e-ISSN: 0975-9506, p-ISSN: 2961-6093

Available online on www.ijpqa.com

International Journal of Pharmaceutical Quality Assurance 2026; 17(6); 329-337

Original Research Article

Pedicle Stump Technique a Simple and Safe Method for Placement of C1 Pedicle Screws

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Received: 02-04-2026 / Revised: 19-05-2026 / Accepted: 26-06-2026

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Conflict of interest: Nil

Abstract:

Background: Placement of C1 pedicle screws is an effective method for atlantoaxial stabilization but remains technically challenging because of the complex anatomy and proximity to critical neurovascular structures. The Pedicle Stump Technique has been proposed as a simple and safe freehand method for accurate screw placement.

Aim: To evaluate the safety, accuracy, and clinical outcomes of the Pedicle Stump Technique for C1 pedicle screw placement in patients with atlantoaxial instability.

Methodology: This prospective observational study included four patients with atlantoaxial instability who underwent posterior C1–C2 fixation using the Pedicle Stump Technique. Demographic, operative, radiological, and clinical outcome data were analyzed using descriptive statistics.

Results: The mean patient age was 49 years, and 75% were male. Mean operative time was 143.75 minutes, and mean blood loss was 180 mL. Grade A screw placement accuracy was achieved in 75% of cases and Grade A in 25%. All patients demonstrated neurological improvement with reduced postoperative Nurick grades. No vertebral artery injury, occipital neuralgia, neurological deterioration, or implant-related complications occurred. Successful fusion was achieved in all patients.

Conclusion: The Pedicle Stump Technique is a simple, safe, and effective method for C1 pedicle screw placement, providing accurate fixation, favorable neurological outcomes, and excellent fusion rates with minimal complications.

Keywords: Atlantoaxial instability, C1 pedicle screw, Pedicle Stump Technique, Posterior C1–C2 fixation, Screw placement accuracy, Spinal fusion.

DOI: 10.25258/IJPQA.17.6.57

Introduction

Atlantoaxial instability is a pathological condition that is caused by excessive movement between the atlas (C1) and axis (C2) caused by trauma, congenital anomalies, degenerative changes, inflammatory disorders, tumors, or infections at the craniovertebral junction. The atlantoaxial joint provides a significant range of cervical rotation and also provides stability of the upper cervical spine. Any disruption to the ligaments or bones at this level could result in loss of spinal stability that can cause neck pain, neurologic deficits, myelopathy or even severe compression of the spinal cord. The upper cervical spine, spinal cord and vertebral arteries are in close proximity to each other and the stabilization of atlantoaxial instability is an important goal in spine surgery [1].

The treatment of atlantoaxial instability has changed over the years. Previous methods of stabilization (posterior wiring) were not as biomechanically sound and had inconsistent fusion rates. The use of screw fixation techniques has greatly increased the rigidity and reliability of atlantoaxial stabilization [2]. These developments include C1 pedicle screw fixation, which offers good biomechanical characteristics and has become increasingly popular because of its ability to offer strong fixation. The technique provides very good resistance to rotational and translational forces, and is useful for increasing fusion rate if using the appropriate C2 instrumentation. Hence, accurate placement of C1 pedicle screw is critical in achieving rigid atlantoaxial fixation [3].

Although very beneficial, pedicle screw placement is technically challenging due to the unique anatomy of the atlas. The back of the atlas (C1) and the pedicle are smaller than usual and lie close to important structures like the vertebral artery, C2 nerve root and spinal cord lies in close proximity to the posterior arch of atlas. The anatomical variations like narrow pedicle corridor or high riding vertebral artery may further complicate the screw insertion process [4].

Misplacement of screws can cause serious complications, such as damage to the vertebral artery, neurological problems, excessive bleeding and failure of fixation. Accurate placement of screws with minimal risks is thus a major challenge for spine surgeons [5].

Several technical advancements have enhanced the accuracy of instrumentation, including fluoroscopy, computed tomography (CT) based navigation and robot assistance [6]. While these techniques can improve accuracy, they also come with higher costs, longer operating times, and require specialized equipment and training. Many healthcare facilities and especially in developing areas lack access to sophisticated navigation. Thus, freehand technique, which requires no technological assistance and provides a rigid fixation, is still needed.

The pedicle stump technique has proved to be a promising approach for the accurate placement of freehand C1 pedicle screws [7]. The technique gives direct exposure and visualization of the pedicle stump to allow the surgeon to determine the best screw entry point and trajectory by using anatomical landmarks. The technique helps to decrease uncertainty when placing the screws and reduce the risk of cortical breach, giving a clear view of the pedicle corridor. Direct visualization is also helpful in protecting of adjacent neurovascular structures, and may enhance the overall safety of the procedure. The pedicle stump technique has been used mainly based on the knowledge of the surgical anatomy, not advanced imaging guidance, which makes the pedicle stump technique a practical solution in a broad spectrum of clinical settings.

The simplicity and reproducibility of the pedicle stump technique is another great benefit. This method can be easily applied to their common surgical practice without depending on expensive equipments and navigation assistance. Less reliance on fluoroscopy can help to lower radiation exposure for patients and operating room staff. Moreover, the technique can reduce the surgical time and enhance the surgical efficiency, while ensuring satisfactory fixation results. This can make the pedicle stump technique ideal for surgeons who prefer an easy and reliable way to place C1 pedicle screws [8].

Initial outcomes have been shown to be promising, both clinically and radiologically, in the pedicle stump technique. Research has demonstrated correct screw placement, good fusion, neurological improvement and low complication rates. But the number of studies published is still limited, and the technique needs to be evaluated in other patient groups to verify its effectiveness and safety. To therefore evaluate the safety, clinical feasibility and radiological accuracy of the pedicle stump technique as a simple and effective approach for transpedicular fixation of C1 screws in the patients who require atlantoaxial stabilization.

Methodology

Study Design: This study will be conducted as a prospective observational study to evaluate the safety, accuracy, and clinical outcomes of the "Pedicle Stump Technique" for placement of C1 pedicle screws in patients undergoing posterior C1–C2 fixation for atlantoaxial instability.

Study Area: The study will be conducted in the Department of Orthopaedics (spine surgery) CISRO Hospital, Patna, Bihar, India.

Study Duration: The study was conducted over a period of one year.

Study Participants

Inclusion Criteria

- Patients diagnosed with atlantoaxial instability requiring posterior C1–C2 fixation.
- Patients who underwent C1 pedicle screw placement using the Pedicle Stump Technique.
- Patients aged 18 years and above.
- Patients with complete clinical and radiological records available for review.

Exclusion Criteria

- Patients with atlantoaxial instability secondary to active infection or rheumatoid arthritis.
- Patients requiring occipitocervical fixation.
- Patients with anatomical abnormalities precluding safe C1 pedicle screw placement.
- Patients with incomplete clinical or radiological data.
- Patients with previous upper cervical instrumentation surgery.

Sample Size: A total of 4 consecutive patients who underwent posterior C1–C2 fixation using the Pedicle Stump Technique were included in the study.

Procedure: All patients underwent detailed clinical, neurological, and radiological evaluation before surgery. Preoperative imaging, including cervical spine radiographs, computed tomography (CT), magnetic resonance imaging (MRI), and CT angiography whenever indicated, was used to assess atlantoaxial instability, pedicle morphology, and vertebral artery anatomy.

Under general anesthesia, patients were positioned prone on bolsters. A standard posterior midline cervical incision was made and subperiosteal exposure of the posterior elements of C1 and C2 was performed. The vertebral artery was carefully mobilized superiorly, while the C2 nerve root was retracted inferiorly to expose the posterior arch of C1.

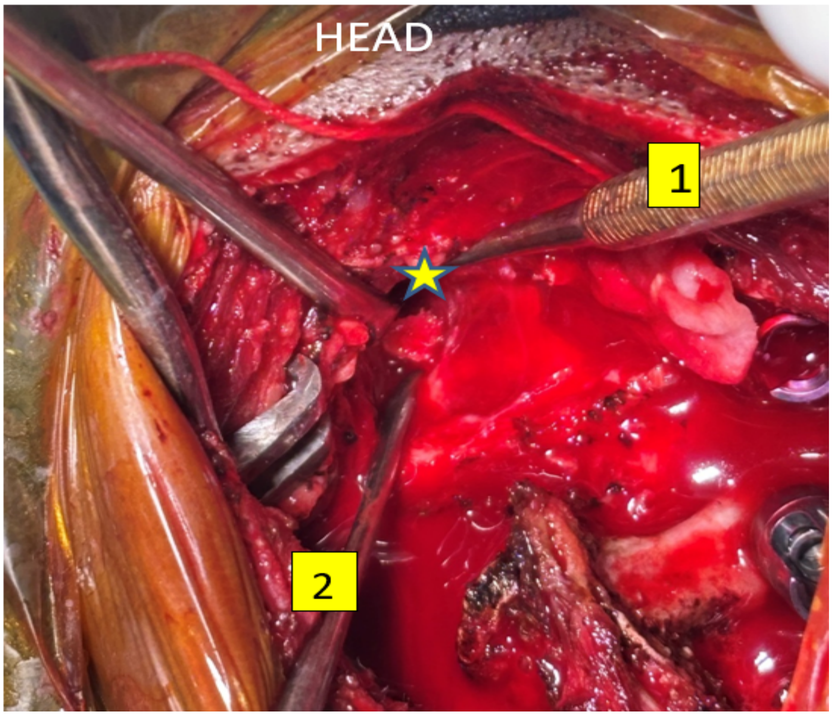

Figure 1: C1 pedicle stump (asterisk) exposed after gradual nibbling of the posterior arch of C1. Medial wall of C1 pedicle can be visualised after excision of posterior arch of C1. Penfield dissector (1) retracting the vertebral artery superiorly. Penfield dissector (2) retracting the C2 root inferiorly.

The posterior arch of C1 was gradually nibbled using Kerrison rongeurs until the pedicle stump and its medullary canal became visible. Exposure of the pedicle stump allowed direct visualization of the pedicle anatomy and facilitated identification of the optimal screw entry point. A pilot hole was created using a high-speed burr, and the pedicle stump served as a natural guide for screw trajectory.

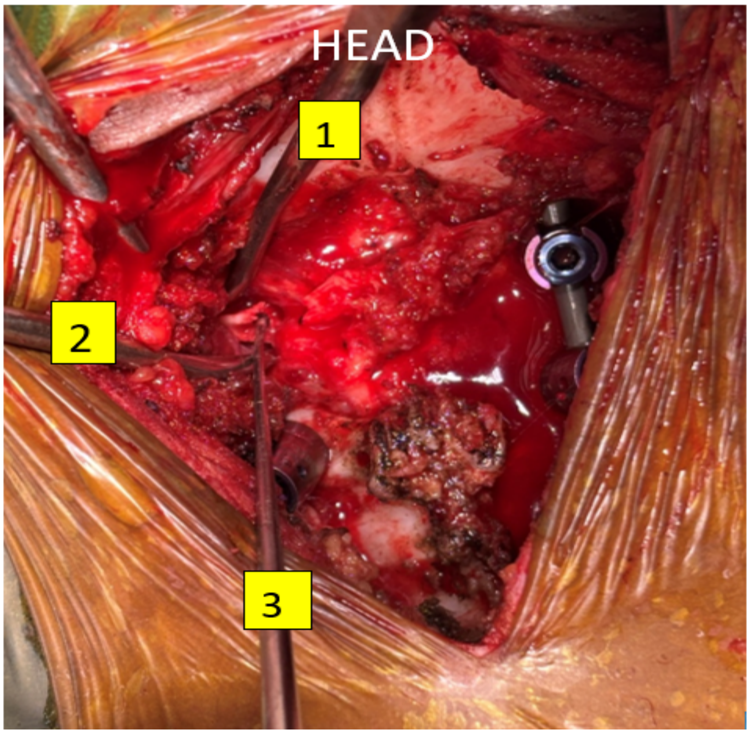

Figure 2: A 2mm burr was used to create a pilot hole for the C1 pedicle screw. A ball tipped probe (3) being used to confirm the trajectory of the screw. Penfield dissector (1) retracting the VA superiorly and Penfield dissector (2) retracting the C2 root inferiorly.

Adequate mediolateral angulation of the screw trajectory was ensured by staying parallel to the medial wall of C1 pedicle. Craniocaudal angulation was determined by orientation of the pedicle stump. Screw length was selected to achieve bicortical fixation within the anterior arch of C1 while avoiding excessive anterior penetration. Following tapping of the pedicle tract, a 3.5-mm pedicle screw was inserted under navigational guidance.

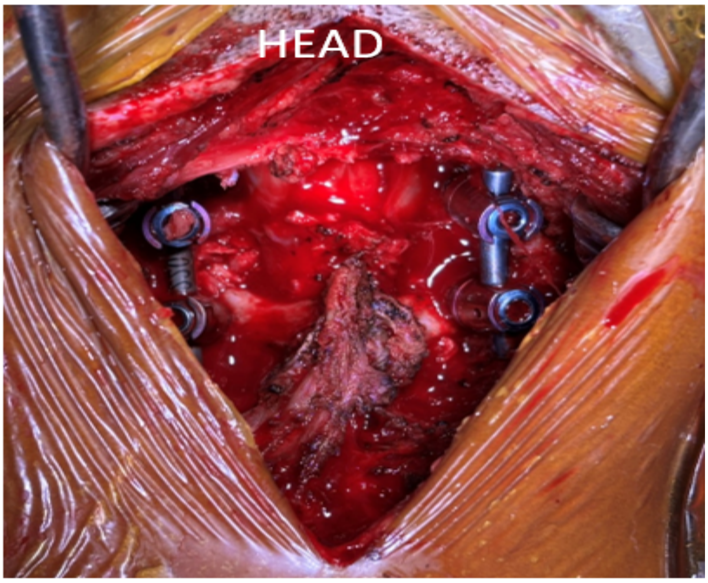

Figure 3: C1 and C2 pedicle screws connected with rods

C2 pedicle screws were subsequently inserted using standard techniques. The C1–C2 facet joints were exposed and prepared for fusion using a burr. Autologous bone graft was then placed within the prepared joint space to promote arthrodesis. Final construct stabilization was achieved using connecting rods.

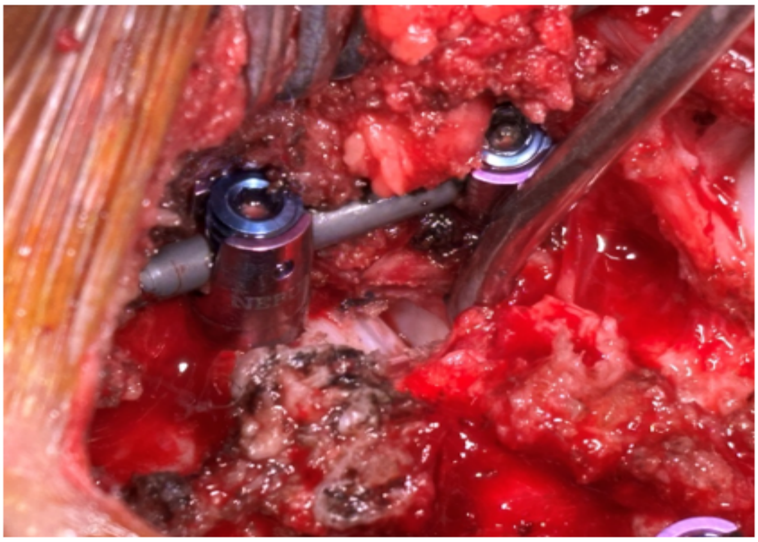

Figure 4 C1-C2 joint debridement and preparation for bone grafting.

Postoperative radiological assessment was performed to confirm screw position, trajectory, bicortical purchase, and overall construct alignment. Clinical evaluation was carried out to identify any neurological deficits, vertebral artery injury, implant-related complications, or other procedure-related adverse events.

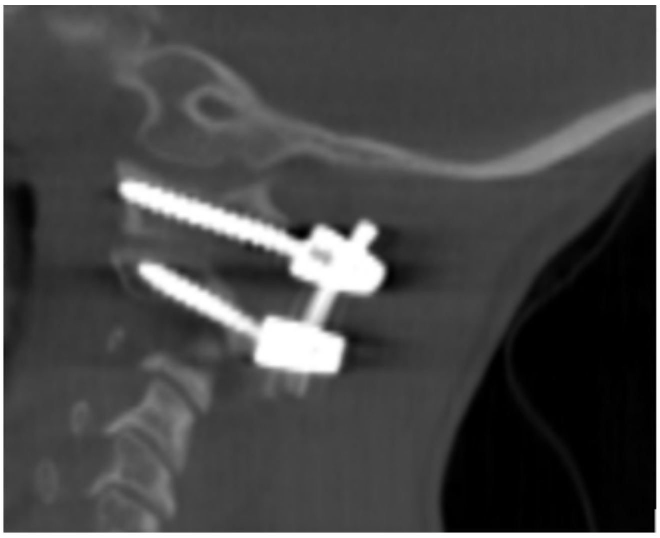

Figure 5. Sagittal trajectory of the C1 pedicle screw

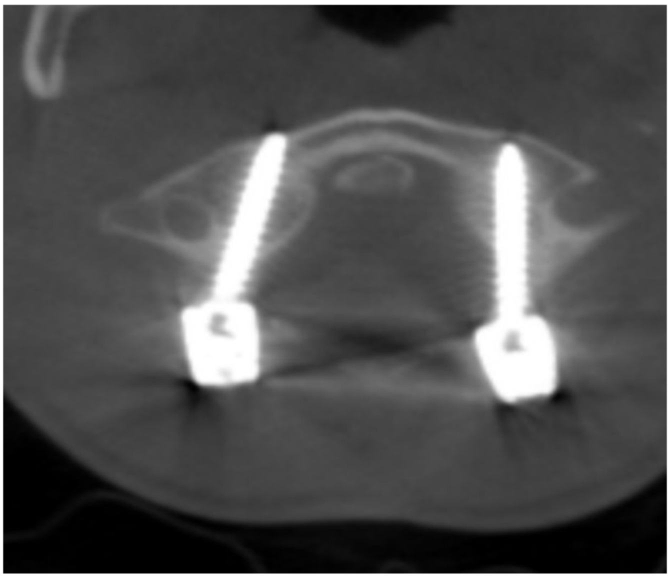

Figure 6. Axial trajectory showing biocritical fixation of C1 pedicle screws

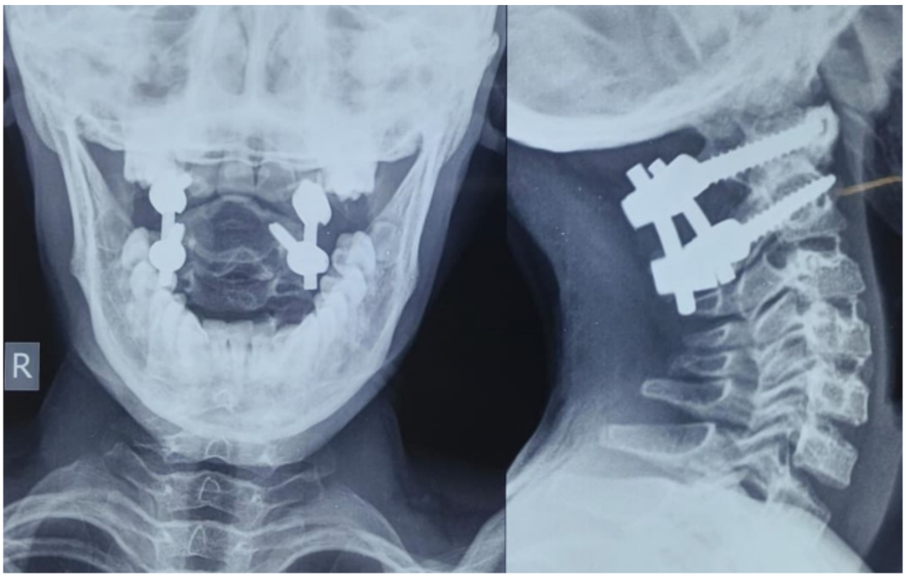

Figure 7. Post operative radiograph of C1-C2 construct

Outcome Measures

- Accuracy of C1 pedicle screw placement.
- Intraoperative safety of the procedure.
- Occurrence of vertebral artery injury.
- Neurological complications.
- Implant-related complications.
- Radiological assessment of screw trajectory and fixation.
- Stability of the C1–C2 construct.

Statistical Analysis: Data were entered into Microsoft Excel and analyzed using Statistical Package for the Social Sciences (SPSS) version 26.0. Due to the small sample size, data were analyzed primarily using descriptive statistics. Continuous variables were expressed as mean ± standard deviation, while categorical variables were presented as frequencies and percentages. Clinical and radiological findings were summarized to assess the safety, feasibility, and accuracy of the Pedicle Stump Technique for C1 pedicle screw placement.

Result

Table 1 presents the demographic and clinical characteristics of four patients diagnosed with atlantoaxial instability. The age of the patients ranged from 38 to 61 years, with a mean age of 49 years. Among the four patients, three (75%) were male and one (25%) was female. The underlying diagnoses included traumatic atlantoaxial instability in one patient, congenital atlantoaxial instability in one patient, and degenerative atlantoaxial instability in two patients, indicating that degenerative causes were the most common in this series. Neck pain was the predominant presenting symptom and was reported by all patients, while associated neurological manifestations included myelopathy, paresthesia, gait disturbance, and limb weakness. The atlanto-dental interval (ADI) values ranged from 5.2 mm to 7.1 mm, with the highest value observed in the patient with congenital atlantoaxial instability and the lowest in a patient with degenerative instability. Overall, the findings demonstrate that atlantoaxial instability affected predominantly middle-aged to older adults, commonly presented with neck pain accompanied by neurological deficits, and was associated with varying degrees of atlantoaxial displacement as reflected by the ADI measurements.

Table 1: Demographic and Clinical Characteristics of Patients

Patient No.	Age (Years)	Sex	Diagnosis	Presenting Symptoms	ADI (mm)
1	42	Male	Traumatic Atlantoaxial Instability	Neck pain, myelopathy	6.5
2	55	Female	Degenerative Atlantoaxial Instability	Neck pain, paresthesia	5.2
3	38	Male	Congenital Atlantoaxial Instability	Neck pain, gait disturbance	7.1
4	61	Male	Degenerative Atlantoaxial Instability	Neck pain, limb weakness	5.8

Table 2 presents the operative and radiological parameters of four patients who underwent surgery. The operative time ranged from 135 to 155 minutes, with a mean duration of 143.75 minutes. Intraoperative blood loss varied between 160 and 210 mL, averaging 180 mL, indicating relatively low blood loss during the procedures. The length of the C1 screws ranged from 28 to 32 mm (mean 30 mm), while the C2 screw length varied from 30 to 34 mm (mean 32 mm). Assessment of screw placement accuracy showed that three patients (75%) achieved Grade A accuracy, indicating optimal screw positioning, whereas one patient (25%) had Grade A accuracy. Overall, the findings demonstrate satisfactory operative outcomes with acceptable surgical duration, minimal blood loss, appropriate screw dimensions, and a high rate of accurate screw placement.

Table 2: Operative and Radiological Parameters

Patient No.	Operative Time (min)	Blood Loss (mL)	C1 Screw Length (mm)	C2 Screw Length (mm)	Screw Accuracy Grade
1	145	180	30	32	A
2	135	160	28	30	A
3	155	210	32	34	A
4	140	170	30	32	A

Table 3 presents the clinical outcomes and complications of four patients following surgery. Preoperatively, the Nurick grade ranged from 2 to 4, indicating varying degrees of neurological impairment. At the 1-month postoperative follow-up, all patients demonstrated neurological improvement, with postoperative Nurick grades decreasing to 1 or 2. The greatest improvement was observed in patient 4, whose Nurick grade improved from 4 to 2, while Patients 1 and 2 improved to grade 1. No procedure-related complications, including vertebral artery (VA) injury or occipital neuralgia, were reported in any patient. Furthermore, successful fusion was achieved in all four cases during follow-up, indicating favorable surgical outcomes, effective stabilization, and a high rate of fusion without significant complications.

Table 3. Clinical Outcomes and Complications

Patient No.	Preoperative Nurick Grade	Postoperative Nurick Grade (1 Month)	VA Injury	Occipital Neuralgia	Fusion Status (Follow-up)
1	3	1	No	No	Achieved
2	2	1	No	No	Achieved
3	3	2	No	No	Achieved
4	4	2	No	No	Achieved

Discussion

The findings from this present study seem to back up the safety and effectiveness of the pedicle stump technique when doing C1 pedicle screw placement, especially in the whole scenario of atlantoaxial instability. In the four cases, all patients managed to reach satisfactory stabilization, showed neurological gains, and also reached successful fusion, with no major neurovascular issues reported. These outcomes line up with earlier works, which have pointed out the benefits of C1 pedicle screw fixation compared with more traditional anchoring approaches. In terms of who was included, the group had a mean age of 49 years, and the majority were males (75%), so it feels pretty in line with the demographic patterns described in several atlantoaxial instability series, where middle aged adults were most common among patients undergoing posterior C1–C2 fixation (Kwan et al., 2010; Menger et al., 2015) [9,10]. Degenerative disease was the most common cause in our set, though traumatic and congenital sources were also seen, and that kind of diversity fits the range of conditions that can call for atlantoaxial stabilization."

All ̀the patients had elevated atlanto-dental interval (ADI) values on radiological evaluation, confirming atlantoaxial instability. The patient with congenital instability had the highest ADI, which means that there was more displacement of the joint than the degenerative cases. Goel and Laheri (1994) [11] reported that congenital and developmental anomalies frequently have more atlantoaxial displacement than degenerative diseases. Our patients were routinely found to have abnormal ADI values, which further endorses the importance of preoperative radiologic assessment in selecting surgical indications and planning screw trajectories. Ma et al. (2005) [12] noted that a thorough pre-operative imaging evaluation is imperative to assess C1 posterior arch dimensions and pedicle morphology prior to pedicle screw placement.

A very important result of the present study was the good operative profile that was obtained with the pedicle stump technique. The mean operative time was around 144 minutes, and the blood loss during surgery was not too large. The results are similar to those of Yan et al. [13] who performed a randomized comparison of the C1 pedicle screws and lateral mass screws and demonstrated significantly shorter operating times and blood loss in the pedicle screw group. They explained these benefits by the fact that no large dissection of the venous plexus was required and that less manipulation of the C2 nerve root was necessary. In the same way, the pedicle stump technique in the current study allowed the direct visualization of the pedicle anatomy, with minimal soft tissue disruption, thus enhancing screw placement and surgical morbidity.

The remarkable thing about this series of screw placements was the accuracy of the screw placements. Three patients (75%) were Grade A with no Grade B screw placement, and no patients were severely breached. The results are consistent with the freehand pedicle screw technique used by Byeon et al. (2020) [14] using direct visualization of the C1 pedicle anatomy and serial dilatation. Similarly, Byeon et al. (2020) reported close screw placement accuracy with the use of advanced navigation systems, and 100% accuracy in screw placement was obtained with O-arm guidance. Despite our use of no elaborate navigation devices, and a simpler pedicle stump technique, our high percentage of ̉ grade A placements shows that direct anatomic visualization can be used as a ̀reliable guide to safe instrumentation. This is a key discovery in resource-poor environments where navigation technology might not be easily accessible.

One of the most important findings of the present study is that no vertebral artery (VA) was injured in all four patients. Vertebral artery injury is one of the most dreaded complications of C1 screw placement because the superior surface of the posterior arch is so close to this artery. Menger et al (2015) showed that careful exposure and direct visualization can drastically decrease the risk of vascular injury when performing C1 pedicle screw fixation. Likewise, Zhang et al. (2017) [15] pointed out that similar anatomical variations like a ponticulus posticus might pose a risk of vertebral artery injury in the event of their being misidentified before surgery. In our series, no vascular complication was encountered in all the procedures, which were technically difficult, suggesting that pedicle stump technique is sufficiently anatomic and safe.

The other interesting observation was that there were no cases of occipital neuralgia in the follow-up period. Previous studies have reported occipital neuralgia as a complication of too much retraction of the C2 nerve root during lateral mass screw placement (Conroy et al., 2010; Lee et al., 2013) [16,17]. The superior entry point for C1 pedicle screw is appropriate to avoid the dissection of the venous plexus and manipulation of the C2 nerve root. Thus, we found our results to agree with that of Yan et al. (2016), who found reduced neural irritation and postoperative pain in patients receiving C1 pedicle screws versus lateral mass screws.

All patients were seen to improve their Nurick grade after surgery indicating neurological recovery. Patients who had severe preoperative deficits had significant improvement in function after stabilization. Kwan et al. (2010) showed that patients who had undergone C1–C2 fixation for atlantoaxial instability had similar neurological recovery in the postoperative period. The improvement seen in the observed case was probably due to proper stabilization of the atlantoaxial complex, avoidance of further spinal cord compression and restoration of a normal biomechanical alignment.

All patients were successfully fused, with a 100% fusion rate. This result is similar to the fusion rates seen with current screw fixation systems. Harms and Melcher (2001) [18] and Magerl's transarticular fixation technique have both shown fusion rates close to 100% in the appropriate patient population. Similarly, Byeon et al. (2020) reported that a nearly complete union was achieved in all patients who underwent C1 pedicle screw placement. The complete fusion achieved in the present study indicates that pedicle stump technique offers an adequate amount of mechanical stability to encourage osseous healing and long-term alignment.

The results of this study agree with the literature and confirm the biomechanical superiority and clinical use of C1 pedicle screw fixation. Fensky et al. 2014 [19] found pedicle screws to have greater fixation strength and increased stiffness and reduced loosening rates than lateral mass screws. High rates of success in our patients, such as 75% Grade A screw accuracy, 100% fusion rates, no vertebral artery injury, no occurrence of occipital neuralgia, and neurological improvement in all of our patients, continue to validate the use of the pedicle stump technique as a simple, safe and effective method for placement of pedicle screws at C1. While this was a small study, the results were very consistent and are comparable to those reported in the literature and indicate that this technique may be a useful alternative to traditional C1 lateral mass screws.

Conclusion

The present study demonstrates that the pedicle stump technique is a simple, safe, and effective method for C1 pedicle screw placement in patients with atlantoaxial instability. The technique provided satisfactory operative outcomes, with acceptable surgical duration, minimal blood loss, and a high rate of screw placement accuracy. Neurological improvement was observed in all patients, as evidenced by improved postoperative Nurick grades, while successful fusion was achieved in every case. Importantly, no vertebral artery injury, occipital neuralgia, neurological deterioration, or implant-related complications were encountered. Direct visualization of the pedicle stump facilitated accurate identification of the screw trajectory and contributed to the overall safety of the procedure. Although the study was limited by a small sample size, the consistent clinical and radiological outcomes suggest that the pedicle stump technique is a reliable and practical alternative for achieving stable atlantoaxial fixation.

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