RECONSTRUCTION OF ANTERIOR SKULL BASE AFTER CRANIOFACIAL RESECTION

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ABSTRACT

Anterior craniofacial resection and reconstruction surgeries were performed upon 21 patients (13 females and 8 males) aged 12-72 years, at the period between 1996-2002 at Mansoura University Hospital, Depatment of ORL Head and Neck surgery. Surgeries were performed for nasal and paranasal sinus malignant tumors with cranial and/or intracranial extention. Various forms of anterior cranial base reconstruction strategies were used in our work, anteriorly pedicled galeal-pericranial flap, galeal-pericranial flap+ skin graft, galeal-pericranial flap+calvarial bone graft, and galeal-pericranial flap+ temporalis osteomuscular flap. Orbital exenteration was done for two patients with ethmoidal undifferentiated carcinoma and obliteration of the orbit was done using pedicled temporalis muscle flap. Subtotal maxillectomy (18 cases), and total maxillectomy (3 cases) were performed. We discribed the technique of the resection and the reconstruction with evaluation of reconstruction results. Our objecive is to evaluate the clinical outcome of our technique in resection and reconstruction of anterior skull base. We concluded that Knowlages about different methods of reconstruction after craniofacial resection enabled the skull base surgeons to extend their resections in order to increase the safety margin. Also we found that the pericranial flap is the most ideal and reliable method for reconstruction of skull base after resection. Rigid bony reconstruction can be used in cases where the re-

section of anterior skull base was extended laterally to involve the orbital roof.

INTRODUCTION

Reconstruction of skull base defects following tumor resection is of paramount importance in avoiding serious and life threatening complications. Cranial base surgery has evolved and outcomes have steadily improved as increasingly reliable reconstructive techniques have been adapted to repair the challenging wounds in this complex anatomic region (Imola et al. 2003).

No one reconstructive method is always satisfactory, especially when considering repair of the region such as the anterior skull base. Increased morbidity and mortality is directly related to failure to adequately isolate the cranial cavity from the respiratory tract. Those surgeons performing craniofacial resection for the lesions of the paranasal sinuses and anterior skull base must be familiar with a variety of reconstructive techniques which they can utilize depending upon the surgical defect that must be closed. For those small to moderate size defects of the anterior fossa it was recommended to use inferiorly based pericranial flap. For larger defects extending laterally from the midline to involve a portion of the orbital roof, a laterally based flap of temporalis and pericranium can be used to provide successful anterior skull base reconstruction (Yucel et al. 2000). Temporalis muscle flap provided well vascularized tissue for obliteration of orbital exentration and total maxillectomy cavities and coverage of surface defects (Bridger et al. 2000). Pericranial flap reconstruction is a reliable method with low morbidity for closure of the most common skull base defect from craniofacial resection that entails removal of the fovea ethmoidalis, cribriform plate, and/or superior septum (Noone et al. 2002). The aim of our study is to evaluate our technique in reconstruction of anterior skull base after tumor resection.

PATIENTS AND METHODS

This work was carried out in the Otolaryngology, Head & Neck Surgery department, Mansoura University Hospital, where twenty one craniofacial surgeries done for nasal and sinus malignant tumors with cranial and/or intracranial extension, were studied from Sept. 1996 to Oct. 2002. This work included 13 female patients and 8 male patients, their ages

ranged from 12 to 72 years with the mean age of 42 years. Maximum follow up period was 7 years and minimum period was one year.

All patients were subjected preoperatively to :

Clinical evaluation including :

History taking and evaluation of the nasal, eye and neurological manifestations. Complete ENT exam, including nasal endoscopy and endoscopic guided biopsy of all the suspected tumors. Neurological examination, including cranial nerves assessment. Ophthalmologic examination, including ocular acuity, ocular motility and visual field assessment. Preoperative oral and dental assessment and preparation of palatal obturation.

Radiographic mapping of the tumor by CT scanning before and after contrast; Axial, Coronal and sagittal reformatting views to the nose and paranasal sinuses to evaluate the anatomical extensions of the tumors as well as the degree of bone resorption and destruction. MRI to evaluate the intra-orbital and intra-cranial extensions. Metastatic work-up was done to all patients with malignant tumors, including, chest X-ray, abdominal ultrasonography, bone survey and in selected cases chest CT scan and bone scan.

Routine laboratory investigation and medical fitness for general anesthesia.

SURGICAL TECHNIQUE

Anesthesia: General anesthesia with special technique.

The patient position : The patient is positioned supine with the head fixed in extended position during the cranial portion of the operation.

Draping : The entire scalp was shaved, and the face and scalp were isolated with sterile drapes.

Surgical steps : The first phase of the operation was commenced after infiltration with 1% xylocaine with epinephrine (1:100,000), by a coronal scalp incision made behind the hairline; the incision began and ended 1 cm anterior to the tragus and situated about 15cm from the nasion. This permits a greater length of pericranium to be available for cranial base reconstruction. Additional length of pericranium, if anticipated, can be raised from posterior scalp flap, which was

then elevated with the frontal scalp in one layer down to the nasion. The entire scalp of the frontal region was mobilized subperiosteally and retracted anteroinferiorly. On the sides the pericranium, the superficial temporalis fascia and adipose tissue are elevated in one layer by establishing plane between them and the deep temporalis fascia to avoid injury to the frontal branch of the facial nerve. The periorbita at the roof and upper parts of the medial and lateral walls are elevated in continuity with the pericranium, with care given at the orbital rims where the tissue may be markedly adherent to the underlying bone. The supraorbital foramina, if present were converted into notches and the neurovascular bundles are carefully dissected inferiorly with the periorbita. These vascular pedicles serve as the principle source of blood supply to the pericranial flap. The periorbita were elevated for 2-3 cm posteriorly from the rims, and this includes the trochlea. The anterior ethmoidal arteries, which serve as an external landmark to indicate the floor of the cribriform plate, were coagulated and divided. The temporalis muscles were elevated from the anterior portion of the temporal fossa, leaving a small cuff for their reattachment. The pericranium remained attached to the elevated scalp since in the later phase of the operation it was partly dissected off from the scalp and used as a pedicled flap for reconstruction of the bony defect in the floor of the anterior cranial fossa.

A bifrontal craniotomy was usually made in two pieces by doing the craniotomy on one side first and then the other side after separating the midline and opposite dura under direct vision. Using a high-speed drill system facilitated this. The free bone flaps were removed providing wide access to the entire frontal fossa giving better estimation of tumor invasion and provided ample space for dural repair. The inferior margin of the bone flap done as law as possible just above the supraorbital ridge. The frontal sinuses were usually entered in the process, if this occurred, either the entire mucosa was removed and the sinuses was washed with saline and antibiotic solution, then pledgets of muscles were inserted into the frontal ducts, or cranialization of the frontal sinuses was done.

The intracranial pressure was then decreased by cerebral dehydrating measures.

A bilateral extradural dissection then was made exposing both orbital plates. Care was taken during dissection in the midline not to do unnecessary tears in the dura. Crista galli was dissected free of the dura and removed. The dural sleeve of olfactory nerve is isolated individually and freed from its exit through the cribriform plate. The dissection was continued posteriorly to the level of the planum sphenoidale or even more if necessary.

After adequate exposure of the floor of anterior cranial fossa was obtained, the extent of the tumor invasion was assessed. If the tumor penetrated the inner table, the overlying dura was sacrificed whether or not involved by the tumor. The further operative steps are held at that time until mobilization from below was achieved.

The head and neck team commenced the second phase of the operation. Extended lateral rhinotomy (with eyebrow incision and upper lip splitting) was done. The maxillary sinus was entered from the front and inspected; the degree of maxillectomy depends on the degree of tumor invasion. If there was no or minimal tumor invasion of the maxillary sinus, partial maxillectomy was done. If there was extensive invasion of the maxillary sinus was found then total maxillectomy was necessary.

The orbit was explored and in our patient we utilized the guideline that 'to be safe' one should resect one anatomic border beyond the tumor. If the tumor abutted the orbital floor or the medial orbital wall but not penetrate bone, then the bone (lamina papyracea and floor) was resected. If the medial orbital wall or floor was invaded and the orbital periosteum not invaded, then the periosteum was resected. If the periosteum was invaded and the fat was intact, then layers of fat were removed. If the invasion was deeper, then orbital exenteration was done. The nasal septum was removed for safety margin and to provide additional exposure on both sides of the ethmoid sinuses.

The neurosurgical team now rejoined the operation and with the use of high-speed air drill with a small diamond burr, the entire cribriform plate was isolated by making a cut around its margin. Laterally the cut extends through the roof of the ethmoid air cells. The lateral extent of intracranial

osteotomy should be wide enough to encompass both medial orbital walls. Anteriorly the cut should extend through the posterior wall of the frontal sinus, and posteriorly into the sphenoid sinuses. After this step, a small osteotome was used to fracture the floor of the ethmoid sinuses to mobilize the specimen. The bony anterior wall of the sphenoid sinus was included in the specimen. The rest of the specimen was mobilized by using sharp dissection with heavy scissors.

The specimen was removed en block from below and included, the entire cribriform plate, both ethmoids with superior and middle turbinate, the bony nasal septum, the posterior wall of the frontal sinuses, and the anterior wall of the sphenoid sinuses. The degree of maxillectomy and orbital resection was dependent on the degree of tumor invasion.

Generous exposure of the frontal sinuses allow them to be opened, completely drained, demucosalized, and furnished with dependent nasal drainage (cranialization of the frontal sinuses).

Reconstruction

The resulting through and through defect in the floor of the anterior cranial fossa was done as follow: if the dura was sacrificed, the dural defect was repaired with a free graft of temporal fascia or pericranium. If not the cut margins of the dural sleeve of the olfactory nerves were closed with 4-0 sutures. A viable pedicled pericranial flap was separated from the previously elevated scalp flap and was laid over the bony defect in the floor of the anterior cranial fossa from above and secured to the dura with sutures. In some cases we applied pedicled temporalis muscle flap and in others skin graft under the pericranial flap. If the bony excision was extended to include roof of the orbit, then bony reconstruction was done using split calvarial bone graft in some cases and temporalis osteomuscular flap in others. The rest of the antral defect was also lined with skin graft. If the orbit was sacrificed, a pedicled temporalis muscle flap was used for orbital obliteration. The lacrimal sac was opened longitudinally and sutured to the orbital periosteum or to the edges of the skin graft. Fixation of the medial canthal ligament was done 1 cm anterior and superior to its normal attachment to counteract the tendency to retract.

The nose and the resultant cavity

were packed by antibiotic ointment soaked gauze. The facial incision and the craniotomy were closed in routine fashion.

RESULTS

Our work included 21 patients with nasal and sinus tumors with cranial and/or intracranial extension, 8 male patients and 13 female patients, their age ranged from 12 to 72 years with a mean age of 42 years.

The Pathological tumor types of our patients are shown in table (1)

Dural invasion was found in two patients with ethmoidal undifferentiated carcinoma that necessitated dural resection and duroplasty using pericranial free graft. Orbital exenteration was done for two patients with ethmoidal undifferentiated carcinoma with extensive intraorbital extension in whom the globes cannot be saved. Obliteration of the orbit was done using pedicled temporalis muscle flap.

Various forms of maxillectomy were done during anterior craniofacial resection in our work, the commonest used was subtotal maxillectomy in 18 cases, and total maxillectomy 3 cases (table 2).

Various forms of anterior cranial base reconstruction strategies were used in our work, anteriorly pedicled galeal-pericranial flap, galeal-pericranial flap+ split thickness skin graft, galeal-pericranial flap+calvarial bone graft, and galeal-pericranial flap+ temporalis osteomuscular flap (table 3).

In cases of total maxillectomy and/or orbital exenteration the reconstruction of the orbit and maxillectomy cavity was done by pedicled temporalis muscle flap.

The median operative time was 6 hours. Average blood loss was 700 cc. The median hospital stay period was 18-days and the median follow-up period was 24-months.

The complications of craniofacial resection through anterior craniofacial approach were classified into immediate (within one month of surgery) and remote, local major and minor complications. Anosmia occurred in all cases. Psychological and behavioral manifestations occurred immediately postoperatively in 85.7% of patients. The table number (4) demonstrates the complications encountered following craniofacial resection through an-

terior craniofacial approach:

We put some elustrative figures in this paper including: elevated pericranial flap (Fig. 1a), bifrontal craniotomy (Fig. 1b), extradural dissection to expose the anterior skull base (Fig. 1c), calvarial bone graft preparation from the frontal bone (Fig. 2a), The insertion of the calvarial bone graft into the anterior base to close the surgical defect (Fig. 2b), preoperative MRI of sinonasal tumor invading both the orbit and anterior cranial base (Fig. 3a), postoperative MRI of the same case after resection of the tumor, total maxillectomy and orbital exentration with reconstruction by temporalis muscel flap (Fig. 3b). Preoperative Sagittal MRI of olfactory neuroplastoma with intracranial extension (Fig.4a) and postoperative MRI of the same case after resection and reconstruction by pericranial flap.

Table (1): the pathological tumor types

Tumor type	No of cases
Squamous cell carcinoma	5
Undifferentiated carcinoma (SNUC)*	5
Adenoid cystic carcinoma	4
Esthesioneuroblastoma	3
Adenocarcinoma	2
Neurogenic sarcoma	2
Total	21

*sinonasal undifferentiated carcinoma

Table(2): Types of maxillectomy during anterior cranifacial resection.

Type of maxillectomy	Histopathology	Number of cases
Subtotal maxillectomy	Undifferentiated carcinoma	4
	Squamous cell carcinoma	4
	Adenoid cystic carcinoma	4
	Olfactory neuroblastoma	3
	Adenocarcinoma	2
	Neurogenic sarcoma	1
Total maxillectomy	Squamous cell carcinoma	1
	Undifferentiated carcinoma	1
	Adenocarcinoma	1
Total		21

Table(3): types of reconstruction of anterior skull base.

Method of reconstruction	Cranial base defect	Number of cases
Galeal-pericranial flap (anteriorly based)	Median Median & paramedian	12 1
Galeal-pericranial flap +skin graft	median	3
Galeal pericranial flap +calvarial bone graft	Median & paramedian	3
Galeal-pericranial flap+ temporalis osteomuscular flap	Median & paramedian	2
Total		21

Table (4) complications of craniofacial resection

complications	Number (%)
Anosmia	21 (100%)
Psychological symptoms	18 (85.7%)
Pneumocephalus	1 (4.3%)
Brain herniation	1 (4.3%)
Meningitis	1 (4.3%)
CSF rhinorrhea	2 (8.6%)
Frontal osteomyelitis	1 (4.3%)
Delayed extradural abscess	1 (4.3%)
Frontal neuralgia	8 (34%)
Diplopia	2 (8.6)
Récurrent dacryocystitis	1 (4.3%)
Nasal deformity	1 (4.2%)
Keloid scar of the coronal incision	1 (4.2%)
Telecanthus	1 (4.2%)

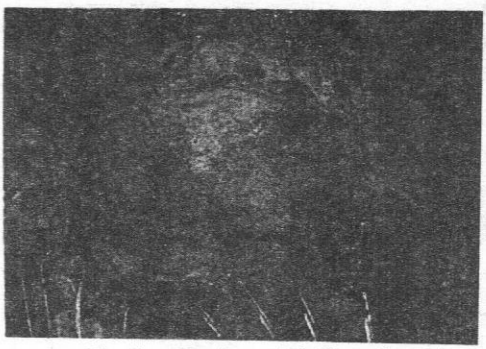


Fig 1a: Pericranial flap elevation.

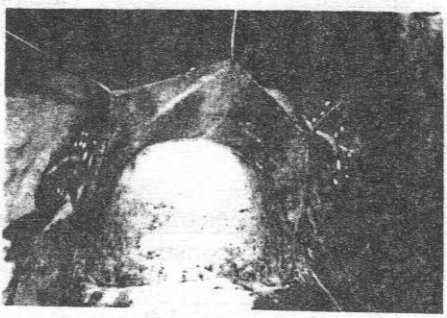


Fig 1b: Bifrontal craniotomy.

Fig 1c: Extradural dissection to expose the anterior cranial base.

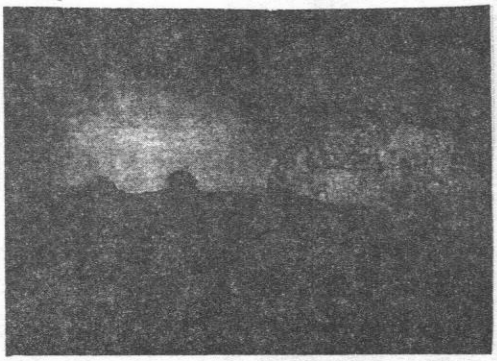
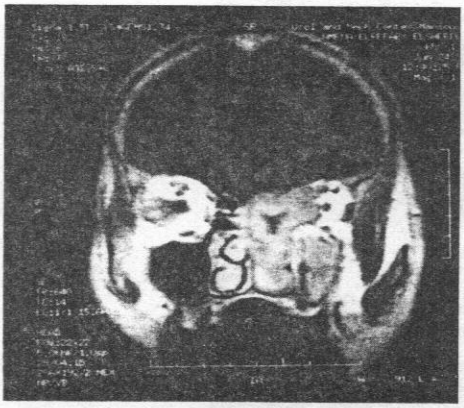
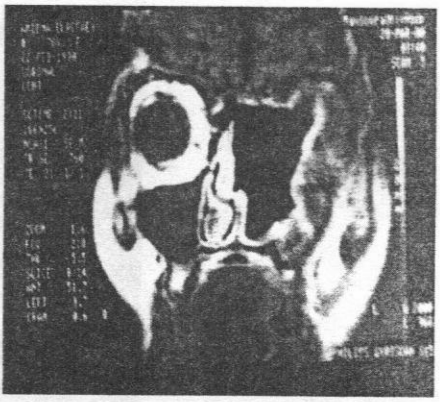


Fig 2a: Calvarial bone graft

Fig 2b: Rigid reconstruction by calvarial bone graft



A



B

Fig (3a): MRI shows left sinonasal carcinoma invading anterior cranial base and the orbite. Fig 3b: MRI after resection of the tumor and excentration of the orbit with reconstruction.

Fig.(4a): MRI sagittal view of olfactory neuroblastoma with intracranial extension

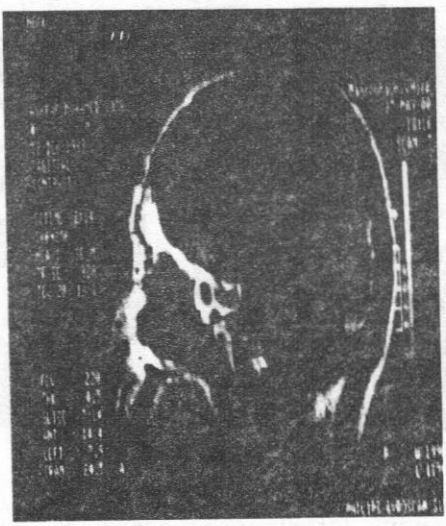


Fig.(4b): Sagittal MRI post operative, Arrow to the galeal pericranial flap

DISSCUSION

With increasing surgical sophistication in skull base and craniofacial surgery, reconstructive efforts are challenged to provide a reliable means of compartmentalization. Preoperative planning of the reconstructive methodology leading to suitable alteration of the operating steps is important for success of skull base surgical procedure. Reconstruction with local and regional flaps is an integral part of the operation and must be adequately planned and performed (Goel, 1996). Contemporary surgical approaches and methods of reconstruction have enabled skull base surgeons to extend their cranial base resections and increase the 5-year survival rates of patients (Dias et al.1999).

The proximity of the skull base to potentially infected spaces such as the paranasal sinuses, nasal, oral, and pharyngeal pathways, long duration of the surgical procedures, and involvement of multiple surgeons with extensive instrumentation adds to the risk of infection (Snyderman et al. 1990).

The basal dura is relatively thin and friable and firmily adherent to the bone. Approximation of edges and water tight suturing often may not be possible especially in areas of vessel and nerve transit. Frequently there are large dead spaces that need to be filled in, after resection of basal bone, soft tissue, and tumor. The reconstruction begins at the end of a relatively long operation when the operative team may be exhausted and errors of omission may be made. Occasional cases of persistent postsurgical or traumatic cerebrospinal fluid fistula can pose a formidable surgical challenge and superadded infection can be a life threatening condition (Watson, 1993).

The principal purpose of reconstruction is to avoid possible herniation of brain matter into the aerodigestive tracts, ear, or orbit. In presence of intact basal dura, even large bone defects can be tolerated without any consequence. Goel, (1996) has observed that as much as one third to one-half of the orbital roof can be removed without any problem of pulsating exophthalmos. Pericranial and galeal flap have been described for reconstruction of anterior cranial base (Goel, 1994b, Noone et al. 2002, and Zhiyuan and Weiliu, 2003). The pericranium is composed of an

outer layer of loose areolar tissue and an inner layer of osteoblast and contain an extensive vascular network. The pericranium derived blood supply from the supratrochlear and supraorbital arteries anteriorly and from the superficial temporal arteries laterally. Pericranial pedicled flaps can be based on either of these vessels and accordingly rotated anteriorly or laterally. Noone et al. (2002) studied the effectiveness of Pericranial flap for closure of anterior skull base defects in 17 patients and they observed no complications related to the pericranial flaps such as hemorrhage, flap loss, or brain herniation except for 2 cases of cerebrospinal fluid leaks.

In our study we used pericranial flaps alone in 13 patients and we observed CSF leakage in 2 cases where spontaneous cure occurred , one case developed meningitis which was treated by massive intravenous antibiotic and brain herniation was detected in one patient with large median and paramedian defect which required re-reconstruction with temporalis osteomuscular flap. Pericranial flap with skin graft put under it, were used in 3 cases where no complications were observed.

Reconstruction of the bone is also carried out to support the dura and help in establishement of watertight sealing of the base and avoiding of the cerebrospinal fluid fistulas. The size of the defect and its site, extent of resection of the associated structures, history of previous operative procedures and radiation treatment are important variables that determine the appropriate reconstructive procedure.

Various methods of reconstruction of the skull basal bone have been described. Price et al.(1988) reported that bone defects in the cranial base can be reconstructed with the help of bone, acrylic and metal plates. Sinha et al.(2002) reconstructed the anterior skull base defects with a three-layer technique (bone graft, titanium mish and pericranial flap).

The reconstruction can be done by split or full thickness cranial bone pedicled on muscle flap (Goel, 1994a). Various experimental studies have been conducted on the evaluation of temporalis osteomuscular flap compared with calvarial free bone grafts (Antonyshyn et al., 1986; Combelles and Zadeh, 1984; Fasano et al., 1987). The studies confirmed that

Vascularized bone flaps remain viable and are characterized by normal evolution, whereas the free bone grafts show typical signs of necrosis and resorption. The pericranium can sustain the calvarial flap by means of multiple small, vertical perforators. Studies have shown that the calvarial flaps can safely be pedicled on the pericranial layer or, galeal-pericranial layer (Casanova et al., 1986; Cutting et al. 1984; Goel, 1994c; Goel and Gahankari, 1995; Price et al. 1988; Snyderman et al. 1990., Watson, 1993). In our study we used calvarial bone graft sandwetched within the pericranial flap in three cases and bone flap pedicled on temporalis muscel in three cases (2 primary cases and the case of brain herniation after primary reconstruction by pericranial flap alone), where large bony areas were removed including orbital roof. We found no brain herniation , infection or CSF leakage in the six cases.

CONCLUSION

The objective of reconstruction is mainly focused on the coverage and protection of the dura and brain from infection, herniation and cerebrospinal leak. Such protection should be completed by separating the intracranial tissues from the underlying extracranial cavities by different methods. Pericranial vascular flap produced good results in most cases with low rate of morbidity. This type of flaps is easy to be obtained in long length and can be rotated in various directions. Its close proximity to the operative field adds to its advantages. Skin graft can be used under the pericranial flap to increase its protection. Rigid reconstruction can be performed by adding bone graft or bone flap especially in cases where large area of resection is required or in cases where herniation of brain occurs after reconstruction using pericranial flap alon.

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إعادة بناء قاع الجمجمة الأمامى بعد الاستئصال الوجهى الجمجمى

ان إعادة بناء قاع الجمجمة الأمامى بعد عمليات الاستئصال الوجهى الجمجمى والتى تستعمل فى حالات بعض أورام الأنف والجيوب الأنفية الممتدة إلى الجمجمة وداخل الجمجمة هى من العمليات المهمة جدا حيث أن عملية البناء تفصل بين تجويف الجمجمة والأنف مما يعمل على منع تسرب السائل السحائى خارج المخ وأيضاً يمنع فتق خلايا المخ إلى خارج تجويف الجمجمة .

ولذلك قمنا بدراسة طرق مختلفة لعملية بناء قاع الجمجمة الأمامى.

اشتملت الدراسة على ٢١ مريضاً (١٣ ذكر و٨ أنثى) تتراوح أعمارهم بين ١٢ إلى ٧٢ سنة قمنا باجراء العمليات بقسم جراحة الأنف والأذن والحنجرة بمستشفى جامعة المنصورة وذلك فى الفترة بين ١٩٩٦ و ٢٠٠٢ ..

والمرضى الذين اشتملت عليهم الدراسة يعانون من أورام خبيثة فى الأنف والجيوب الأنفية منتشرة إلى المخ .

وقد اشتملت الدراسة على شرح طريقة الاستئصال المخى الوجهى للأورام وطريقة إعادة البناء وقد قمنا بإعادة البناء بواسطة : شريحة من غشاء سمحاق الجمجمة فى ١٣ مريض

شريحة من غشاء سمحاق الجمجمة ورقعة الجلد الرقيق فى عدد (٣) مريض

شريحة من غشاء سمحاق الجمجمة ورقعة عظمية من العظمة الجبهية فى عدد (٣) مريض

شريحة من غشاء سمحاق الجمجمة وشريحة عظمية عضلية متصلة بالعضلة الصدغية فى حالتين .

ولقد استخلصنا من النتائج أن معرفة الطرق المختلفة لعمليات إعادة البننا ء لقاع الجمجمه الأمامى مهم جدا للجراح أثناء استئصال الأورام الممتدة من الأنف إلى الجمجمة أو داخل الجمجمة حيث يمكن توسيع مجال الاستئصال لاختيار الطريقة المناسبة لإعادة البناء .