

LITERATURE REVIEW

Open surgical approaches to the anterior skull base and paranasal sinuses

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ABSTRACT

The route of spread of tumours originating in the anterior skull base and paranasal sinuses is determined by the complex anatomy of the cranio-maxillo-facial compartments. These tumours may invade laterally to the orbit and middle fossa, inferiorly to the maxillary antrum and palate, posteriorly to the nasopharynx and pterygopalatine fossa (PPF), and superiorly to the cavernous sinus and brain. Recent improvements in endoscopic technology now allow the resection of mostly benign neoplasms or early malignant tumours with minor dural involvement. For advanced-stage malignant tumours and benign tumours with frontal bone involvement, the classical transfacial approaches remain viable surgical techniques. In this article, the common open approaches used for resections at the cranio-maxillo-facial area and the reconstruction techniques are described.

KEYWORDS: anterior skull base, paranasal sinuses tumors, open approaches

INTRODUCTION

The route of spread of tumours originating in the anterior skull base and paranasal sinuses is determined by the complex anatomy of the cranio-maxillo-facial compartments. These tumours may invade laterally to the orbit and middle fossa, inferiorly to the maxillary antrum and palate, posteriorly to the nasopharynx and pterygopalatine fossa (PPF), and superiorly to the cavernous sinus and brain. Recent improvements in endoscopic technology now allow the resection of mostly benign neoplasms or early malignant tumours with minor dural involvement. For advanced-stage malignant tumours and benign tumours with frontal bone involvement, the classical transfacial approaches remain viable surgical techniques.

Conventional open approaches involve various skin or scalp incisions and osteotomies of the maxillary, frontal and ethmoidal bones. Conventional transfacial skin incisions are used for accessing the paranasal sinuses and nasal cavity up to the level of the anterior skull base. The craniofacial approach, which requires facial and coronal incisions, is used for excision of tumours above and below the cribriform plates. The subcranial approach is an alternative to the craniofacial technique, which eliminates the need for a facial incision. Midfacial degloving (MFD) offers an alternative to skin incisions for removal

of various benign neoplasms. In this article, the common open approaches used for resections at the cranio-maxillo-facial area are described.

PREOPERATIVE EVALUATION AND ANAESTHESIA

All patients scheduled for operation are evaluated preoperatively by a head and neck surgeon, a neurosurgeon and an anaesthesiologist. Patients younger than 18 years of age are also examined by a paediatrician. If a free flap is planned, preoperative physical examination by a plastic surgeon is required. Radiological evaluation of the patients includes axial and coronal CT and MRI of the head and neck. Neuroangiographical evaluations may also be performed in cases of highly vascular tumours invading the skull base or the cavernous sinus. A PET/CT has been lately advocated for staging and surveillance.

TRANSFACIAL APPROACHES

The conventional exposure of the supra-structure of the maxilla involves a lateral rhinotomy incision, whereas supra- and infrastructure maxillectomy is per-

formed via Weber-Fergusson incisions. A Lynch incision may be used to approach the frontal sinus lateral to the supra-orbital nerve, where endoscopic resection is unfeasible. Lateral rhinotomy may be combined with a Lynch incision. A Dieffenbach incision, combined with a lateral rhinotomy incision, is used for tumours that extend to the infra-orbital rim, lateral orbital wall, zygoma and orbit. All facial incisions are performed along normal skin lines for enabling concealing of the scar. Figure 1 illustrates the common transfacial incisions. The MFD approach allows elimination of facial incision. Instead, the incisions are performed above the superior alveolar ridge and between the upper lateral and inferior lateral nasal cartilages.

LATERAL RHINOTOMY INCISION

The lateral rhinotomy approach is used in case of a malignant tumour originating in the nasal cavity and maxillary sinus without palatal invasion. Benign tumours with anterior maxillary wall involvement are similarly approached. This approach allows wide exposure of the maxillary antrum, nasal cavity, ethmoidal sinuses and sphenoid sinus. The facial incision extends along the lateral border of the nose, ~1cm lateral to the midline. It starts from the cephalad medial cantus and extends down through the skin crest bordering the nasal ala. It is continued towards the filtrum. The flaps can be developed to the level of the maxillary tuberosity laterally, the upper gingival sulcus inferiorly, the frontal sinus and infra-orbital rim superiorly, and to the nasion and nasal septum medially.

WEBER-FERGUSSON INCISION

In cases of malignant tumours infiltrating the lateral maxillary wall or palate, total maxillectomy is performed via a Weber-Fergusson incision. This incision permits complete exposure of the maxilla, from the upper alveolar ridge to the orbit. This incision allows exposure of the superior and inferior aspects of the maxilla and its complete en bloc resection. The facial incision starts as a lateral rhinotomy incision, and is continued towards the filtrum and extended down to the lip in the midline. Inferiorly, the incision continues along the gingivobuccal sulcus, extending laterally up to the retromolar area. The soft tissue of the cheek is raised from the anterior surface of the maxilla, transecting the infra-orbital nerves and vessels should the superior and lateral walls of the maxilla need to be approached. An upper cheek flap is developed laterally and superiorly up to the level of the inferior orbital rim and the maxillary tuberosity. Inferiorly it can reach the PPF.

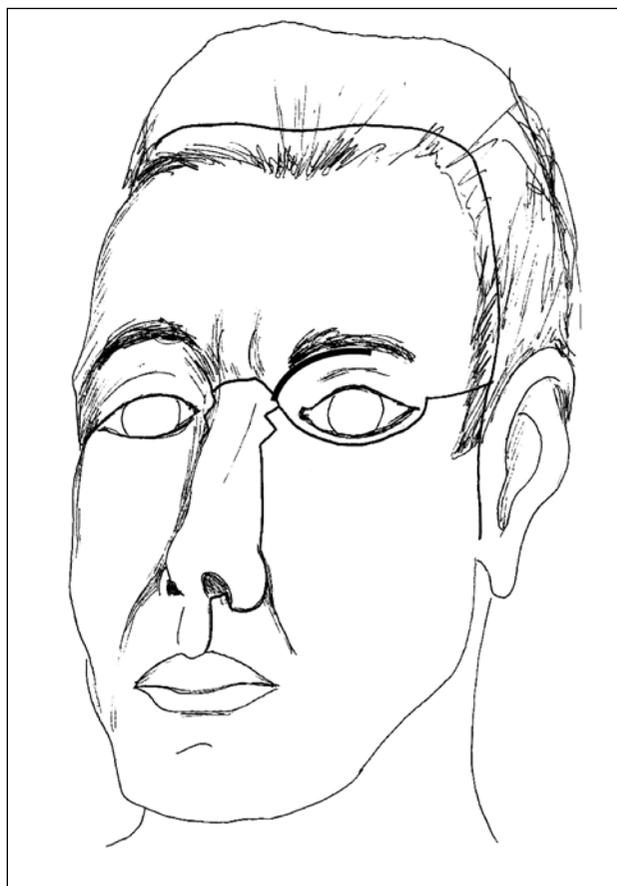


Figure 1 Facial incisions for resection of craniofacial neoplasms. Lateral rhinotomy, Weber-Ferguson, Lynch, Sub ciliary, Mid ciliary, Dieffenbach, are presented. Combined approaches are possible

LYNCH INCISION

The Lynch incision is used to approach tumours involving the frontal sinus. It can be extended laterally up to the level of the lateral cantus, or inferiorly to be included in a lateral rhinotomy incision. This incision is used nowadays almost only for orbital biopsies or for neoplastic lesions originating in the frontal sinus. The facial incision extends along the lower border of the eyebrow or in a skin crest along the upper lid, allowing it to be concealed at the hair-skin junction. If the incision is made inside the eyebrow, a thick scar may be noticed, giving inferior cosmetic results. The incision is extended down, ~0.5 cm medial to the medial cantus.

DIEFFENBACH INCISION AND ITS MODIFICATIONS

These incisions are used to approach tumours involving the infra-orbital rim and zygomatic root. It can be extended medially up to the level of the medial cantus, or inferiorly, to be included in a lateral rhinotomy inci-

sion. The classical Dieffenbach incision extends along the lower border of the eyelid, along a skin crest. The incision extends from the medial cantus to the lateral cantus. A later modification of this incision is the subciliary incision, which is located just below the cilia of the eyelid, or the mid-ciliary incision, which is located half-way between the Dieffenbach and subciliary incisions.

The superior border of the flap includes the infra-orbital rim and orbit; its inferior border is the anterior maxillary wall, laterally it is extended to expose the maxillary tuberosity and root of the zygoma, and medially it extends to the nasal bone. In elderly and in previously irradiated patients, the redundant skin and subcutaneous tissue of the lower eyelid tend to swell, as the incision may include the lymphatic drainage of this area. The skin is closed with a subcutaneous, continuous number 5.0 prolene stitch to prevent contractions of the thin skin in this area.

MIDFACIAL DEGLOVING (MFD)

The MFD approach combines the sublabial incision used in external approaches to sinus surgery with intranasal incisions used in cosmetic rhinological surgery. The main advantage of this approach over conventional lateral rhinotomy or Weber-Ferguson approaches is avoidance of facial incisions. Traditionally, this approach was designed for benign tumours, including inverted papilloma, juvenile angiofibroma, odontogenic cysts, and benign fibro-osseous lesions. Nowadays, MFD has been replaced by the endonasal approach as the main technique for extirpation of these lesions.

Nevertheless, it can be used for large tumours or after failure of endonasal resections. The MFD ap-

proach involves a complete transfixation incision, with a complete intercartilagenous incision. This effectively separates the upper lateral cartilages from the lower lateral cartilages, the latter of which is later included with the superiorly retracted flap. Next, a "degloving" of the facial soft tissues from the nasal skeleton and maxilla is performed. This is achieved through a sublabial incision which extends from first molar to first molar (Figure 2).

APPROACHES TO THE ANTERIOR SKULL BASE

The subcranial or craniofacial approaches are single-stage procedures used in cases of tumours involving the anterior skull base. The extent of exposure of these approaches includes the frontal sinus anteriorly, the clivus posteriorly, the frontal lobe superiorly, and the paranasal sinuses inferiorly. The lateral boundaries of this approach include both superior orbital walls. The surgical treatment of anterior skull base tumours dates back to 1963, when the combined craniofacial approach was first described by Ketchum and Van Buren. Subsequently, the craniofacial approach and its modifications became the standard of care for treating malignant tumours involving the anterior skull base.

Conventional anterior skull base approaches involve the subcranial approach or the craniofacial approach.

CRANIOFACIAL RESECTION

The craniofacial resection is a well established technique for the surgical excision of tumours involving

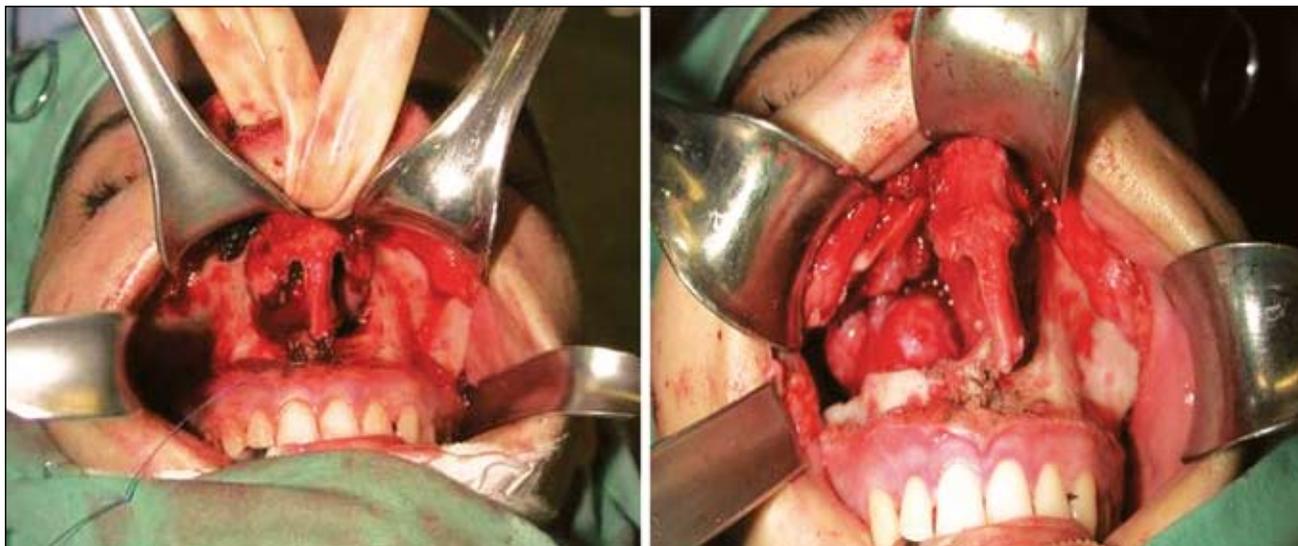


Figure 2 The midfacial degloving (MFD) approach. Intraoperative pictures: the soft tissue of the face is elevated (see text description), left. Following anterior, medial and lateral maxillectomy the juvenile angiofibroma is visible in all dimensions, right

the anterior skull base and paranasal sinuses¹. This technique requires a frontal craniotomy along with a transfacial approach to allow broad exposure of the anterior cranial fossa and subcranial compartment. Initially, a lateral rhinotomy incision is made, followed by medial maxillectomy, anterior and posterior ethmoidectomy and sphenoidectomy, which are performed under the microscope. The cribriform plate and frontal recess are exposed along with the lamina papiracea bilaterally. Next, elevation of a coronal flap and frontal craniotomy are performed. The craniotomy includes the frontal bone from the level of the glabella below, to roughly 4-5 cm above the skull base superiorly.

The lateral borders of the craniotomy are the midpupillary line bilaterally. Next, the dura is incised, if indicated, and the frontal lobes are retracted superiorly, exposing the anterior skull base from above. The final stage of the operation involves resection of the tumour, which extends through the cribriform plate in a combined fashion from below and above (Figure 3).

The use of craniofacial surgery has been documented for a variety of malignant and benign tumours. This technique has two major advantages: (i) it affords broad exposure of the anterior skull base from above and below, providing excellent access to the orbital, speno-ethmoidal and paranasal cavities; and (ii) intradural and extradural tumour resection can be performed in a single

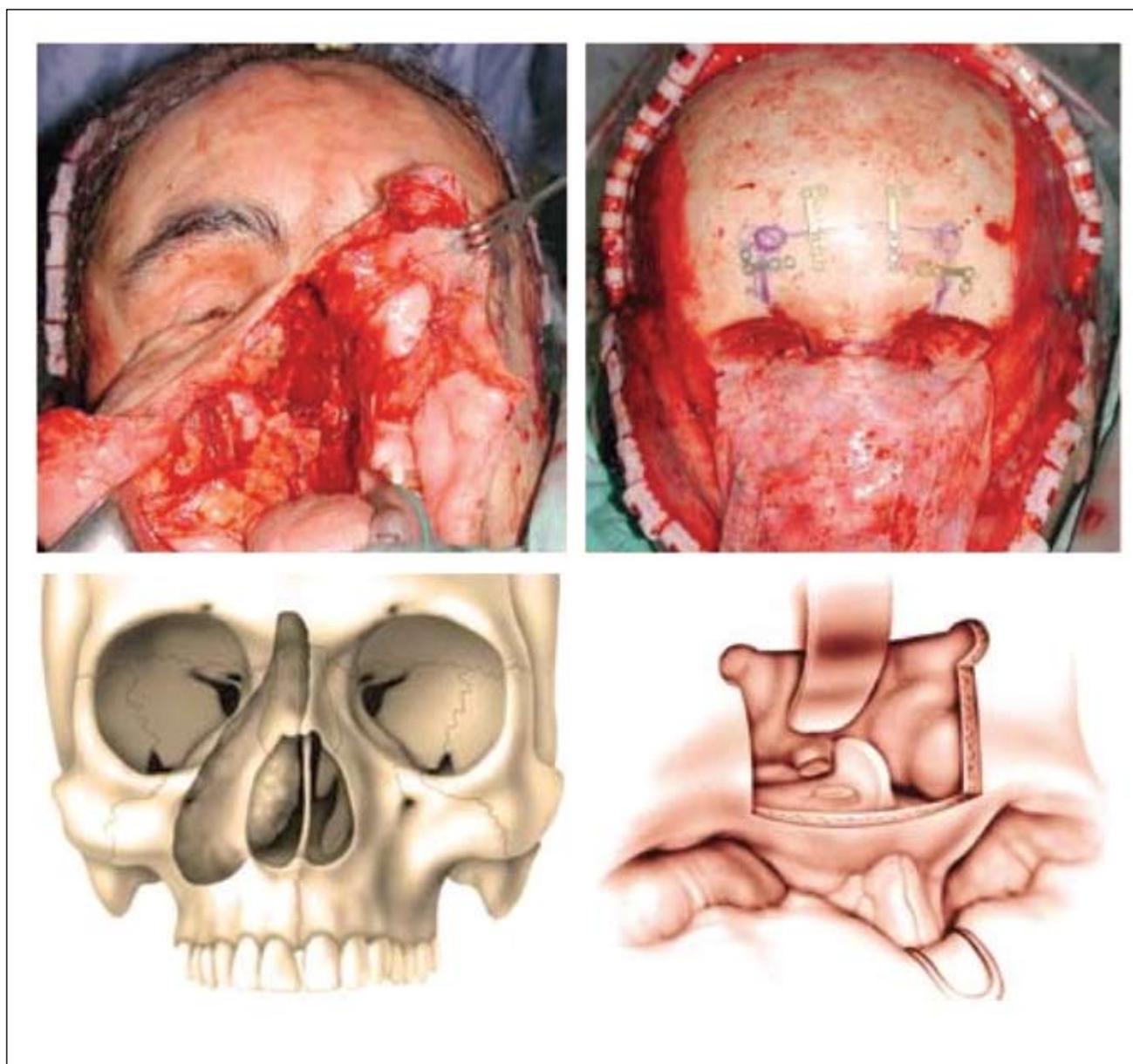


Figure 3 The craniofacial approach. A Weber-Fergusson incision (upper left) and coronal incision (upper right) are performed. The pericranium is flipped anteriorly. The cartoons depict the frontal craniotomy (lower right) and medial maxillectomy and ethmoidectomy (lower left)

procedure that also allows precise reconstruction of the dura. Despite the technical reproducibility of the craniofacial approach, this procedure still involves a high-risk of postoperative complications. The main limitation of this approach is the need of frontal bone retraction, which may lead to encephalomalacia, brain edema and subdural bleeding, especially in the elderly population.

THE SUBCRANIAL APPROACH

The subcranial approach is a single-stage procedure used for tumours involving the anterior skull base². The extent of exposure of the subcranial approach in-

cludes the frontal sinus anteriorly, the clivus posteriorly, the frontal lobe superiorly and the paranasal sinuses inferiorly. Laterally, the boundaries of this approach are both superior orbital walls.

The subcranial approach has several major advantages: (i) it affords direct exposure of the anterior skull base from anterior to posterior instead from above and below, as in the craniofacial approach; (ii) it allows simultaneous intradural and extradural tumour removal from anterior to posterior; (iii) it does not require facial incisions; and (iv) minimal frontal lobe manipulation is required.

The subcranial approach involves coronal incision and osteotomy of the naso-fronto-orbital bone seg-

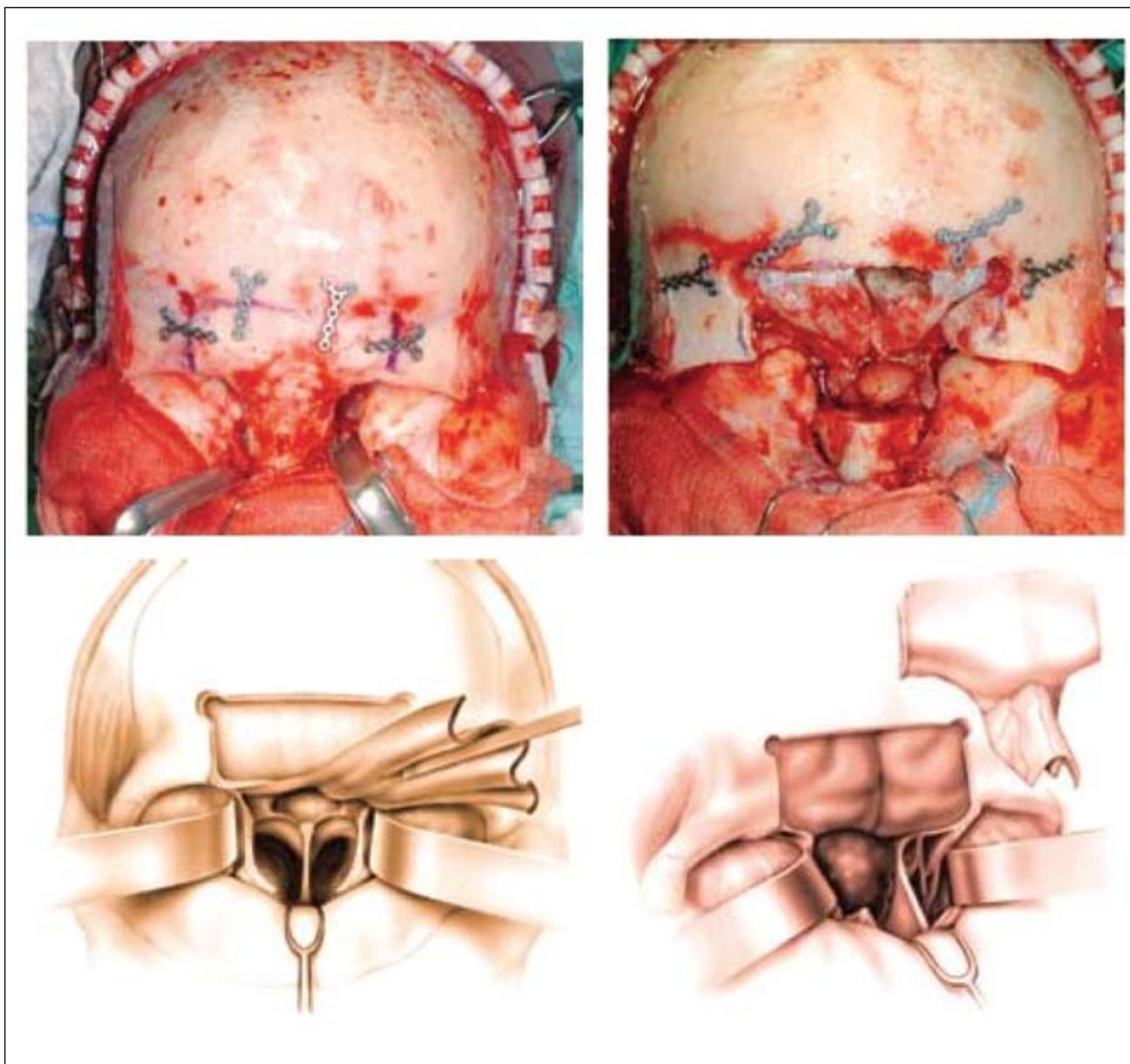


Figure 4 The subcranial approach. Intraoperative pictures showing the elevation of the coronal and pericranial flaps (upper left) and osteotomies (upper right). The cartoons show the exposure after the craniotomy and the reconstruction with the fascia lata

ment, which allows access to the intra- and extra-cranial compartments of the anterior skull base (Figure 4). The main disadvantage of this approach is bone osteonecrosis, especially after RT.

COMBINED APPROACHES

Although both the subcranial and craniofacial approaches permit complete tumour resection in the majority of cases, situations still arise in which the inferior, lateral or posterior aspects of the tumour are not adequately exposed. These include neoplasms with extensions to the hard palate caudally, to the cavernous sinus posteriorly, to the orbital apex, PPF, or infratemporal fossa (ITF) laterally, and to the nasopharynx and clivus inferoposteriorly³. Such cases require a combination of the standard craniofacial/subcranial approach with other approaches as a one-stage procedure to allow proper exposure and tumour extirpation. In these combined approaches a second approach may include one or more of the following procedures: MFD, orbito-zygomatic, trans-facial, Le-Fort I, or transorbital approach. These combined approaches require additional incisions and osteotomies according to the type and extent of the tumour.

COMBINATION WITH THE PTERIONAL APPROACH

This approach is a combination of the subcranial approach and the pterional approach (Figure 5)⁴. A unilateral pterional approach is added to the subra-

nial approach to expose the more lateral aspect of the orbit, the retro-orbital region, the cavernous sinus, the PPF, the chiasmatic region, or the ITF. Large central nervous system tumours with extracranial extent, such as meningiomas involving the orbit or upper nasal and sinus cavities, can also be resected via this combined approach. In this modification, the coronal incision is performed and the skin flap elevation continues down to the level of the fat pad overlying the zygoma, above the temporalis fascia. On the ipsilateral side, the remainder of the dissection dips below the level of the temporalis fascia from the horizontal line above the arch and continues as a fasciocutaneous flap. The muscle is detached anteriorly and superiorly, exposing the temporal fossa. The next stage includes osteotomies in both the frontal and pterional regions. The standard osteotomy described above is modified by its extension laterally, to include a portion of the orbital roof and temporal bone. The bone segment is then removed in one or two pieces, exposing the orbital, ethmoid and sphenoid roofs, the cribriform plate, the temporal fossa and the parasellar area.

COMBINATION WITH THE MFD APPROACH

The subcranial MFD approach is used for resecting benign tumours involving the anterior skull base and the inferior wall of the maxillary sinus. This is indicated mainly for resection of juvenile angiofibromas with anterior skull base invasion⁵. It can be also combined with an orbitozygomatic or pterional approach for tumours that extend to the lateral skull base.

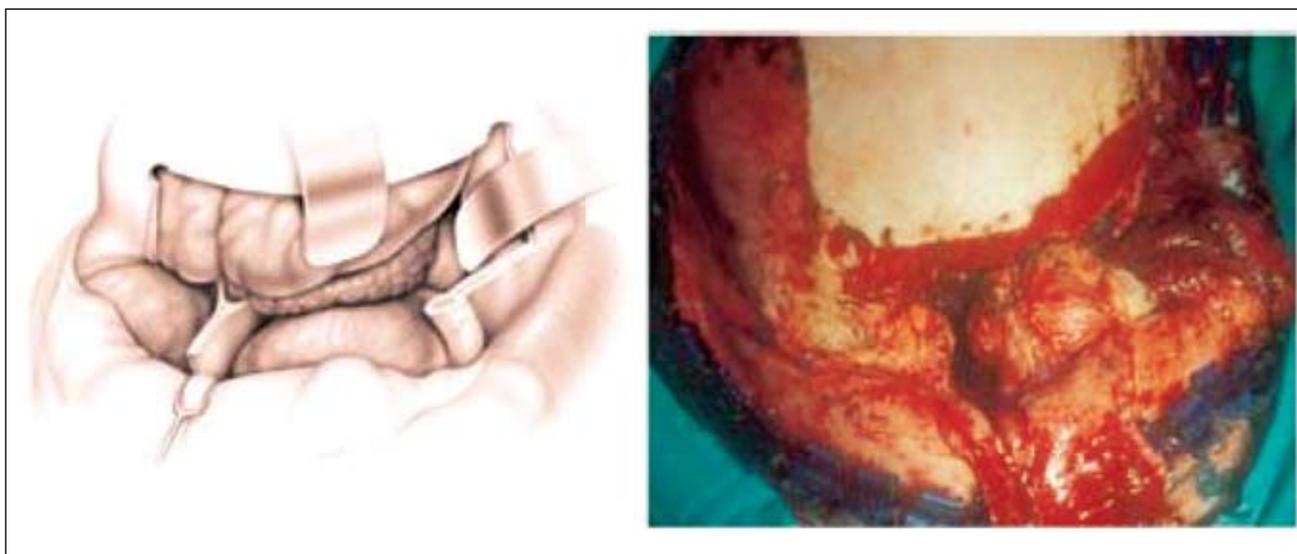


Figure 5 Combined subcranial and pterional craniotomy. The standard osteotomy described above is modified by its extension laterally, to include a portion of the temporal bone and the orbital roof. The bone segment is then removed in one or two pieces, exposing the orbital, ethmoid and sphenoid roofs, the cribriform plate, the temporal fossa and the parasellar area

COMBINATION WITH LEFORT I APPROACH

The subcranial - LeFort I approach (Figure 6) allows a wide exposure of the tumour from the cribriform area to the lower part of the clivus, maxillary sinuses and nasal cavity. It is indicated only for selected cases that cannot be approached by the subcranial approach or combined endoscopic - subcranial approach. This approach may be selected for extirpation of large chordomas or chondrosarcomas originating in the clivus, which extend superiorly to the sphenoid sinus, planum sphenoidale and cribriform plate.

COMBINATION WITH A TRANSORBITAL APPROACH

A combined transcranial - transorbital approach is used for malignant tumours that penetrate the

bony orbit and periost and infiltrate the anterior orbital content (T4a) or orbital apex (T4b). A coronal flap is performed and the flap is extended inferiorly in one side of the coronal-facial flap. The superior and medial walls of the orbit are exposed and stripped from their periostium.

During dissection along the medial orbital wall, the anterior and posterior ethmoidal arteries are identified and clipped. If the roof or medial orbital wall is involved by the tumour, they are removed at this stage. If not involved, the upper and lower lids may be spared, allowing a future insertion of an orbital implant and an improved cosmetic result. If the lids are involved, a circular skin incision is made along the superior and inferior orbital rims and the skin of the lids is kept on the main specimen. Table 1 summarizes the surgical approaches discussed in this chapter and their indications.

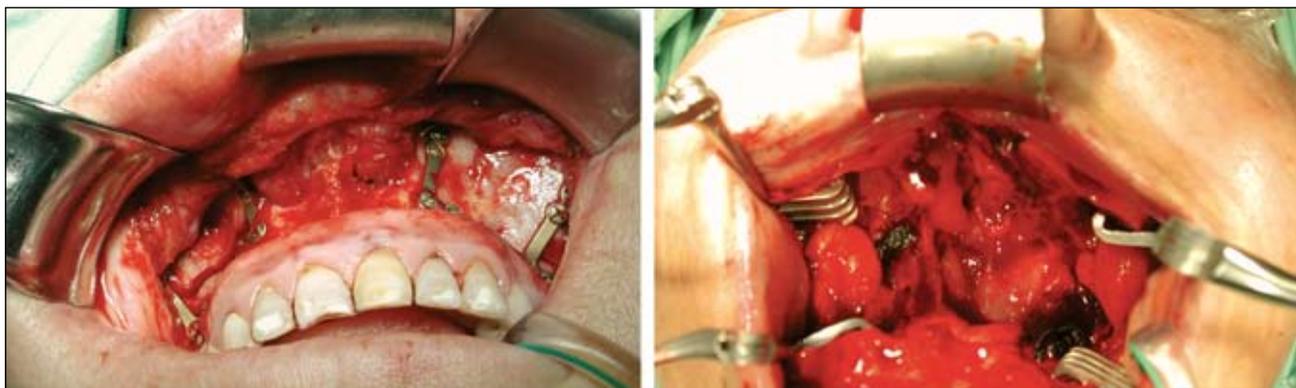


Figure 6 Combination with LeFort I approach. Following osteotomies the maxillary infrastructures is retracted downwards, enabling an excellent exposure of nasopharynx and clivus, left. Rigid fixation of the osteotomized segment, right

Table 1

Summary of the surgical approaches used for excision of anterior skull base tumours

Tumour extension	Surgical approach	
The anterior skull base, frontal/ ethmoidal /sphenoidal sinuses, sphenoid clivus, planum sphenoidale	Subcranial or craniofacial	
The medial or superior maxillary walls and periorbit	Subcranial or craniofacial with ipsilateral /bilateral partial maxillectomy	
Benign tumours extending to the maxillary sinus compartment \pm PPF or nasopharynx	Subcranial-MFD	
Malignant tumours extending to the inferior/ anterior/lateral/posterior maxillary walls	Craniofacial with Weber-Fergusson incision	
Extension to the lateral skull base, cavernous sinus, middle fossa or ITF	Subcranial or craniofacial with pterional	
Extension to the lower clival region	Subcranial - LeFort I	
Orbital apex or intraorbital extension	Subcranial or transcranial with transorbital	
Malignant tumours extending to the maxillary sinus with intraorbital extension	Transcranial-transfacial-transorbital	
PPF Pterygopalatine fossa	ITF Infratemporal fossa	MDF- Midfacial degloving

RECONSTRUCTION

After tumour extirpation, cranial base defects require reconstruction in order to provide a secure barrier between the intracranial content and the paranasal cavity⁶. Reconstructive failure carries potential life threatening complications (e.g. CSF leakage and meningitis) that may delay the initiation of adjuvant therapy.

The reconstruction technique is designed according to the size and location of the cranial defect, and is based on radiological and intra-operative calculations. Primary closure of the dura is performed with a large fascia lata sheath. First, the dura is repaired with a patch of fascia lata, with the aim of making a water-tight closure. The dural repair is then covered with a second layer of fascia that is applied against the entire undersurface of the ethmoidal roof, the sella and the sphenoidal area. Free-flap reconstruction is indicated in cases of orbital exenteration and total maxillectomy. Similarly, large skin defects may also require free-flap reconstruction^{7,8,9,10}.

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