentials (SSEPs) was used in all cases. Baseline signals were recorded in the supine position, followed by prone positioning with neutral alignment and gentle 2 kg traction. Reverse Trendelenburg positioning was used to minimize venous bleeding.

A standard posterior midline approach was used to expose the occipital bone and sub axial cervical spine. Foramen magnum decompression was performed in all cases, including removal of approximately 1 cm of occipital bone and partial posterior arch resection of C1 (up to 1.5 cm bilaterally) to decompress the cervicomedullary junction. Instrumentation was performed under fluoroscopic guidance. C2 laminar screws were used. Additional lateral mass screws were placed in sub axial cervical vertebrae depending on fixation requirement. Occipital fixation was achieved using 8–12 mm cortical screws. Rods were contoured and assembled, followed by controlled alignment and sequential tightening. Neuromonitoring signals were checked after each critical step. Decortication of occiput and posterior elements was performed, and autologous iliac crest bone graft was placed to promote fusion. Wound closure was performed in layers over a suction drain. Postoperatively, patients were mobilized on day 2 with a rigid cervical collar.

Patients were evaluated clinically and radiologically at 6 weeks, 6 months, and 12 months after surgery. Clinical outcomes included Nurick grade, VAS, and ODI, while radiographs were obtained to assess implant stability, construct alignment, and maintenance of alignment throughout follow-up.

Case 1

A 43-year-old man presented with progressive gait instability, ataxia, and paraesthesia involving all four limbs. Neurological examination revealed cervical myelopathy with hyperreflexia and positive long tract signs (Nurick Grade IV). CT and MRI demonstrated basilar invagination with atlantoaxial instability, an atlantodental interval (ADI) of 7.5 mm, clivo-axial angle (CXA) of 128°, odontoid migration 6 mm above Chamberlain's line, violation of McRae's line, and significant cervicomedullary compression (Fig. 1). The patient underwent posterior Occipito-cervical fusion extending to C5 with foramen magnum decompression. At 12-month follow-up, neurological function, gait, and balance had improved without implant-related complications or neurological deterioration.

Case 2

A 14-year-old boy presented with neck pain, progressive gait difficulty, and loss of hand dexterity. Examination demonstrated bilateral hand weakness, hyperreflexia, positive Hoffmann's, Babinski, and finger escape signs, and Nurick Grade III myelopathy. Imaging confirmed basilar invagination with atlantoaxial instability, an ADI of 6.2 mm, CXA of 132°, odontoid migration 4 mm above Chamberlain's line, and mild

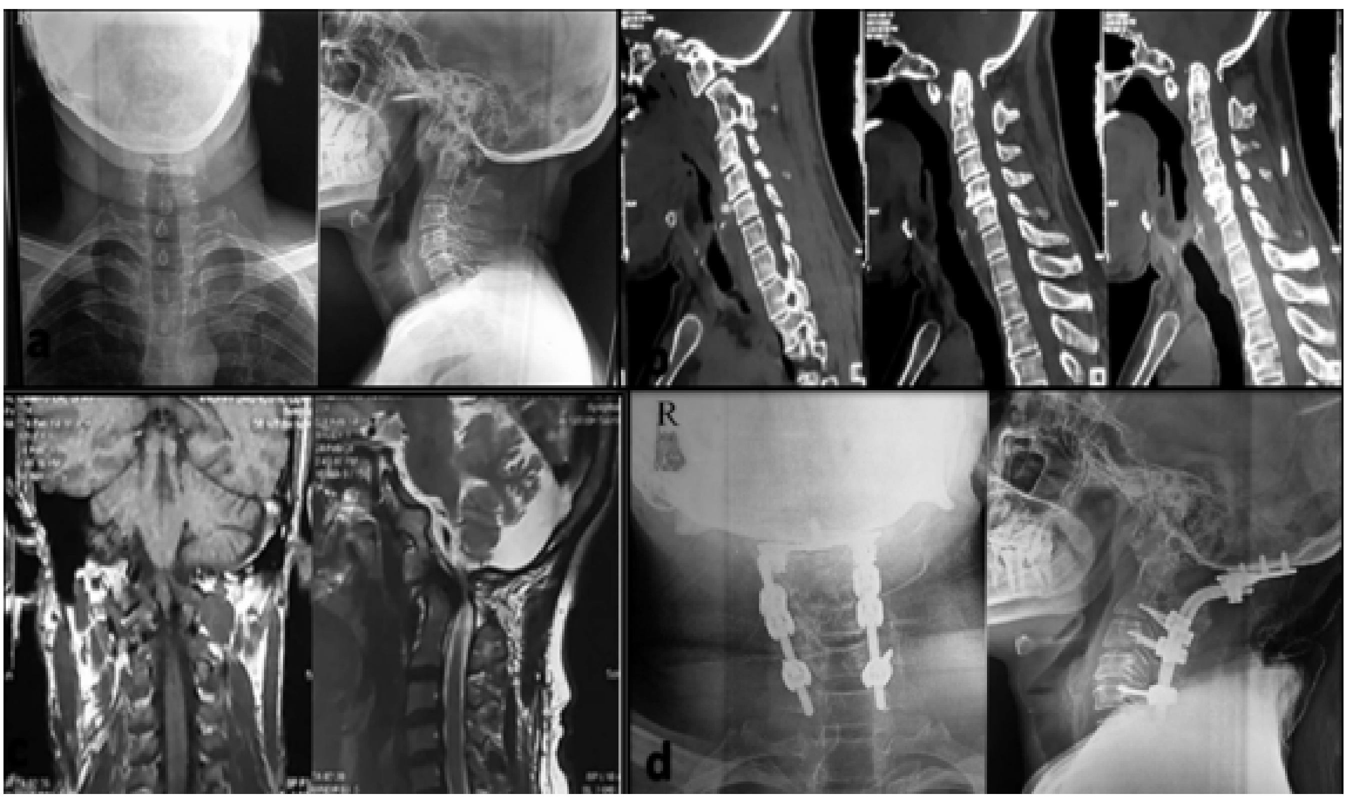

Figure 1: Preoperative and Postoperative Radiological Assessment of Basilar Invagination With Atlantoaxial Instability Following OccipitoCervical Fusion (a) Preoperative anteroposterior and lateral cervical radiographs demonstrating craniovertebral junction malalignment with basilar invagination and atlantoaxial instability. (b) Preoperative sagittal computed tomography (CT) images showing superior migration of the odontoid process, atlantoaxial subluxation, reduction in the clivo-axial angle, and significant craniovertebral junction deformity. (c) Preoperative magnetic resonance imaging (MRI) demonstrating marked cervicomedullary compression with ventral brainstem indentation secondary to basilar invagination and C1-C2 instability. (d) Postoperative anteroposterior and lateral radiographs demonstrating satisfactory occipito-cervical fixation extending from the occiput to C5 with screw-rod construct, restoration of craniovertebral alignment, and adequate stabilization following foramen magnum decompression and C1 posterior arch excision.

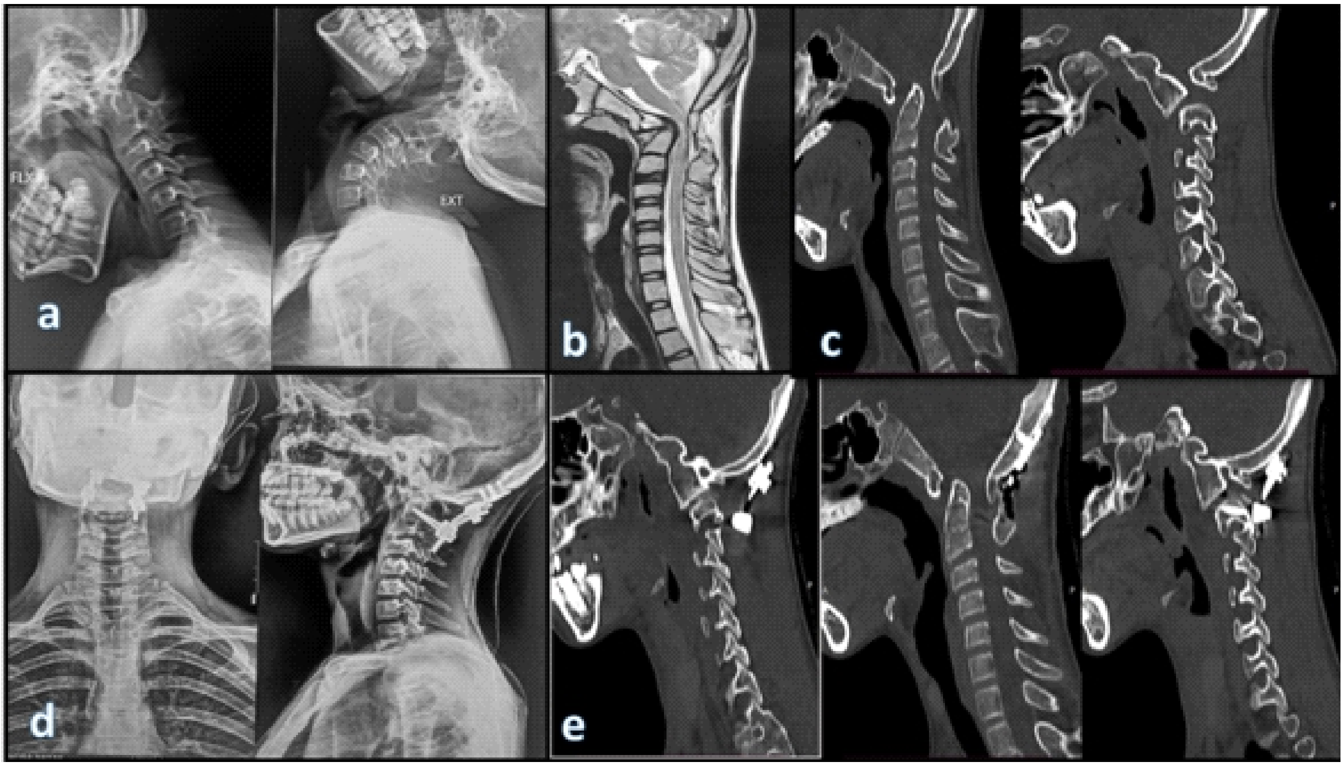

Figure 2: Dynamic Radiographic, CT, and MRI Evaluation Demonstrating Craniovertebral Junction Instability and Postoperative Occipito-Cervical Stabilization (a) Preoperative dynamic flexion-extension cervical radiographs demonstrating significant atlantoaxial instability with abnormal craniovertebral junction mobility and reducibility assessment. (b) Preoperative sagittal magnetic resonance imaging (MRI) showing basilar invagination with severe cervicomedullary compression and ventral indentation at the cervicomedullary junction. (c) Preoperative sagittal computed tomography (CT) images demonstrating superior migration of the odontoid process, atlantoaxial subluxation, and altered clivo-axial alignment consistent with craniovertebral instability. (d) Postoperative anteroposterior and lateral cervical radiographs demonstrating satisfactory occipito-cervical fixation extending from the occiput to C2 with restoration of craniocervical alignment following posterior stabilization. (e) Postoperative sagittal CT images confirming appropriate placement of the occiput-to-C2 fusion construct, adequate decompression at the craniovertebral junction following foramen magnum decompression and C1 posterior arch excision, and improved cervicomedullary alignment.

violation of McRae's line, producing cervicomedullary compression (Fig. 2). Posterior Occipito-cervical fusion with foramen magnum decompression was performed. At 12 months, the patient showed sustained neurological improvement with better gait, hand function, and independent ambulation.

Case 3

A 23-year-old man presented with severe neck pain and progressive quadriparesis. Neurological examination revealed diffuse upper motor neuron signs with Nurick Grade IV–V myelopathy. Preoperative VAS and ODI were 8/10 and 64%, respectively. CT and MRI demonstrated infective C1–C2 spondylodiscitis with atlantoaxial instability, basilar invagination, ADI of 9.0 mm, CXA of 125°, odontoid migration 8 mm above Chamberlain's line, violation of McRae's line, and marked cervicomedullary compression (Fig. 3). The patient underwent posterior Occipito-cervical fusion to C3 with foramen magnum decompression. At 12-month follow-up, VAS

Table 1: Clinical, functional, and radiological characteristics of patients with basilar invagination and atlantoaxial subluxation treated with Occipito-cervical fusion

Case	Age/Sex	Diagnosis	Nurick Grade	VAS (Preop)	ODI (%)	ADI (mm)	Clivo-axial Angle (CXA)	Chamberlain's Line	McRae's Line	Levels Fused	Key Radiological / Clinical Notes
1	43/M	BI with C1–C2 subluxation	IV	07-Oct	56%	7.5 mm	128°	Tip of odontoid 6 mm above line	Odontoid above foramen magnum	Occiput–C3–C5	Severe myelopathy with ataxia; cervicomedullary compression
2	14/M	BI with atlantoaxial subluxation	III	06-Oct	48%	6.2 mm	132°	Odontoid 4 mm above line	Mild basilar impression	Occiput–C2–C4	Paediatric instability with gait disturbance and hand weakness
3	23/M	Infective C1–C2 spondylodiscitis with BI	IV–V	08-Oct	64%	9.0 mm	125°	Odontoid 8 mm above line	Marked basilar migration	Occiput–C3	Severe instability due to infection; ligamentous destruction

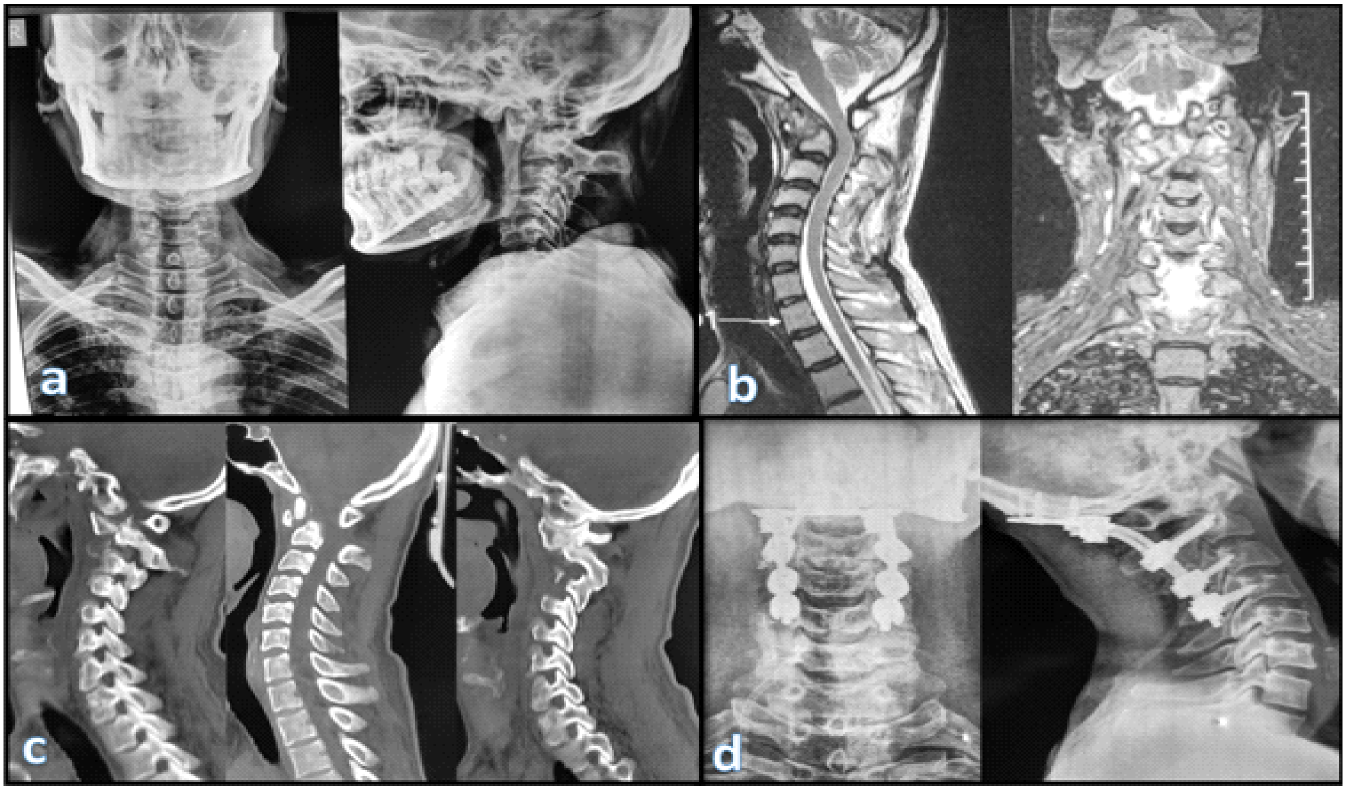

Figure 3: Radiological Evaluation of Infective C1-C2 Spondylodiscitis with Basilar Invagination Before and After Occipito-Cervical Fusion. (a) Preoperative anteroposterior and lateral cervical radiographs demonstrating craniovertebral junction malalignment with atlantoaxial instability and features suggestive of basilar invagination. (b) Preoperative sagittal and coronal magnetic resonance imaging (MRI) demonstrating infective spondylodiscitis involving the C1-C2 articulation with associated soft tissue inflammation, cervicomedullary compression, and ventral brainstem indentation. (c) Preoperative sagittal computed tomography (CT) images demonstrating Osseo ligamentous destruction at the atlantoaxial complex, superior migration of the odontoid process, increased atlantodental interval, and altered clivo-axial alignment consistent with severe craniovertebral instability. (d) Postoperative anteroposterior and lateral radiographs demonstrating satisfactory Occipito-cervical fixation extending from the occiput to C4 with restoration of Craniocervical alignment following posterior stabilization, foramen magnum decompression, and C1 posterior arch excision.

improved to 3/10, ODI to 38%, and neurological status remained stable without implant-related complications or revision surgery.

Follow-up Outcomes

All three patients completed clinical and radiological follow-up at 6 weeks, 6 months, and 12 months. No implant-related complications, wound infection, neurological deterioration, implant loosening, or revision surgery occurred during the follow-up period. Serial radiographs demonstrated maintenance of construct alignment and implant stability in all patients. Progressive improvement in neurological function and ambulatory status was observed throughout the 12-month follow-up.

Discussion

The craniovertebral junction is one of the most biomechanically complex regions of the spine, where even minor instability can result in significant neurological compromise because of its close relationship to the brainstem and upper cervical spinal cord. Basilar invagination (BI) with atlantoaxial instability is increasingly recognized as a dynamic instability-driven disorder characterized by progressive odontoid migration and cervicomedullary compression rather than a static congenital anomaly [1,2]. In the present series, all patients presented with advanced myelopathy (Nurick Grade III–V) and radiological evidence of significant craniovertebral junction instability, highlighting the progressive nature of untreated BI and the importance of timely surgical stabilization.

Modern management of basilar invagination has evolved from decompression-focused procedures to stabilization and realignment-based strategies. Goel proposed that atlantoaxial instability is the primary pathological driver of BI and that C1–C2 fixation alone may achieve indirect reduction without direct decompression in selected patients [3-5]. Subsequently, reduction-based techniques such as distraction–compression–extension–reduction (DCER) were developed to achieve controlled anatomical realignment and have demonstrated favourable radiological and clinical outcomes in carefully selected reducible deformities [1]. However, these techniques require appropriate anatomical conditions and specialized expertise, limiting their applicability in patients with rigid deformity, severe instability, or infective craniovertebral junction pathology.[5,6]

However, reduction-based techniques are not feasible in all patients with basilar invagination. Rigid deformity, advanced instability, infective Osseo-ligamentous destruction, and poor bone quality may preclude safe anatomical reduction. In our series, all patients demonstrated advanced craniovertebral junction instability, characterized by an atlantodental interval of 6.2–9 mm, clivo-axial angle of 125°–132°, and odontoid migration beyond Chamberlain's and McRae's lines, consistent with significant cervicomedullary compression [6,7]. Although DCER provides excellent deformity correction in reducible BI [8,9], conventional Occipito-cervical fusion with foramen magnum decompression achieved sustained neurological stabilization and functional improvement throughout the 12-month follow-up in our patients, supporting stabilization as an effective strategy in carefully selected complex CVJ pathologies.[10]

Long-term studies have demonstrated that Occipito-cervical fusion provides durable stabilization and sustained neurological improvement in complex craniovertebral junction disorders [11,12]. Modern screw-rod constructs further enhance biomechanical stability and clinical outcomes [13]. The infective case in our series illustrates the value of stabilization-first surgery in C1–C2 spondylodiscitis, where progressive Osseop-ligamentous destruction frequently precludes reduction-based procedures. Consistent with previous reports [9], rigid posterior stabilization with foramen magnum decompression resulted in sustained neurological recovery despite severe structural compromise.

Biomechanically, Occipito-cervical fusion eliminates pathological motion at the craniovertebral junction, providing immediate stability and facilitating neurological recovery [10-14]. Although upper cervical motion is sacrificed, preservation of neurological function and spinal stability remains the primary objective in advanced CVJ instability. Because postoperative CT was not routinely performed, this study focused on clinical outcomes and construct stability rather than radiological fusion.[15] Table 1.

This study has several limitations. The small sample size and retrospective single-center design limit statistical analysis and generalizability. Although all patients completed 12 months of follow-up, longer-term evaluation is required to assess implant longevity, adjacent segment degeneration, and radiological fusion. In addition, the absence of a comparison group precludes direct evaluation of conventional Occipito-cervical fusion against reduction-based techniques such as distraction–compression–extension–reduction (DCER).

Conclusion

Conventional occipitocervical fusion remains a dependable stabilization strategy for selected patients with basilar invagination and atlantoaxial instability, particularly in advanced, rigid, or infective cases. In this series, sustained neurological stabilization and functional improvement were maintained throughout the 12-month follow-up, highlighting that restoration of stability alone can achieve favourable clinical outcomes in carefully selected patients.

Clinical Message

Occipito-cervical fusion remains a safe, reliable, and effective treatment for advanced basilar invagination with atlantoaxial instability, including infective craniovertebral junction pathology. Even without complex reduction techniques, rigid stabilization can provide significant neurological recovery, pain relief, and durable functional improvement when guided by careful clinical and radiological assessment.

Declaration of patient consent: The authors certify that they have obtained all appropriate patient consent forms. In the form, the patient has given the consent for his/ her images and other clinical information to be reported in the journal. The patient understands that his/ her names and initials will not be published and due efforts will be made to conceal their identity, but anonymity cannot be guaranteed.

Conflict of interest: Nil **Source of support:** None

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