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Original research article

Three-layered osteodural plasty for severe anterior skull base and facial injuries. Report of eleven cases

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ARTICLE INFO

Article history:
Received 28 September 2012
Accepted 25 March 2013
Available online 23 January 2014

Keywords:
Skull base fracture
Osteo-dural plasty
Cranioplasty
Autogenic bone graft
Anteriorly pedicled pericranial flap

ABSTRACT

Background and purpose: The upper cranial trauma of high force and wide area of application leads to fractures of calvaria, the skull base, and the viscerocranium. The aim of the study was to present eleven patients treated for severe anterior skull base and facial defects by means of three-layered osteodural plasty.

Materials and methods: The operative tactics consisted of bicoronal incision, bifrontal craniotomy, closure of the dura mater damage with a pericranium, reconstruction of bone defects with autologous bone grafts and plasty with anteriorly pedicled pericranial flap on the supratrochlear and supraorbital vessels.

Results: During follow-up, which lasted 2–7 years, none of the patients developed any early or late postoperative complications.

Conclusions: The three-layer osteodural plasty of severe anterior skull base injuries with the use of autologous bone grafts for the reconstruction of craniofacial skeleton resulted in a good final functional, morphological and aesthetic outcome in all patients.

1. Introduction

The upper cranial trauma of high force and wide area of application centrally impacting frontal squama, superciliary arches and the base of the nose crushes glabellar and both fronto-orbital crowns. After crushing these crowns, uncontrollable force spreads in star-like directions between three Felizet arch pillars to the whole base of the anterior cranial fossa reaching the sphenoid bone and then descends between Sicher columns onto face causing true fronto-orbitonasal fractures (FONF) [1–3].

Fractures formed by this mechanism affect both calvaria and the skull base, and the viscerocranium. As a result of crushing the base of anterior cranial fossa, its bone structure is destroyed. This in turn leads to the formation of large bone and dural defects which entail serious neurological, ophthalmological, morphological, functional and aesthetic consequences [3]. In FONF, sharp bone fragments formed after crushing frontal sinus walls, cribriform plates, crista gali, the roofs of the orbits and the nasal fossae, moving with the wave of the injury towards the sphenoid, frequently intersect in a scissor-like manner olfactory fibres and tear dura in a varying degree. Dural defects on the base of the anterior cranial fossa, with no

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0028-3843/$ – see front matter
http://dx.doi.org/10.1016/j.pjnns.2013.03.003

tendency to scarring, entail cerebrospinal fluid rhinorrhoea. In this situation, the most important therapeutic challenge is to seal the dural defect through which the cerebrospinal fluid leaks and to separate the brain from the nasal cavity and paranasal sinuses.

Misdiagnosis or insufficient dural plasty leads to persistent cerebrospinal fluid rhinorrhoea or pneumocranium with symptoms of increased intracranial pressure. It also increases the risk of ascending infection with subsequent meningitis and encephalitis. In order to reduce the risk of the aforementioned consequences, several methods of dural defects plasty are used [4–11]. Because the dural tear does not heal spontaneously, it always requires a thorough surgical treatment.

The aim of this study was to present eleven patients treated for anterior severe skull base and facial defects by means of three-layered osteodural plasty.

2. Materials and methods

Between 2005 and 2010, eleven patients (nine men and two women) were treated for FONF (Table 1) with the three-layer osteodural plasty of the anterior cranial fossa. The surgical procedure involved covering the damaged dura with pericranium harvested at occipito-parietal area and separating the cranium from the face with autogenous bone graft. Additionally, anteriorly pedicled pericranial flap was placed between the dura mater and autogenic bone graft to reconstruct bone defects emerging at the base of the anterior cranial fossa.

2.1. *Surgical tactics*

2.1.1. *Preparation of pericranial flap*

Under general anaesthesia, bicoronal incision was used to detach the dermo-muscular flap from the pericranium in the central region up to the base of the nose and upper edges of orbital rims, and laterally to the zygomatic arch at the same time exposing the lateral edges of orbital rims. Then, the central anteriorly pedicled pericranial flap was detached from the frontal squama extending to the upper orbital rims and the nasal base. The flap was detached in a way that prevented damage to the supraorbital and supracochlear nerve and vascular bundles.

2.1.2. *Craniotomy*

Subsequently, bifrontal craniotomy was performed to obtain epidural access to the base of the anterior cranial fossa (Fig. 1A). Dura mater was detached across the whole base of the anterior cranial fossa up to the lesser wings of the sphenoid bone and *jugum sphenoidale*. Injury and defects of dura mater mostly occurred in the roofs of the orbits and nasal fossae and had a diameter ranging from 15 to 40 mm.

2.1.3. *Dural plasty with pericranium*

The same bicoronal approach was used to collect the autograft. Pericranium was harvested at the occipito-parietal area. The size of the autograft exceeded the dural defects. Suturing of the pericranium, covering in excess the edges of the dural defect always started at the base of the lesser wings of the sphenoid bone and *jugum sphenoidale*. After stretching, the autograft was tightly sutured with the dura at the periphery of the defect (Fig. 1B).

2.1.4. *Cranialisation of the frontal sinus*

Wherever there was damage to the frontal sinuses walls, the mucous membrane was carefully removed from all its recesses. In all 11 patients, posterior walls of the frontal sinuses were fractured or crushed in many places. Broken and dislocated bone fragments were removed and sinuses cranialisation was performed.

Table 1 – Data of eleven patients with fronto-orbitonasal fractures.

No.	Sex	Age (years)	Type of injury	Intracranial complications				Anosmia	Vision	Follow up (years)
				Concussion	Pneumocranium	CSF leak	Other CNS complications			
1.	M	24	Impaction with wood in sawmill	Yes	Yes	Yes	Epidural haematoma	Yes	Diplopia	7
2.	M	57	Beating – wound from sharp object	Yes	Yes	Yes	Epidural haematoma	Yes	Blindness of the left eye	7
3.	F	26	Beating	Yes	Yes	Yes	Epidural haematoma	Yes	No	7
4.	M	40	Car accident	No	Yes	Yes	Epidural haematoma	Yes	Diplopia	5
5.	M	34	Crushed by wooden ball	No	No	Yes	Subdural haematoma	Yes	No	4
6.	M	51	Beat by horse head	No	Yes	Yes	–	No	No	4
7.	M	26	Beat by brunch of a tree	No	No	Yes	–	No	No	4
8.	M	19	Car accident	No	No	Yes	–	Yes	Diplopia	3
9.	M	42	Car accident	Yes	Yes	Yes	–	Yes	No	3
10.	M	35	Car accident	Yes	No	Yes	–	Yes	Diplopia	3
11.	F	31	Car accident	Yes	Yes	Yes	–	Yes	Diplopia	2

CSF, cerebrospinal fluid; CNS, central nervous system; M, male; F, female.

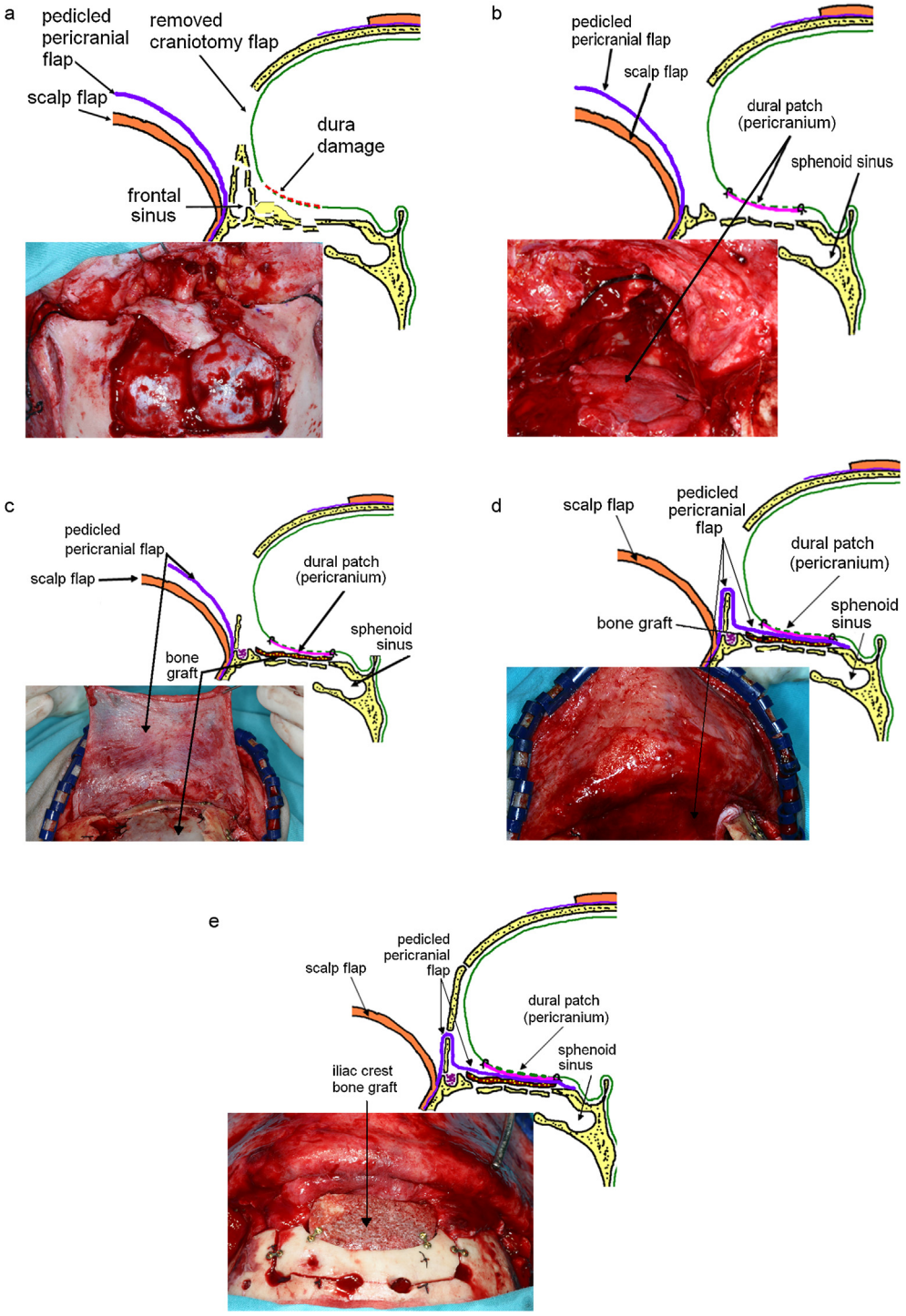

Fig. 1 – Intraoperative view of fronto-orbitonasal fracture. (A) Following the detachment of scalp flap and frontal pedicled pericranial flap with consequent bifrontal craniotomy. Comminuted fracture of the frontal bone affecting median sections of the upper orbital rims, anterior and posterior wall of the frontal sinus, nasal bones and the glabella is present. (B) Following the removal of bone fragments constituting the frontal bone. Bone defect of the base on the anterior cranial fossa involving the roof of the nasal fossae and two-thirds of both orbital roofs is visible. Dural defect about 40 mm in diameter covered with pericranium. (C) Reconstruction of the base on the anterior cranial fossa, nasal bones and part of the supraorbital bar with autogenous iliac crest bone graft. Raised frontal pedicled pericranial flap. (D) Frontal pericranial flap inserted between the dura and the autogenic bone graft reconstructing the skull base. (E) Frontal bone lined and peripherally fixed with single microplates. Glabellar defect reconstructed with iliac crest bone graft.

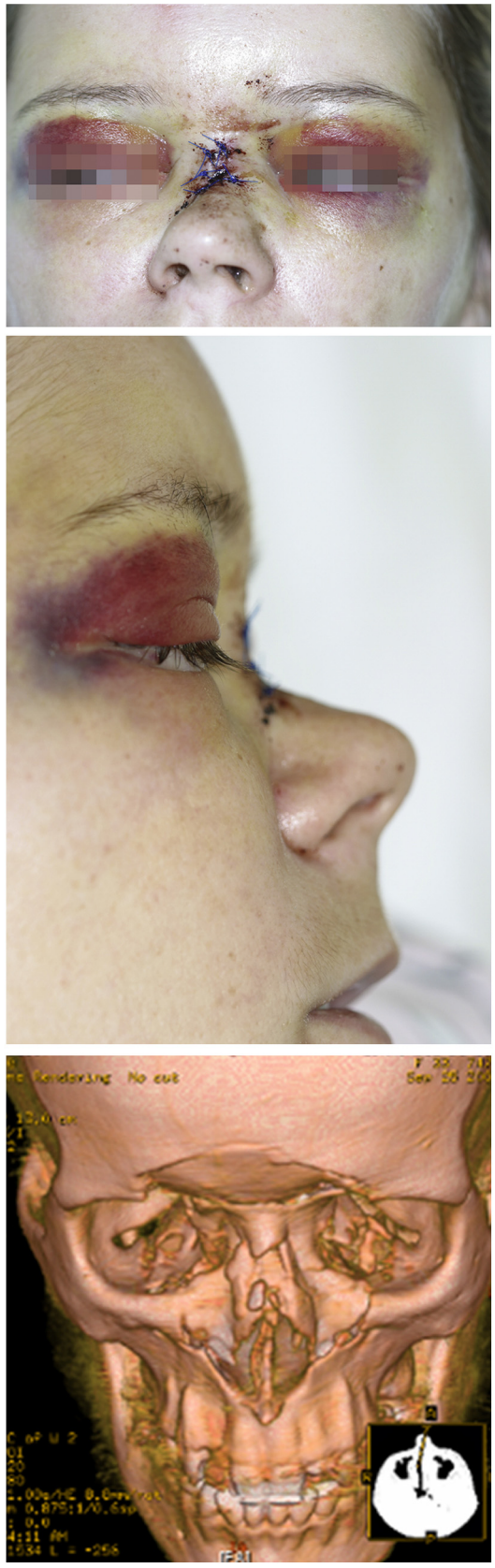

Fig. 2 – A 26-year-old female patient admitted with fronto-orbitonasal fracture, cerebral concussion, cerebrospinal fluid rhinorrhoea, pneumocranium. Visible collapse and invagination with nasal bone dislocation; nasal skin laceration sutured during emergency treatment. (A) en-face. (B) Side view. (C) Computed tomography 3D reconstruction.

2.1.5. *Bone plasty of the base of the anterior cranial fossa*

After dural defects plasty with pericranium and cranialisation of frontal sinuses, the reconstruction procedure of the anterior cranial fossa was performed. The size of bone defects of the skull base in these eleven patients with FONF varied. Most defects involved one or both sides of *crista galli* at the roof of the nasal fossae (three patients). In six patients, defects concerned both orbital roofs and the ethmoid roof, and in two cases there was a crush and bone indentation of the base of the anterior cranial fossa with cerebral hernia protruding into the bone defect.

Bone defects of the base of the anterior cranial fossa were reconstructed with autogenic grafts of different sizes: harvested from the iliac crest or the inner table of the skull, which was removed during craniotomy. Modelled bone grafts, which are always exceeding the size of defect, are positioned on the bone defect's periphery to prevent their displacement. Before bone reconstruction, the entrance to the fronto-nasal ducts was always closed with autologous bone wedges (Fig. 1C).

2.1.6. *Reconstruction of the supraorbital bar*

Bone fragments that were removed at the beginning of the surgery, and the supraorbital bar sometimes removed in part or in full were placed in position and stabilised at the periphery with microplates. If the supraorbital bar was crushed, then the defects within the glabella, the superciliary arches, the orbital rims, the orbital roofs and the nasal base would be reconstructed with adequately modelled autogenic grafts.

2.1.7. *Plasty with frontal pedicled pericranial flap*

Previously dissected, pedicled on supraorbital and supracochlear vessels pericranial flap was inserted between the dura mater and the autogenic bone graft reconstructing the cranial base. After careful spreading, the pericranial flap would line the base of the anterior cranial fossa. It can be either sutured to the dura or placed loosely (Fig. 1D).

2.1.8. *Reposition of the frontal bone*

Finally, the craniotomy flap was positioned and fixed with microplates on the periphery (Fig. 1E). The dura mater was suspended at the defect's margins and above the craniotomy flap with Dandy sutures. Concluding the procedure, it was important for the lower edge of the frontal bone—not to press on the pericranial flap. The musculo-cutaneous flap was sutured in layers.

The case presented below will serve as an illustration of the three-layer osteodural plasty of the base of the anterior cranial fossa, which we have been performing since 2005 in patients with FONF.

2.1.9. *Case*

A 26-year-old female patient was admitted to the clinic immediately after the injury. The following diagnosis was made: FONF, cerebral concussion, cerebrospinal fluid rhinorrhoea and pneumocranium. On admission, the patient was conscious, but sleepy. The physical examination revealed

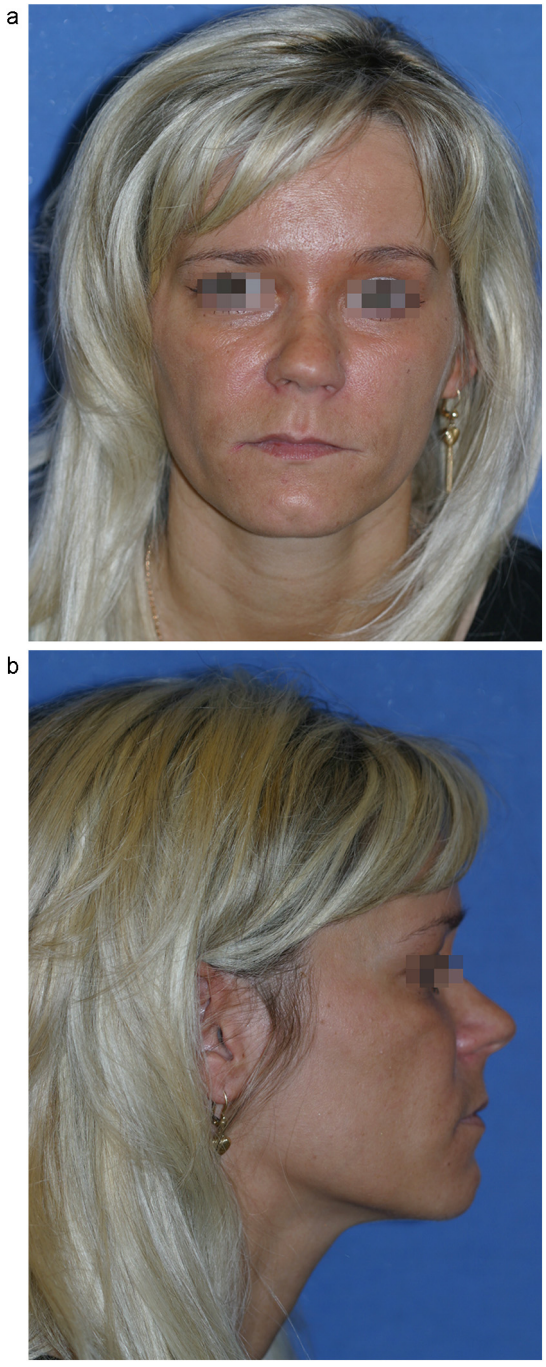

Fig. 3 – The patient 7 years postoperatively. (A) en-face. (B) Side view.

collapse and invagination within the glabella and the nasal base, and skin wounds in a nasal region (Fig. 2A and B). The computed tomography (CT) revealed the presence of pneumocranium with the possibility of traces of blood at that level and traces of air around the anterior part of the cerebral falx. There was also the presence of fluid within the ethmoid, sphenoid sinus, and both maxillary sinuses, oedema in the anterosuperior segment of the right orbit. Comminuted fracture of frontal bone in glabellar region, and crushed nasal bones, fractured ethmoid and medial walls of both orbits, fracture with invagination of the anterior wall of the frontal sinus and its posterior wall, as well as medial and anterior walls of both maxillary sinuses were additionally confirmed (Fig. 2C).

The procedure was performed 15 days after injury. After bifrontal craniotomy, dura was detached over the entire surface of the base on the anterior cranial fossa to the *jugum sphenoidale*. At the base of the anterior cranial fossa, a bone defect was found involving the roof of the nasal fossae (both lamina cribrosa with broken and displaced *crista galli*, which was removed) and covering two thirds of both orbital roofs. At the base of the frontal lobes over the ethmoid roof and medial parts of both orbital roofs, dural defect was localised about 40 mm in diameter.

The three-layer osteodural plasty of the base of the anterior cranial fossa was performed using surgical technique described above. In addition, nasal bone was reconstructed with adequately modelled autogenous iliac crest bone graft. The 7-year follow-up revealed no complications. The only complaint that occurred postoperatively was anosmia. The final, morphological, functional and aesthetic outcome of treatment should be assessed as good (Fig. 3A and B).

3. Results

During follow-up that lasted two to seven years, none of the eleven patients treated for FONF with three-layer osteodural plasty manifested recurrence of the cerebrospinal fluid leakage, brain oedema, intracranial haemorrhage, symptoms of intracranial infection or cranial lobe necrosis.

With this procedure it was possible to remove significant post-traumatic deformities of the orbital rims, the base of the nose and supraorbital bar, and adjust restricted eyeball movements with diplopia, whenever such a complication occurred after injury. The only complaint reported by the patients was posttraumatic loss of smell, which usually occurred immediately after the injury.

4. Discussion

Undiagnosed and untreated dural tears, brain hernia or abscesses often accompanying FONF are life-threatening. Severe meningitis occurring even several years after trauma can reveal the existence of these complications [2,5,12]. Due to extensive bone loss emerging at the base of the anterior cranial fossa, there is a high risk of central nervous system infection [13].

Indication for surgical intervention in FONF includes fractures of frontal squama, the nose, orbital roofs with displacement of bone fragments into the cranium cavity. Then, apart from separating the cranium from the sinuses by means of autogenous bone grafts that restore the base of the anterior cranial fossa, it is necessary to perform cranialisation of the frontal sinus, and obliteration of fronto-nasal ducts and supraorbital bar reconstruction. Using this procedure, the ascending infection from the paranasal sinuses can be avoided [11].

A frequently reported argument against the implementation of craniotomy and extradural approach to the base of the anterior cranial fossa in the case of cerebrospinal fluid leakage is the loss of smell, post-surgical brain oedema, intracranial

haemorrhage [14] and the risk of cerebrospinal fluid leakage recurrence [15]. More often used the endoscopic technique utilises grafts of adipose tissue, muscle, fascia lata, and nasal septum mucosa [16–23]. The first report of successful endoscopic closure of a cerebrospinal fluid leak was by Wigand in 1981 [16]. Despite the popularity gained by the endoscopic approaches, their use and indications are not universally accepted [24,25]. In all 11 patients described in this report, contraindications for endoscopic repair of cerebrospinal fluid leaks were present due to wide bone damage requiring its reconstruction.

Although transcranial approach provides direct access to the defect, it is not preferred due to high reported failure rates, the morbidity of the craniotomy and brain retraction. These techniques are used in patients who require an exposure to a skull base and to treat intracranial pathologies [26].

If the injury involves the whole ethmoid roof behind the olfactory fissure, then the olfactory nerve damage occurred already during the trauma. Such a situation occurred in nine out of eleven of our patients with FONF. In the other two, the sense of smell was only partially preserved. In these cases, severing the remaining olfactory nerve was necessary to detach dura mater over the entire surface of the base of the anterior cranial fossa up to *jugum sphenoidale*. This approach allows a full view of the base of the anterior cranial fossa and enables effective repair of bone and dural defects located at the base of the anterior cranial fossa. In this situation, it is important to inform the patient before surgery about the absence or impairment of the sense of smell after three-layer cranioplasty of the base of the anterior cranial fossa [27].

In the first stage of cranioplasty, we propose to cover dural defect with pericranium popularised by Tessier [4,5], which will revascularise after suturing and is quickly remodelled. The use of anteriorly pedicled pericranial flap not only reinforces the free pericranial flap, but also significantly reduces the risk of ascending infection, effectively separating the neurocranium from the viscerocranium [11,13]. The best material for bone reconstruction of the floor of the anterior cranial fossa is autogenous bone graft harvested from the iliac crest or the inner table of the skull bone which was removed during the craniotomy [28].

In our opinion, in the first stage of reconstruction it is essential to cover the dural defect tightly by means of the periosteal graft. Another important element is placing the frontal pedicled pericranial flap on the bone graft to reconstruct the base of the anterior cranial fossa. Frontal pedicled pericranial flap not only fills the space created by the cranialisation of the frontal sinus, but also provides vascularisation to the bone graft.

5. Conclusions

1. The surgical tactics of 11 cases with FONF and cerebrospinal fluid rhinorrhoea described allowed to prevent the recurrence of cerebrospinal fluid leaks. During this procedure reposition, reconstruction and fixation of fractured viscerocranium were done.
2. It seems that the total craniofacial reconstruction guarantees a good final functional, morphological and aesthetic outcome.

Conflict of interest

None declared.

Acknowledgement and financial support

None declared.

Ethics

The work described in this article has been carried out in accordance with The Code of Ethics of the World Medical Association (Declaration of Helsinki) for experiments involving humans; Uniform Requirements for manuscripts submitted to Biomedical journals.

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