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Reconstruction of Anterior Skull Base Fracture Using Autologous Fractured Fragments: A Simple Stitching-Up Technique

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Conflict of Interest
The authors have no financial conflicts of interest.

ABSTRACT

Objective: A displaced fracture in the anterior cranial base may be complicated by cerebrospinal fluid (CSF) rhinorrhea and enophthalmos. This study introduces a reconstruction technique with direct dural repair and reduction and fixation of the autologous fractured fragments.
Methods: Displaced fractures in the anterior cranial base were reconstructed using a stitching-up technique: A bicoronal scalp incision and frontal craniotomy was performed and the displaced bone was withdrawn. The lacerated dura was repaired primarily using a graft. Small holes were created in the intact cranial bones and the displaced harvest bone. Black silk was passed through the holes and the displaced bone was repositioned on tying the silk. Lumbar drain was not placed in any of the cases. The feasibility and outcome were evaluated.
Results: Five patients with displaced skull fractures of the anterior cranial base were included. All cases were men who had a direct impact on the forehead and/or eye. All the displaced fractures occurred in the orbital roof, and ethmoid bone fractures were present in 4 cases. Dural laceration was involved in 4 cases and repaired by placing artificial dura in 3 cases and a pericranial graft in 1 case. Following surgery, all cases were uneventful, and the anterior cranial fossa was well reconstructed. CSF leakage or enophthalmos did not occur in any of the cases.
Conclusion: Direct dural repair and autologous stitching-up reconstruction using the fractured fragment could be an effective method to prevent CSF leakage and enophthalmos in displaced fractures of the anterior cranial base.

Keywords: Skull base; Orbital fracture; Reconstruction; Craniocerebral trauma

INTRODUCTION

Trauma to the anterior skull base is related to the orbital roof and the paranasal sinuses.[15] Injury to the anterior fossa may result in cerebrospinal fluid (CSF) leakage and damage to the olfactory nerves and the orbital contents, including the optic nerve. Even though the management of patients with skull base trauma is dependent on the extent of intracranial injuries, usually linear nondisplaced fractures are managed conservatively initially.[3] Moreover, the majority of patients with post-traumatic CSF leaks stop spontaneously within a few weeks.[4,20]

Displaced fractures of the orbital roof can cause ophthalmologic and neurologic complications and surgical intervention is occasionally required.[5,9,17] The displaced fragment could injure the dura creating a large dural defect, which increases the possibility of a CSF leak resulting in significant ophthalmologic and cosmetic morbidities, such as proptosis, blindness, eye immobility, diplopia, enophthalmos, and orbital encephalocele.[8,9] An interdisciplinary approach involving neurosurgery, ophthalmology, and plastic surgery is crucial for providing comprehensive care.

Various reconstruction methods have been proposed for orbital roof fractures. Bone grafts from split-calvarium were simply laid across the floor of the anterior cranial fossa and held in place by the overlying dura and brain without any fixation.[17] Removal of the bone fragment and reconstruction using titanium mesh has been reported.[9] We introduce a simple technique for reconstructing the anterior skull base fracture using autologous fractured fragments and stitches.

MATERIALS AND METHODS

After review and approval from the Institutional Review Board of Soonchunhyang University Bucheon Hospital, we reviewed the clinical and radiological records of all patients who underwent surgical repair of anterior skull base fractures based on the proposed methods. We reviewed the mechanism of injury, clinical findings on admission, initial imaging findings, and outcomes. The image findings included the fracture characteristics of the skull base, combined fractures, and associated intracranial pathologies.

All the patients underwent high-resolution computed tomography (CT) scans on admission. Serial CT images of the head were taken to assess the intracranial pathology and cranial fractures. Facial CT was also performed when a facial injury was suspected. The coronal reconstruction of the CT scan in either the head or face was useful for assessing the displacement of the fractured fragments in the anterior cranial fossa.

Surgical techniques

After general anesthesia, a bicoronal scalp incision and sub-pericranial dissection were performed, and the frontal bone was exposed up to the orbital rim. A pericranial flap was not routinely created. Unilateral frontal or bifrontal craniotomy was performed. The displaced bone fragment was withdrawn by retracting the dura mater. The lacerated dura was repaired as tightly as possible using an artificial or pericranial graft. After completion of the direct dural repair, small holes were made on the undisplaced bone of the orbital roof. The undisplaced bone was included in the lateral orbital roof (sphenoid ridge), ethmoid bone, or contralateral orbital roof. To create a hole, a high-speed drill passer was not considered suitable owing to its depth and relatively parallel working angle. The backhaus towel clamp was effective in creating the holes since it has sharp and strong ends and the bone of the anterior basal skull is relatively thin. Holes were also made in the displaced fractured fragments using a high-speed drill. Black silk was passed through the holes of the undisplaced and displaced bones (**FIGURE 1**). The displaced bones were brought back in place on tying the silk, thereby, reducing and fixing the fractured bony fragments. This technique is similar to stitching up the bony fragments (**FIGURE 2**).

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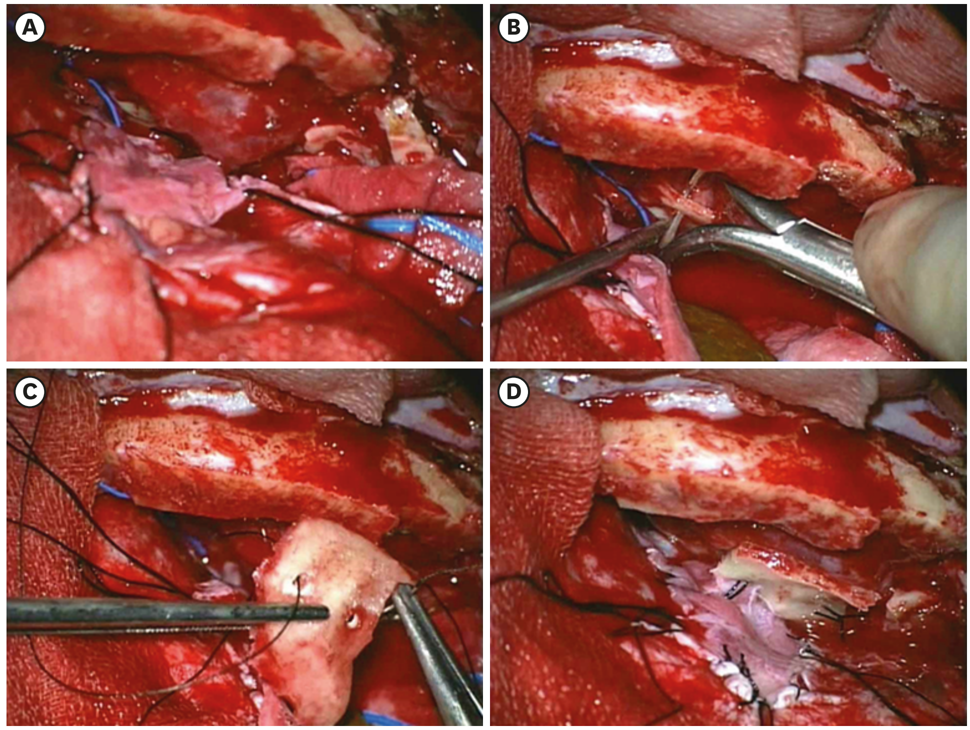

FIGURE 1. Surgical images of the stitching-up technique in case 3. Dural laceration on the frontal base is primarily repaired with #4-0 black silk using a free graft of pericranium (A). Bone defect is detected in the anterior cranial fossa and the periorbital region is exposed. A hole in the sound bone of the anterior cranial bone is created using a towel clip (B). The free bone flap from the fractured fragment contain holes for stitches and is repositioned in place (C). The dural repair and a reduction and fixation of the displaced bone using the stitching-up technique (D).

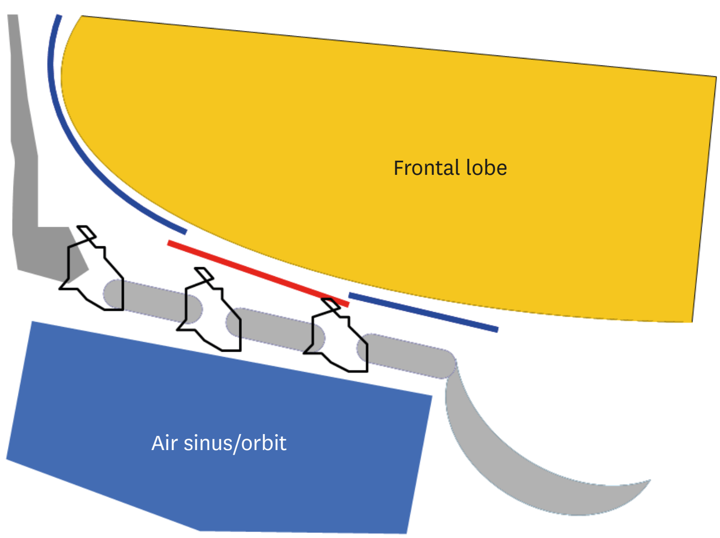

FIGURE 2. Sagittal drawing of a dural repair and a skull base reconstruction as a stitching-up technique. The dural laceration is primarily repaired using a graft (red line). The skull base is reconstructed by fixing the fractured bony fragments in a stitching-up manner.

RESULTS

Five patients in the anterior basal skull fractures were managed using the “stitching-up technique” to fix the displaced fracture bones. All the cases were men who had a direct

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TABLE 1. Characteristics of the 5 cases with anterior basal skull fractures

Case	Sex	Age	Symptoms	Trauma mechanism	Forehead laceration	Frontal/zygomatic fracture	Ethmoid/ sphenoid fracture	Fractured fragment	Intracranial lesion
1	Male	49	Headache	Traffic accident	(+)	Depressed & comminuted	(+)	Multiple	Pneumocephalus, frontal contusion
2	Male	41	Headache	Falling on stairs	(−)	None	(+)	Single	Pneumocephalus, frontal contusion
3	Male	51	Blindness	Impact by horse-shoe	(−)	Comminuted fracture on orbit	(+)	Multiple	Frontal contusion
4	Male	24	Stupor	Motorcycle accident	(+)	Linear	(+)	Multiple	Pneumocephalus, frontal contusion, subdural hematoma
5	Male	49	Mydriasis	Slip-down	(−)	None	(−)	Single	Epidural/intra-orbital hematoma

TABLE 2. Operative findings and results of the 5 cases

Case	Operation day after trauma	Dural injury	Graft material of dural repair	CSF leakage	Enophthalmos
1	0	(+)	Artificial dura	(−)	(−)
2	6	(+)	Artificial dura	(−)	(−)
3	1	(+)	Pericranium	(−)	(−)
4	0	(+)	Artificial dura	(−)	(−)
5	3	(−)	None	(−)	(−)

impact on the forehead and/or eye, regardless of the mechanism of injury (**TABLE 1**). One patient had multiple lacerations on the forehead. Blow-out fracture with a single fragment developed in 2 cases, who had directly injury to the eye. Four cases were accompanied by ethmoid bone fractures. Surgery was performed promptly to reduce the risk of meningitis. Dural laceration was observed in 4 cases and was repaired primarily (**TABLE 2**). In the cases of dural repair, artificial dura (Lyoplant®; B. Braun, Melsungen AG, Hessen, Germany) was used in 3 cases and a pericranial graft was placed in 1 case. After surgery, all the cases were uneventful. The anterior fossa was well reconstructed in all the cases. CSF leakage or enophthalmos did not occur in any of the cases (**TABLE 2**).

Illustrative cases

Case 1

A 49-years-old man was involved in a traffic accident. He was driving a minivan and ran into an oncoming sedan. His forehead hit the dashboard and windshield. Multiple lacerations were observed on the forehead, and the frontal skull bone was exposed and depressed (**FIGURE 3**). No other injury was observed in the body. He was alert and his pupils were reactive to the light. An emergency operation was planned to reduce the infection from the open wound and reduce the depressed fractures. He was transferred to the operating room and was put under general anesthesia. After massive saline irrigation and aseptic scalp preparation, the frontal bone was exposed using an extended incision of the forehead lacerations. A frontal craniotomy was performed along the margin of the fracture, and the frontal dura was exposed. A dural defect was detected in the right frontal base from the frontal convexity to the planum sphenoidale. No definite brain edema was observed. After removal of the fractured fragments of the cranial base, the contused brain tissues were herniated into the sphenoid sinus. The dural defect was primarily repaired using the graft of an artificial dura. The bony fragments removed from the anterior cranial fossa were repositioned using the aforementioned stitching-up technique. The craniotomy and comminuted frontal bones were fixed using miniplates (**FIGURE 3**). The scalp was carefully closed considering the cosmetic aspect. No infection or CSF leakage was observed following surgery. The patient had no complaints regarding the cosmetic outcome in the forehead and orbit following surgery.

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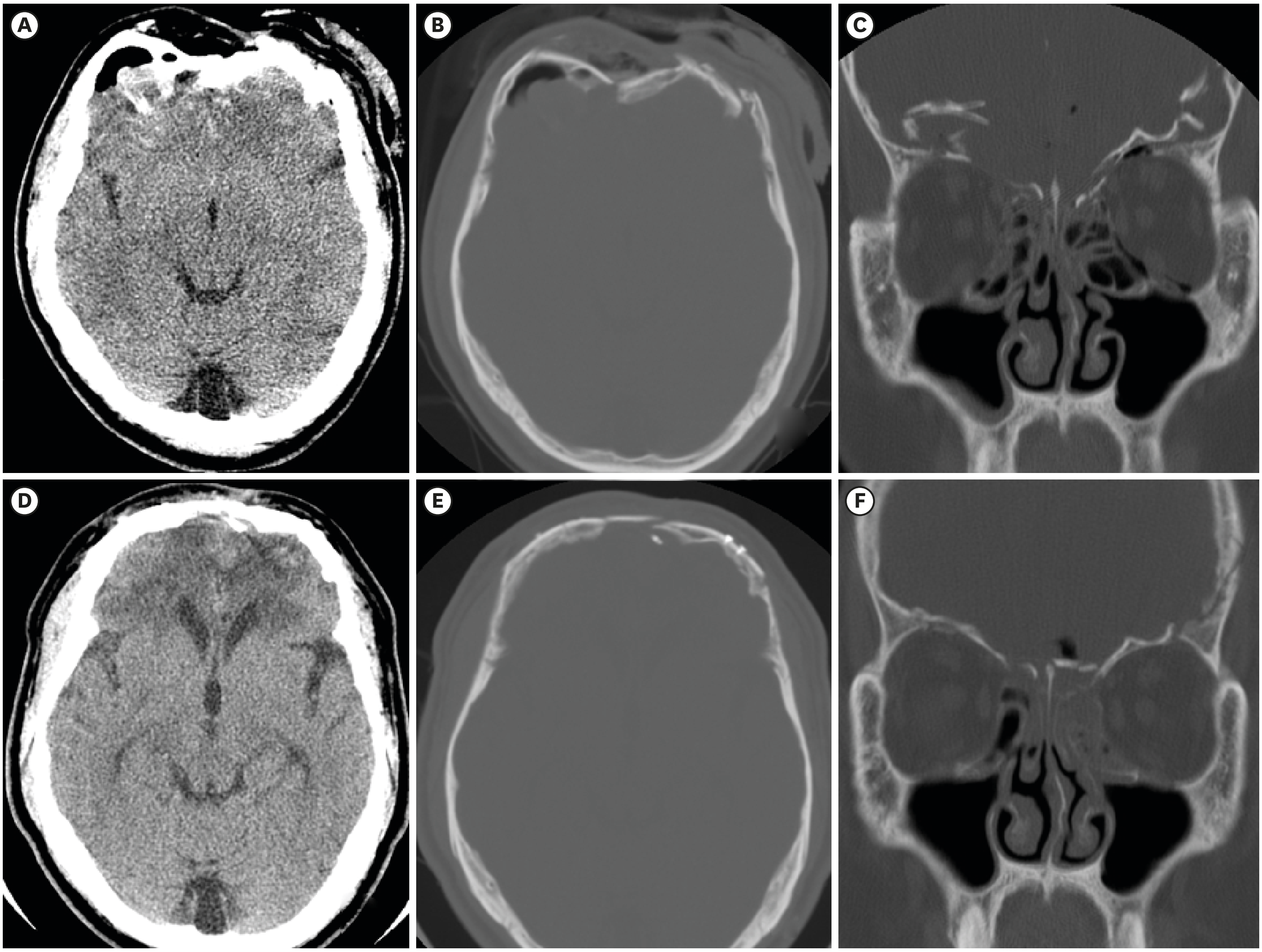

FIGURE 3. Initial and postoperative CT scans of case 1. Multiple forehead lacerations were observed and the frontal skull was exposed. The frontal bone revealed a comminuted and depressed fracture (A, B). The fractured fragments were impacted in the brain parenchyme and cerebral contusions were detected in both the frontal lobes. Bilateral orbital roof and ethmoid bones were fractured and the fractured bone of the right orbital roof was superiorly displaced (C). Depressed frontal bones were well reduced and fixed as observed in the postoperative brain CT (D, E). The displaced bony fragment in the orbital roof was reduced and the bony contour of the anterior cranial fossa was well maintained (F).
CT: computed tomography.

Case 5

A 49-year-old man presented to the emergency room with a severe headache in the morning. He experienced a loss of consciousness. He was fishing the previous night and had slipped. His left eyelid was swollen. No direct or indirect light reflex was observed in the left eye; however, his left vision was grossly intact. He had no memory of the injury. He could have been hit by something directly to his left eye while falling. Brain CT revealed that the orbital roof was fractured and superiorly displaced (**FIGURE 4**). An epidural hematoma and an intra-orbital hematoma were also observed. On the 3rd day of the trauma, hematoma evacuation and bone reduction were performed. After a bicoronal scalp incision, a left frontal craniotomy was performed. The hematoma was detected above and beneath the bone fragment. No dural injury was observed when the epidural hematoma or intra-orbital hematoma was evacuated. Two passer-drilled holes were made on sound orbital rim and 2 holes on the displaced orbital roof using a backhaus towel clamp. Black silks were passed through both the holes and tied to the displaced fragments for reduction and fixation

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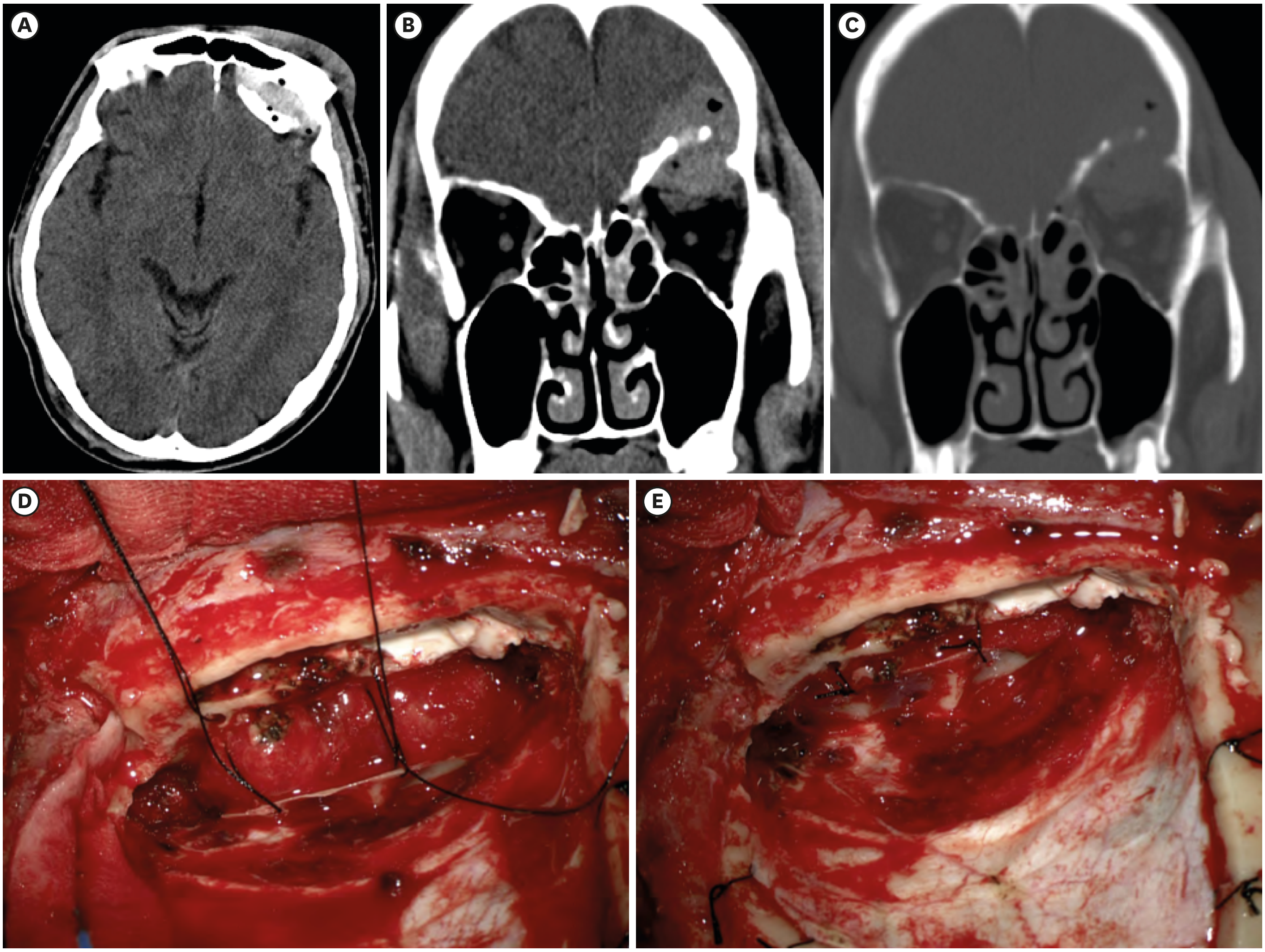

FIGURE 4. Initial CT scans and surgical photographs of case 5. Following direct impact on the left orbit at night, the patient had developed severe headache and mydriasis on the left eye. An epidural and an intra-orbital hematoma were detected on the axial and coronal CT (A, B). The fractured bone in the orbital roof was superiorly displaced (C). Following a frontal craniotomy, the epidural and intra-orbital hematoma was evacuated. After creating holes on the orbital rim and the displaced fragment, black silk was passed through both the holes and set for tying (D). After tying the black silks, the displaced bone was well reduced and fixed (E). CT: computed tomography.

(**FIGURE 4C & D**). The postoperative course was uneventful; the mydriasis improved 2-weeks following the surgery.

DISCUSSION

Skull base surgery remains challenging for reconstruction of large dural and bone defects.[7,14,16] It includes surgery for skull base tumors that create dural and bone defects as well as post-traumatic CSF leaks with skull base fractures.[12] In the case of head trauma with a skull base fracture, it is crucial to complete the initial surgery in order to prevent delayed CSF leakage. The risk of CSF leakage and meningitis is high in anterior skull base fractures owing to the proximity of the paranasal sinuses. Therefore, application of an appropriate surgical technique to prevent this future complication is necessary. To achieve this goal, water-tight sealing of the dura and bone reconstruction may be mandatory during surgical intervention.

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Orbital roof fractures are less common but potentially serious craniofacial injuries. Intracranial or intraorbital injury may warrant surgical intervention to detach impinging bone fragments, repair the dura, or reconstruct the orbital roof.[2] Primary restoration of the volume of the orbit and its contour should be achieved to prevent possible enophthalmos and impairment of eye motility.[13] Orbital roof reconstruction may be required in displaced orbital roof fractures. Various reconstruction methods have been proposed.[10,13,17] Split-bone grafts from craniotomy were simply laid across the floor of the anterior cranial fossa and held in place by the overlying dura and brain.[17] No fixation was used in this report. After removal of the fractured orbital bone, the orbital roof was reconstructed using 3-dimensionally fabricated titanium micro mesh plates and screws.[9] Anterior orbitotomy via the supraorbital eyelid incision and removal of displaced orbital roof fragments was used in the case of a metal rod penetration injury.[18]

A vascularized flap has been proposed for complex skull base pathologies.[1,7,11] A large defect in the anterior skull base was reconstructed using a triple-layer graft, which is composed of dural repair, vascularized pericranium, and hard cranial fixation. The vascularized tissue over a free graft may promote rapid wound healing. The anterior skull base fractures were classified into 3 groups (class I–III).[1] Class I fractures were defined as those involving only the frontal sinus or frontal bone, class II fractures were defined as those that extended to the ethmoid cribriform plate, and class III fractures were defined as those extending to the sphenoid bone or sinus. Aggressive treatment, including a single anterior pericranial flap or multiple flaps, was conducted in class II and III fractures. The vascularized pericranium cannot be prepared sometimes in trauma due to the associated scalp injuries. Four cases in our cases were class II or III fractures and did not develop CSF leakage without the use of a pericranial flap. We believe that direct dural repair and bony reconstruction for supporting the dura may help prevent CSF leakage. When the dural defect is located at the base of the skull, there are many difficulties associated with the appropriate access and fragility of the dura. This ensues direct suturing quite difficult. However, we recommend direct suturing in trauma patients as much as possible.

The risk of CSF leakage is less likely when the craniotomy bone flap is replaced compared to craniectomy.[6] The bony support may prevent dural sutures from tearing out, thereby, minimizing CSF leakage. In any case, meticulous dural sutures should be performed before bone replacement. For this reason, bony reconstruction may help prevent CSF leakage when the dural defect is repaired. Therefore, if CSF leakage is expected, dural closure and bony support are necessary. We attempted to repair the lacerated dura in water-tight manner and reconstructed the fractured basal skull. The dural defect was primarily repaired using a dural graft to avoid tension on the dural edge and fix the bone fragments firmly. Immediate replacement of bone fragments in compound depressed skull fractures has not been associated with an increased risk of infectious complications.[19] To fix the fractured fragment, mini-plate and screws, used commonly in the surgery, may be utilized. However, screw insertion is not easy due to the narrow surgical field and screwdriver angle, especially in patients with trauma. We created holes on the fractured fragments and the non-displaced skull base bones, connected threads between holes, and tied them to reduce and fix the displaced fragments. The backhaus towel clip is sufficient for creating holes in the deep skull base bone without any angle inconvenience. By applying this method, the pericranium was preserved, and the inclusion of foreign materials were minimized. The absence of the reconstruction of the orbital roof following displaced bone removal may not result in any further complications. However, we believe that reconstruction of the skull base is advantageous.

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The choice of the reconstruction technique for skull base fractures depends on multiple factors and the treatment should be individualized based on the nature of the displacement. Aggressive surgical repair of anterior skull base fractures may be necessary for patients in whom conservative management has failed.[1] Vascularized flaps are well-recognized ideal substrates for multilayered skull base repair. However, we believe minimal surgery is desirable in the absence of a large dural defect or bone loss. This technique was performed in 5 patients. Although the number was small, none of the patients presented any complication related to surgery or delayed CSF leaks. When surgery is indicated in patients with anterior skull base fracture and the fractured fragment is not very small, our stitch-up technique could be preferred as the first surgical method. If CSF leakage occurs in the follow-up period following our surgical technique, a more aggressive surgery such as graft of the preserved vascularized pericranium could be considered. Further studies are required to confirm the validity of this simple technique.

CONCLUSION

Despite very few cases were included to evaluate the efficacy of our techniques, direct dural repair and autologous stitching-up reconstruction using the fractured fragments could be an effective method to prevent CSF leakage and enophthalmos.

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