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Original Investigation

Occipital Condyle-C1 Complex Screw for Fixation of Basilar Invagination Patients with Atlas Assimilation

Huaiyu TONG[1], Lianfeng LI[2], Xin-guang YU[1], Yuanzheng ZHANG[1], Wang PENG[1]

[1]Chinese PLA General Hospital, Department of Neurosurgery, Haidian District, Beijing 100853, China
[2]The 306th Hospital of PLA, Department of Neurosurgery, Chaoyang District, Beijing 100101, China

Huaiyu Tong and Lianfeng Li are co-first authors.

ABSTRACT

AIM: To investigate whether C1-occipital condyle complex (CC complex) screws can be safely and rapidly placed without guidance in basilar invagination patients with atlas assimilation.

MATERIAL and METHODS: The occipital-cervical (OC) junction was fixed posteriorly in 8 basilar invagination patients with atlas assimilation using polyaxial titanium screws inserted unicortically into the CC complex and C2 pedicles and subsequent fixation to a 3-mm rod. Anatomic landmarks were used during the drilling. The screw angles and lengths of the CC complex were analyzed.

RESULTS: The width, length, and height values of the left-side CC complex were 7.96±2.23, 16.06±2.73, and 13.76±2.06 mm; those of the right-side CC complex were 7.84±1.38, 16.66±2.58, and 12.81±2.62 mm. The CC complex entry point was at the central point of posterior surface of the CC complex. The angle used for medialization was 10-15°, which was also the maximal superior screw angulation in the sagittal plane. The screw length required for unicortical purchase was 16-22 mm. The screw was not misplaced or poorly positioned, and no neurovascular complications associated with screw insertion were detected.

CONCLUSION: In patients with atlas assimilation, CC complex screws can be placed safely. The CC complex screws can be safely inserted assisted by microscope without image guidance.

KEYWORDS: Occipital condyle, Occipital-cervical junction, Occipital-cervical fusion, Occipital condyle screws, Occipital-cervical instability

■ INTRODUCTION

The occipital-cervical (OC) junction is the junction of the cranium and vertebral column, which spans from the occiput to C2. Protecting the lower brain stem, upper spinal cord, and lower cranial nerves, the biomechanical stability of this osseous complex is vital important. OC instability can have life-threatening consequences, and in China, it is not at all rare. This type of instability may emerge as pain, paralysis, cranial nerve dysfunction, or even sudden death (15). Congenital malformation is the leading pathologic processes that result in chronic OC instability in China. One of the indications for OC fusion is instability of the OC junction (2).

Early OC fixation techniques using cable fixation had a high rate of failure. For this reason, they were supplanted with rigid posterior fixation systems involving plates and screws or rods and screws because these have higher rates of fusion and provide better biomechanical stability (1,4,6,8,13,19,20). However, there is still no currently available system that is totally satisfactory. For the OC fixation systems, most of the limitations involve the cephalad part of the construct (24), because instrumentation can often not be easily attached to the occiput. To date, various plate constructs have been developed that use multiple fixation points to adjust for differences in the thickness of the lateral occipital bone and of the dural sinus anatomy (6,9). Of note, a previously performed

Corresponding author: Xin-guang YU
E-mail: xinguangyucn@163.com

suboccipital craniectomy can further restrict the available area for hardware placement, and occipital screws have been associated with intracranial injuries.

The current investigation of new methods of occipital screw fixation was inspired by the unsatisfactory nature of currently available. The new method discussed here includes the use of occipital condyles for OC fusion. Clinical analysis shows that application of screws fixation at normal occipital condyle structure can provide sufficient stability (7,18,22). However, because of the complex geometry and bony structure in patients of basilar invagination with atlas assimilation, the form of various C1-occipital condyle complexes (CC complex) and arterial anomalies may distort the usual anatomical landmarks, thereby misleading the surgeon during the fixation procedure. This report describes our microscope-assisted technique sharing the idea of using condyle screws in fused occipital condyle-C1 complex as fixation points for screws in the stabilization of the OC junction in basilar invagination patients with atlas assimilation. To date, only few studies have reported occipital condyle-C1 complex screw fixation in this patient population.

■ MATERIAL and METHODS

Subject

A combination of fused occipital condyle and C1 screw insertion techniques was performed on 8 consecutive patients (3 female and 5 male; age range, 32-58 years; mean age, 40 years;) between 2008 and 2010. The mean follow-up period was 30.2 months (range, 24-36 months). The indications for the surgery included basilar invagination with atlas assimilation.

Plain radiographs, CT, and MRI were obtained from each patient preoperatively. The CT scans of the CC complex were carefully examined and the dimension was measured to determine the ideal screw insertion positions, trajectory and lengths.

Bilateral titanium polyaxial screws 3.5 mm diameter were placed unicortically into the CC complex, and we analyzed the screw angles and lengths in relation to the morphometric measurements, the hypoglossal canal location, and the regional neurovasculature. The pars interarticularis of C2 screws were used as caudal anchors. Both constructs were fixed to a 3-mm titanium rod, and anatomic landmarks were used during drilling. Postoperative CT reconstructions were obtained for each construct. This study was in agreement with the declaration of Helsinki. Approval was obtained from the Ethics Committee of the Chinese PLA General Hospital, and all patients provided written informed consent.

Surgical Technique

The patients were first placed in the prone position, and then their heads were secured using 3-pin head frames. Next, the posterior OC junction was exposed using a standard midline incision. The occipital and cervical musculature was dissected in a subperiosteal manner. Then the lower end of the occiput and of the C1 arch were exposed. Next, a surgical microscope was focused upon the foramen magnum. Using curettes, the tissue corresponding to the atlantal-cervical membrane, which extended laterally from the foramen magnum to the medial aspect of the CC complex, was gently dissected. Subsequently, the periosteum was dissected downward from the CC complex while maintaining contact to the bone so as to not injure to the horizontal portion of the VA, which is located medial and inferior to the CC complex and is surrounded by a dense venous plexus (Figure 1A). Laterally, the dissection was limited by the condylar foramen and vein. The superior articular processes of the C2 vertebra were dissected to their lateral margins. C2 pars interarticularis screws were placed as described by Harms and Melcher (10,16). The C2 pedicle screws ranged from 18 to 22 mm in length. The act of inserting the cervical screws may be suitable for use as a marker of the location of the CC complex in the axial direction. The CC complex entry point was at the center posterior surface of the CC complex (Figure 1A). We used an awl slightly angled rostrally to make pilot holes at the entry point. These holes were then drilled using a convergent trajectory and a 10-15° medial angulation and cranial angulation in the sagittal plane (Figure 1A,B). Intraoperative landmarks were used as guidance during the drilling for 10-14 mm. Then the hole was taped. A polyaxial screw 3.5 mm in diameter and 16–22 mm in length, as appropriate, was inserted into the CC complex in a unicortical manner. After fixation, the posterior edge of foramen magnum was decompressed by removing the lower end bony structure.

■ RESULTS

Sixteen CC complex screws were inserted into 8 patients. The width, length, and height values of the left-side CC complex were 7.96±2.23 mm, 16.06±2.73 mm, and 13.76±2.06 mm, respectively, while the width, length, height values of the right-side CC complex were 7.84±1.38 mm, 16.66±2.58 mm, and 12.81±2.62 mm, respectively. There were no cases of injury to the vertebral artery or of leakage of the cerebrospinal fluid during the screw insertion process. The positions of the screws were found to be satisfactory under postoperative CT scans (Figure 2A, B), and no revision was required in our series.

The operative time was 240±33 (210-275) min, and average blood loss was 150±65 (80-220) ml.

After surgery, all patients wore soft cervical collars for 3 months. Follow-up CT and MRI were performed in all patients, and we did not encounter any construct failures or loosened screws. None of the implants were found to have failed. All patients were found to have experienced fusion within the follow-up period.

■ DISCUSSION

OC fixation procedures are still a major challenge for neurosurgeons due to the anatomic complexity and functional significance. Correcting deformities or dislocations and decompressing neural structures as well as mechanically stabilizing the area are necessary to treat patients with OC malformations successfully. The goals of instrumentation include improved fusion rates, immediate stability, decreased need for postoperative external immobilization, and shorter rehabilitation times. There is currently no single system of instrumentation that can meet the requirements satisfactorily.

OC plate fixation offers rigid fixation and increases fusion rates while resulting in a decreased need for external immobilization. The design of most currently available plates forces the surgeons to place the screws in suboptimal locations, laterally on the occiput. In this location, the bone is thinner, giving the screw less purchase. Systems with independent cervical rods and occipital plates are secured rigidly to the bone. This improves the intraoperative contour of the entire system and its connection to the CVJ. These systems promote higher fusion rates, but the occipital bone's slope and angle to the cervical spine can cause unfavorable geometrical constraints, which give the occipital screw only weak purchase on the bone. This can cause breakage, pullout, loosening, and difficulties with insertion (7). In addition, cerebrospinal fluid leakage and formation of sub/epidural hematomas can be caused by the occipital screw insertion (15,24). Furthermore, the occipital plate limits the area of occiput for bone implantation, especially in suboccipital craniectomy patients, thereby impeding fusion.

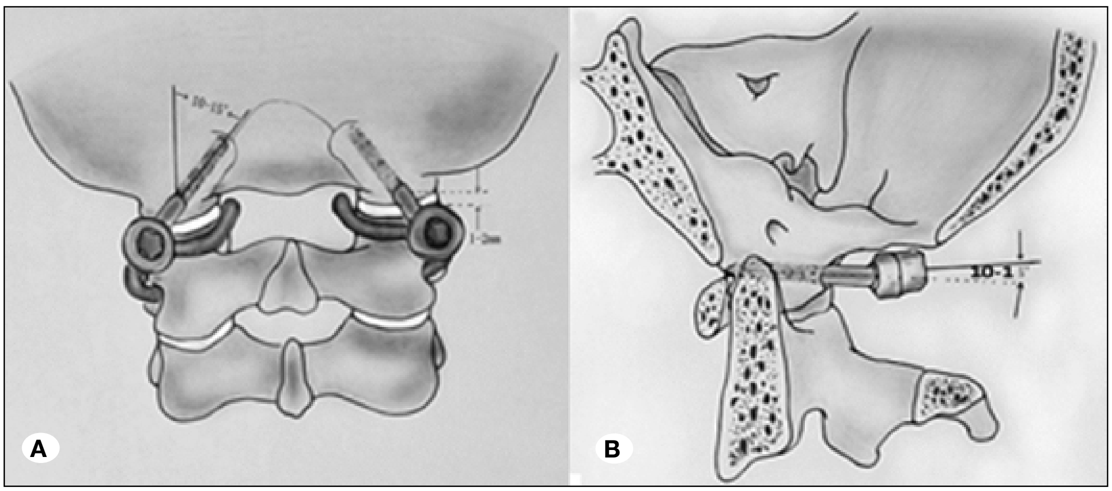

Figure 1. Illustration of insertion of CC complex screws. **A)** Posterior view of the occipital-cervical junction, location of the entry point of the CC complex entry point, and location of the vertebral artery; **B)** Midline sagittal illustration of the occipital-cervical junction showing CC complex screw trajectory in the sagittal plane.

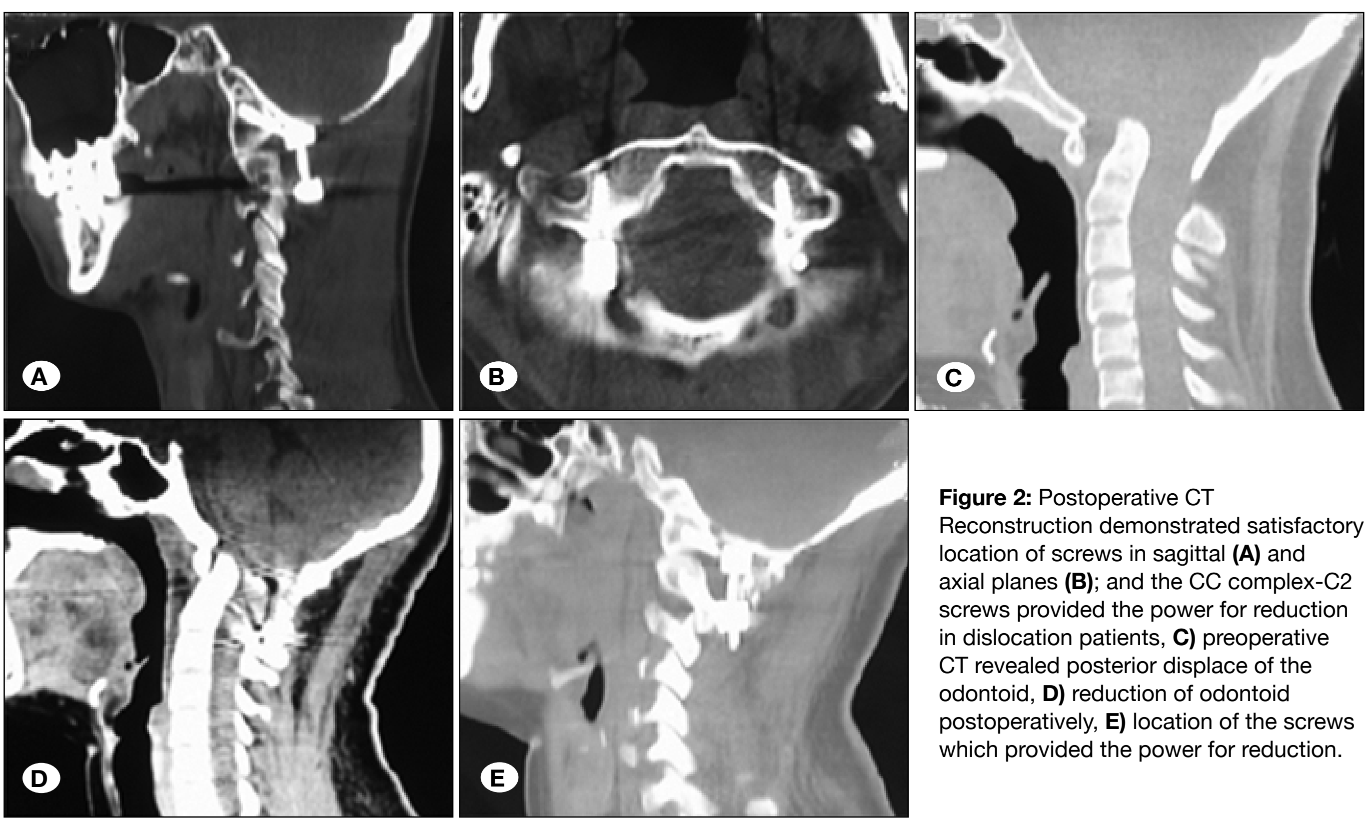

Figure 2: Postoperative CT Reconstruction demonstrated satisfactory location of screws in sagittal **(A)** and axial planes **(B)**; and the CC complex-C2 screws provided the power for reduction in dislocation patients, **C)** preoperative CT revealed posterior displace of the odontoid, **D)** reduction of odontoid postoperatively, **E)** location of the screws which provided the power for reduction.

Overall, these limitations of the techniques prompted the development of new alternatives. Condylar screws may decrease complications such as pullout, screw loosening, breakage, and lessened the need for multiple points of occipital fixation (25). We shared the idea of condylar screws to use CC complex screws for fixation in basilar invagination patients with atlas assimilation. The advantages of this technique include adequate purchase for reduction in dislocation patients (Figure 2C-E), availability of the entire posterior occipital area for bony implantation, and a decrease in segments to be fixed.

To instrument the CC complex successfully, it is imperative to have a clear understanding of the OC junction anatomy. Wen et al. (25) stated that the suboccipital triangle floor contains all the neurovasculature involved in this approach, including the VA (V3) horizontal segment, the posterior condylar emissary vein, the vertebral venous plexus, and the root of the C1 nerve. Uribe et al. (23) evaluated the relationship between these anatomical structures to determine a suitable trajectory for the condylar screw. The occipital condyle has a mean length of 23.6 mm (16.7-30.6 mm), width of 10.5-mm (6.5-15.8 mm) and height of 9.2-mm (5.8-18.2 mm) (14,17). The CC complexes are formed through fusion of the lateral mass of C1 and the occipital condyle, which articulate with the superior articular process of C2. In our patients, the width, length, height values of the left-side CC complex were 7.96±2.23 mm, 16.06±2.73 mm, and 13.76±2.06 mm, respectively, while the width, length, height values of the right-side CC complex were 7.84±1.38 mm, 16.66±2.58 mm, and 12.81±2.62 mm, respectively. The main difference between the CC complex screw procedure and the condylar screw procedure is the location of the horizontal segment of the VA (V3), which is located between the lower edge of the foramen magnum and C2 in patients with atlas assimilation undergoing CC complex screw procedures, while it is between the foramen magnum and the C1 arch in the condylar screw procedure.

The technique described here differs from the common techniques described in previous works in that it relied on the following 3 major factors: a preoperative CT scan must be performed to determine a suitable point of entrance and trajectory for the screw and dimensions of the CC complex; the surgical team must have a clear appreciation of these intraoperative surgical landmarks and must use a microscope to direct the insertion and trajectory of the screw; a microscope must be used to overcome the difficulty of the dissection process and to visualize and control any venous bleeding.

After identification of suitable anatomy, the insertion of the CC complex screw usually proceeds smoothly. The average width of the CC complex is 7.96±2.23 mm on the left side and 7.84±1.38 mm on the right side. This provides a large margin of error with respect to screw trajectory for insertion of screws 3.5 mm in diameter. Although some researchers recommend bicortical C1 lateral mass screws, the unicortical screw fixation process was successful in this case, and no failures were detected (5, 10, 21). The use of unicortical screws can prevent injury to the internal carotid artery and hypoglossal nerves, which can be caused by tips of other types of screws (3, 11, 12). Further biomechanical studies on the stability of these types of occipital condyle-C1 lateral mass complex screws are needed.

The limitations of the current surgical technique include microscope-assisted screw insertion. This process relies partially on tactile feedback to produce the crunching sensation in cancellous bone when preparing the path of the screw. The CC complex usually consists of chronic cervical deformities in sclerotic bone, and tactile feedback may not be a reliable source of information. Even when a microscope provides a good view of the surgical field, the screw entrance point, trajectory, and CC complex dimensions have to be analyzed preoperatively and considered intraoperatively. Placing a Penfield dissector between the lower edge of the CC complex and the artery could further protect the vertebral artery during insertion of the screw. However, despite these limitations, we were successful with the microscope-assisted screw insertions.

■ CONCLUSIONS

We developed a novel technique for OC fusion to improve the screw's purchase on the occipital bone and it may circumvent the need for multiple points of attachment. In this technique, polyaxial titanium screws are inserted bilaterally into the CC complexes. The technique requires microscope-assisted occipital condyle-C1 complex screw insertion. It is a reproducible and feasible alternate method of screw insertion. It does not require the any intraoperative fluoroscopy, which has been known to be harmful. Preoperative imaging studies, assessments of intraoperative tactile feedback, and clear microscopic visualization are crucial to maximizing successful screw placement.

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