Skull base highways: surgical approaches to lesions of the cranial base

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Sinopse
Vias Expressas à base do crânio: abordagem cirúrgica de lesões da base do crânio

Com os avanços na cirurgia da base do crânio, lesões consideradas previamente como inoperáveis, são hoje abordadas e tratadas com sucesso. O crescente interesse da comunidade neurocirúrgica no estudo da anatomia e técnicas cirúrgicas para a base do crânio, fez surgir uma nova subespecialidade neurocirúrgica. No entanto, para realizar um procedimento cirúrgico com baixa mortalidade e morbidade, o neurocirurgião deve tornar-se mestre nas abordagens para a base do crânio. Neste artigo, nós descrevemos as etapas das seguintes abordagens: A cranio-orbito-zigomática; a zigomática-infratemporal; a petrosa; a transcondilar e a abordagem transmacular. As indicações e limitações de cada abordagem serão apresentadas. Nós encorajamos os neurocirurgiões a explorar este campo e estudar minuciosamente as técnicas apresentadas neste artigo.

Palavras-Chave
Base do Crânio; Abordagens; Anatomia.

Abstract
With the advances in the field of the skull base surgery, lesions previously considered inoperable can now be approached and treated successfully. Because of the increased interest by the neurosurgical community in the anatomy and surgical approaches to the skull base, a new neurosurgical subspecialty is forming. However, to perform a safe surgical procedure with low morbidity and mortality, the neurosurgeon must gain expertise in surgical approaches to the skull base. In this report, we describe the steps and illustrate with artist’s renderings the following skull base approaches: the cranio-orbito-zigomatic, the zigomatic-infratemporal, the petrosal, the transcondylar and the transmacular. We also discuss the indications for and limitations of each approach. We encourage neurosurgeons to explore this field to carefully study the anatomy and surgical techniques presented in this report.

Key Words
Skull Base, Approaches, Anatomy.

Introduction
The emergence of the skull base surgery as a neurosurgical subspecialty has greatly increased interest in the management of skull base lesions. However, because of the complexity and extension of these lesions, conventional approaches are suboptimal for treating them. Successful surgical management of skull base lesion requires that the neurosurgeon clearly understand the surgical techniques as well as the surgical anatomy. We herein describe the
procedural steps and provide artistic rendering of the following approaches: the cranioorbito-zygomatic, the zygomatic-infratemporal fossa; the petrosal; the trans-condylar; and the transmaxillary approaches. We also discuss the indications and limitations of each approach. Certainly, the thorough knowledge of the surgical anatomy acquired in the microsurgical laboratory are essential to perform these surgical approaches with success.

**Cranioorbito-zygomatic approach**

The cranioorbito-zygomatic (COZ) approach is indicated for lesions located in the anterior fossa, middle fossa and upper third of the posterior fossa (Fig 1H). The advantage of this approach is that it provides multiple routes as obtained with the pterional, transbasal, transsylvian, and subtemporal approaches. The surgical technique is relatively simple and requires only a single cranial bone flap, eliminating the need for bony reconstruction. The COZ is not indicated for lesions with lower extensions into the posterior fossa.

**Surgical technique**

The patient is placed supine with the head rotated 30 to 40° to the opposite side, dropped toward the floor, and tilted 5 to 10°. A spinal needle is inserted and connected to a collecting bag to allow drainage of approximately 25 ml of cerebral spinal fluid (CSF) following exposure of the dura. This procedure, which allows brain relaxation while simultaneously keeping the cisterns full of CSF, facilitates the microsurgical dissection.

A bicornoral incision is made behind the hairline, extending from the zygomatic arch on the side of the lesion to the superior temporal line on the opposite side. The scalp flap is turned anteriorly, and the superficial temporal artery is preserved. The superficial and the deep fascia of the temporal muscle are cut parallel and 2 cm superior to the

**FIGURA 1A**

In these figures, the surgical technique of the COZ is presented. A: A bicornoral incision is performed, and the pericranial flap is cut as posterior as possible.

**FIGURA 1B**

After the zygoma had been cut, the bony flap is made including the orbita rim, the temporal and frontal bone. The keyhole (upper insert) is opened in both orbital and intracranial compartments. An osteotomy around the supraorbital foramen is performed to release the supraorbital nerve and vessels (lower insert).

**FIGURA 1C**

A posterior orbitotomy is made and replaced in position afterwards.
FIGURA 1D
The dura mater of the middle fossa is elevated exposing: the middle meningeal artery; the third division of the V nerve; the greater and lesser petrosal nerves. The intrapetrous portion of the ICA is exposed underneath the course of the greater petrosal nerve, which should be cut sharply avoiding traction of the geniculate ganglion.

FIGURA 1E
After the proximal control of the ICA is obtained in the petrous canal, the plan of dissection turns to the frontal area. The remaining of the orbital roof and the anterior clinoid process are removed extradurally, exposing the optic nerve, the superior orbital fissure and the clinoidal segment of the ICA.

FIGURA 1F
The superior entrance in the cavernous sinus is made by opening the dural rings of the ICA. The outer and inner rings are opened, extending posteriorly and laterally in the direction of the III cranial nerve. This aperture provides the visualization of the medial compartment of the cavernous sinus. The posterior clinoid process can be removed to enlarge this area.

zygomatic arch and then dissected from the muscle fiber; the frontal branch of the facial nerve which runs between the superficial and deep fascia of the temporal muscle is preserved. The pericranium is incised as posterior as possible, and the large pericranial flap is reflected forward over the scalp flap (fig.1A). Special attention is given to the supraorbital nerves at the incisura in the orbital rim. If necessary, an osteotomy around the supraorbital notch is performed to release the supraorbital nerve and vessels (fig.1B). The zygomatic arch is dissected subperiosteally and incised at anterior and posterior ends. Oblique cuts are made to allow the zygomatic arch to be anchored during reattachment. The zygoma is displaced downward and held in place by inserting the masseter muscle. The temporalis muscle is detached from its cranial insertion and retracted posteriorly and inferiorly.

Three burr holes are drilled. The first is drilled at the frontoparamedian above the nasion; the second is drilled at the keyhole behind the zygomatic process of the frontal bone at the frontosphenoidal junction, opening into both the orbit and frontal fossa, with the root of the orbit separating the two compartments (fig.1B); and the third burr holes is drilled posteriorly near the floor of the middle fossa. The first and third burr holes are connected with a craniotome, passing 4 cm above the supraorbital rim. The second and third holes are connected with a craniotome or a high-speed drill, passing just above the floor of the temporal fossa. The lateral orbital rim is cut at the level of the junction with the zygomatic bone. The osteotomy continues inferiorly and anteriorly to connect with the
keyhole. The orbital roof is cut with a chisel or a Gigli saw. The cranioorbital flap is freed by drilling the remaining sphenoid wing (fig.1B).

A posterior orbitotomy extending medially from the lateral wall of the ethmoid sinus (without entering the ethmoid sinus) to the lateral wall of the orbit is performed (fig.1C).

The temporal dura is elevated, exposing the middle meningeal artery, the greater superficial petrosal nerve, the arcuate eminence, and the foramen ovale. The middle meningeal artery and the greater superficial petrosal nerve arc cut. The petrous portion of the ICA is located posterior to the foramen ovale, medial to the foramen spinosum, and inferior to the greater superficial petrosal nerve (fig.1D). A Fogarty catheter is inserted distally into the bony canal of the ICA, providing proximal control of the ICA. The anterior clinoid process is removed extradurally, exposing the subclavian segment of the ICA (fig.1E). Electromyographic electrodes are placed directly into the lateral and superior rectus and the superior oblique muscles.

A C-shaped dural incision is made centered in the pterion. The Sylvian fissure is split widely. Entry into the cavernous sinus depends on both the lesion and its origin. The extracavernous portion of the tumor is removed first. The residual tumor is followed in the sinus through the most readily available avenue, which is usually through the superior and lateral walls. The superior entrance (fig.1F) is made after the fallopian ligament is opened and the optic nerve is liberated, which allows, if necessary, gentle medial mobilization of the optic nerve. The distal and proximal rings are opened at their medial aspects, and the dural incision is extended posteriorly to the third nerve, allowing entry into the cavernous sinus through its superior wall. The posterior clinoid process can be dissected and removed, providing further exposure of the upper clivus. The lateral entry to the cavernous sinus is through Parkinson's triangle, limited medially by the IV cranial nerve and laterally by the first division of the V cranial nerve (fig.1G). After the tumor has been removed, the cavernous sinus is filled with fat. The dura mater is closed watertight and the pericranial flap is rotated downward covering the base of the skull and the frontal sinus. The closure is made as usual fashion.

**Zygomatic-infratemporal fossa approach**

The zygomatic approach is ideally designed to reach tumors that invade the cavernous sinus extradurally, or extend inferiorly into the infratemporal fossa or posteriorly into the posterior fossa. We currently are using this
approach to treat trigeminal schwannomas limited to the cavernous sinus with or without extension into the infratemporal fossa, juvenile angiofibromas with cavernous sinus extension, and some types of chordomas. This approach can also be used as an alternative to the classical subtemporal approach to avoid severe brain retraction. The surgical technique is simple and easy performed. The limitations of the zygomatic approach to extradural lesions are the height of the jugular bulb inferiorly, the superior orbital fissure anteriorly and the superior petrosal sinus superiorly. Intradural access can be obtained by opening the dural of the temporal fossa or by coagulating and cutting the superior petrosal sinus and tentorium.

**Surgical technique**

The patient is placed supine with the ipsilateral shoulder elevated and the head turned to the opposite side. A curvilinear preauricular skin incision is made, extending behind the hairline from the anterior border of the tragus to the superior temporal line. In some cases, the skin incision may be extended more inferiorly. A subfascial dissection is performed to preserve the frontal branches of the facial nerve. The zygomatic arch is cut and displaced downward; the inserted masseter muscle is held in place at the inferior face of the zygomatic arch. The displacement of the zygoma provides the visualization of the origin of the temporal muscle on the coronoid process of the mandible. The process is totally exposed subperiosteally and cut at its base. Small holes are made in the bone that remains attached to the temporal muscle and mandible. The temporal muscle is elevated upward, exposing the infratemporal and temporal fossa, while the large insertion of the muscle on the temporal squama is maintained. A small crani-orbital or low temporal craniotomy is performed (fig. 2A). For tumors with extensions into the paramasal sinuses, we prefer to displace the temporalis muscle inferiorly, to allows us to rotate the vascularized muscle caudally to close the cavity.
**FIGURA 3A**

In the petrosal approach, the patient is placed supine, the operating table is flexed to allow 20° to 30° elevation of the head and trunk. The patient’s ipsilateral shoulder is slightly elevated. A question-mark incision is made with its center in the ear.

**FIGURA 3B**

The craniotomy is performed in the middle and posterior fossa. Four burr holes are performed superiorly and inferiorly to the venous dural sinuses. We recommend do not use the front-plate crossing over the sinuses, because of the high-risk of damage to the sinus wall. After the mastoidectomy has been made, the dura-mater anteriorly to the sigmoid sinus.

**FIGURA 3C**

The dura-mater is opened in the middle fossa and in the posterior fossa, anteriorly to the sigmoid sinus. In the junction of the incision of the middle and posterior fossa, is located the superior petrosal sinus who can be coagulated or clipped.

**FIGURA 3D**

The tentorium is opened parallel to the petrous pyramid. Special attention is given to avoid damage to the IV cranial nerve when the tentorium border is cut.
The foramen spinosum is the most constant landmark in the middle fossa, the middle meningeal artery is followed medially toward the base of the skull. The foramen ovale and the greater superficial petrosal nerve (GSPN) are identified. The intrapetrous segment of the ICA commonly is located infero-medial to the GSPN. For tumors located in the cavernous sinus, (e.g. trigeminal schwannoma, chordoma) an extradural route should be used. The dura mater layer of the lateral wall of the cavernous sinus is carefully dissected, starting over the third division of the V nerve and extending anteriorly and cranially, exposing the second division and the inferior border of the first division of the fifth nerve. A wide extradural corridor is created from the superior orbital fissure to the VII-VIII complex. Tumors extension into the infratemporal fossa, the sphenoid sinus, the pterygopalatine fossa, and the petrous apex can easily be followed.

**Petrosal approach**

The petrosal approach is indicated for lesions located in the petroclival junction (e.g. meningioma, epidermoid, trigeminal schwannoma, some aneurysms of the basilar trunk) (Fig 3E). The limitations of the approach are given
by the jugular bulb inferiorly, the clivus anteriorly and the brain stem posteriorly. The size of the mastoid process is inversely related with the advantages of the petrosal approach. In case who the mastoid is very well developed, the removal of it and the posterior displacement of the sigmoid sinus provide a wide surgical corridor. In cases which the hearing is absent or useless, the petrosal approach can be combined with the transtemporal or translabyrinthine approaches.

Surgical technique

The patient is placed supine with the head at the foot-end of the operating table. It is flexed to allow 20° to 30° elevation of the head and trunk. The patient's ipsilateral shoulder is slightly elevated. The head is turned to the opposite side, and inclined toward the floor and fixed with a three-point Mayfield headrest (fig.3A). Special care should be taken to avoid compression of the contralateral jugular vein. During the surgical procedure, the table can be rotated from side to side or up and down. A reverse question-mark incision is made starting at the zygoma in front of the ear, circling 3 cm above the ear and descending 2 cm behind the mastoid process. The skin flap is elevated and retracted anteriorly and inferiorly. The fascia of the temporal muscle is dissected from the muscle and displaced posteriorly and inferiorly contiguous with the suboccipital muscles that insert in the superior and inferior nuchal line. The posterior half of the temporal muscle is dissected from the temporal squama and displaced anteriorly and inferiorly. At this stage of the procedure, the posterior end of the zygomatic arch, the temporal and the posterior fossa can be identified.

The bony work starts with the demarcation of the burr holes. Essentially four burr holes are drilled. Two superior and two inferior to the transverse-sigmoid sinus. The first burr hole made at the asterion; the second is performed 2 cm posteriorly to the former; both holes will open into posterior fossa. The third burr hole is placed in the most anterior point of the mastoid suture and will open in the middle fossa and the last burr hole is placed 2 cm superior to the third. These holes will open into middle fossa (fig.3B).

The posterior fossa craniotomy is performed by connecting the first and second burr hole with a craniotome, the bone cut in the posterior fossa being made in a curvilinear fashion and as caudal as possible. The middle fossa craniotomy is performed connecting the third and the fourth burr hole. The bone cut in the temporal fossa should be made as anterior and basal as possible in order to provide a flat surface with the base of the temporal fossa. Because the high risk of damage to the venous sinus, the craniotome should never be used for crossing over the dural sinus. We prefer to connect the first and third burr holes and the second and fourth burr holes using a thin rongeur or a high-speed drill.

A single bone flap is elevated, exposing the transverse and sigmoid sinus, middle and posterior fossa. Commonly severe adherence is found at the junction of the transverse and sigmoid sinus requiring a careful dissection and elevation of the flap. An alternative technique is to perform a temporal craniotomy, followed by a posterior fossa
craniectomy extending superiorly over the transverse sinus. The next step of the bony work is reserved to the drilling of the temporal. We strongly advocate that this step of the surgical procedure must be performed by a neurosurgeon, and, hence, a thorough knowledge of the anatomy of the petrous bone acquired in the laboratory is crucial. A mastoidectomy is performed using a high-speed drill. Initially, a cutting bit can be used, but once the dissection comes close to important vascular or bony structures a diamond drill should be used.

The dissection of the temporal bone is performed in a sequence of steps. The first step is the localization and skeletonization of the sigmoid sinus, sphenoidal angle of Cistelli and jugular bulb. The second step is the identification of the bony structures of the superior, posterior, and lateral semicircular canals. Generally a large mastoid cell called the antrum orientates toward the elements of the inner ear. During this dissection a diamond bit should be used to avoid inadvertent damage. The third step is the careful removal of the thin layer of bone left over the sigmoid, superior petrosal sinus (located in the sphenoidal angle of Cistelli), and the middle fossa, after which the dura, located anteriorly to the sigmoid sinus and in the basal aspect of the middle fossa can be visualized. The dural opening is performed along the anterior margin of the sigmoid sinus. The dural incision in the middle fossa extends straight anteriorly on the floor of the middle fossa. The posterior limb of the dural incision in the middle fossa should extend posteriorly crossing superiorly to the transverse-sigmoid junction. At this point special care should be taken to avoid damage to the vein of Labbé, which enters at the level of the transverse-sigmoid junction (fig. 3C).

The next step is the cutting and coagulation of the superior petrosal sinus and tentorium. Before the tentorial incision be opened, CSF is released from the lateral medullary cisterns with consequent brain relaxation. The superior petrosal sinus is coagulated. The dural incision is continued on the tentorium parallel to the pyramidal and extended through the incisura. Before the border of the tentorium be incised, the IV cranial nerve must be identified and preserved (fig. 3D). The posterior leaf of the tentorium is elevated and fixed superiorly by the brain spatula, a maneuver that allows the enlargement of the surgical field and the protection of the vein of Labbé. At this point of the procedure, the III cranial nerve, posterior cerebral field and superior cerebellar artery can be easily identified. After the removal of the tumor, the dura-mater is closed watertight. The cavity remaining is covered by the posterior third of the temporal muscle which is rotated inferiorly and fixed to the suboccipital muscles. The temporal muscle fascia, displaced inferiorly fixed to the suboccipital muscle is anchored anteriorly at its original place. The skin flap is close as usually.

Transcondylar approach

The transcondylar approach is indicated for lesions located at the anterior or lateral aspect of the cranio-cervical junction and the lower clivus. Intradural or extradural lesions (e.g. aneurysm of the posterior inferior cerebellar artery, meningiomas of the foramen magnum chordomas or rheumatoid arthritis) are better attached by this approach (Fig. 4GD). The limitations of the transcondylar approach are the jugular bulb superiorly and the cervico-medullary junction medially. The inferior limit should be tailored to each case. The transcondylar approach should be designed to combine superiority with the petrosal or transcervical approaches and inferiorly with the transcervical or infratemporal approaches.

Surgical technique

The patient is rotated in block 45° to the opposite side. The head of the table is elevated 30°; the angle can be adjusted, if necessary. The skin incision begins 4 cm behind the ear at the level of the external auditory canal and extends caudally and anteriorly to reach the anterior border of the sternocleidomastoid muscle (SCM). The greater auricular nerve and the external jugular vein are identified at the surface of the SCM. The superficial muscular plane of dissection is created along the anterior border of the SCM, which is followed superiority to its attachment on the mastoid process. The SCM, the splenius capitis, the longissimus capitis, and the semispinalis muscles are detached from the mastoid in one layer and retracted inferiorly and medially. The XI cranial nerve is identified and preserved. If it has a high entry into the muscle, additional length can be gained by dissecting along its course in the medial aspect of the muscle. A considerable amount of fat tissue is commonly found between the superficial and the deep muscular layers. The deep muscular layer forms two suboccipital triangles, superior and inferior (fig. 4A). The superior triangle is limited by the major and minor rectus capitis muscles medially, the superior oblique muscle superiorly, and the inferior oblique muscle inferiorly. It contains the horizontal segment of the vertebral artery, with its correspondent venous plexus, and the posterior branch of the C1 root. The inferior suboccipital triangle contains the segment of the vertebral artery between the atlas and the axis, with its correspondent venous plexus, and the anterior ramus of the C2 root; it is limited superiorly by the inferior oblique muscle, laterally by the splenius cervicis, and medially by the semispinalis cervicis. After the muscular layers have been clearly identified and dissected, the vertebral artery can be identified and controlled at the superior or the inferior suboccipital.
The osteotomies used to performed a transmaxillary approach can be designed to each case or to adopt the preferences of the surgeon. In the classical Le-Fort I osteotomy (A), the maxilla is displaced inferiorly, providing the visualization of the superior and middle third of the anterior craniofacial junction. The association of the Le-Fort I osteotomy with a median or paramedian osteotomy

Of the hard palate allows the visualization of the entire aspect of the craniofacial junction from C3-C1 interspace to the base of the frontal fossa. Previously to perform the osteotomies, the miniplates must be fixed in place and removed.

The chordoma of the clivus is optimally treated by the transmaxillary approach.

Vebral artery now can be identified from the transversarium foramen of C2 to its entry into the dura mater (fig.4B). Troublesome bleeding can be avoided by maintaining a considerable amount of connective tissue around the vertebral artery and its venous plexus. To achieve inferomedial displacement of the vertebral artery, the foramen transversarium of C1 must be carefully opened with a diamond drill. A lower posterior fossa
cranietomy and a partial mastoidectomy are performed. The occipital condyle and the posterior arch of C1 are exposed and removed. The extent of removal of the former should be tailored to each case. In cases of lesions located in the anterior margin of the foramen magnum, a more extensive bony removal should be made. To approach intradural lesions, the dura-mater is opened medially to the vertebral artery, extending superiorly along the posterior border of the sigmoid sinus. Rather than performing complex dural opening, we prefer to open the dural in the usual fashion following the contours provided by the bony removal. This technique allows the visualization of the intra- and extradural segment of the vertebral artery and the lateral displacement of the dura and sigmoid sinus. The closure should be made watertight to avoid the risk of CSF leakage.

Another point of concern is craniocervical stabilization. We routinely perform when the occipital condyle has been totally removed, or the preoperative workup evidenced signs of instability. The conventional transcondylar approach, used to treat intradural lesions located in the lower clivus or craniocervical junction, rarely requires instrumentation and bone graft. Craniocervical stabilization is performed with the aid of a titanium plate that is held in place superiorly at the occipital squama by a wire cable or screw and inferiorly by a pedicle screw in C2. The bone graft is performed using a solid corticocancellous bone harvested from the anterior iliac crest, placed along the medial side of the titanium plate and secured with a cable passed around the plate and graft.

The transmaxillary approach

The transmaxillary approach is performed using several variations, namely the Le Fort I osteotomy associated or not with midline splitting of the hard and soft palate or the unilaterial maxillectomy with paramedian splitting of the hard palate and soft palate 5,6,8. It is recommended for lesions located in the clivus and nasopharynx, with minimal lateral extension (Fig.5D). The limitations of the transmaxillary approaches are made by the medial face of the medial pterygoid plate, the foramen lacerum, the jugular foramen, and the hypoglossal canal. Generally the interpterygoid distance range between 20 and 40 mm. The clivus extends 45 mm (range 37-52 mm) from the dorsum sella to the foramen magnum and 27.9 mm (range 19-34 mm) from the base of the vomer to the basion. At level of the foramen lacerum the width of the clivus is 22.5 mm (range, 13-28 mm) and 42.7 mm (range, 33-52 mm) at the jugular foramen. At level of the hypoglossal canal the maximum width of exposure varies between 36 to 46 mm. The thickness of the clivus at the level of the foramen magnum ranges from 1.5 to 5.8 mm and 18.3 mm (range, 14-24 mm) at the junction of the vomer with the clivus.

Surgical technique

The patient is positioned supine with the head supported in a three-point head clamp. The neck is slightly extended, but is kept straight relative to the table and the body. A tracheostomy is performed under local anesthesia. After careful aseptic technique is performed, a curvilinear transfixing incision is made in the nasal mucosa anterior to the nasal septum and along the floor of the nose to allow for easier dissection of the septal mucosa. The mucoperiosteum is dissected up the entire side of the nasal septum adjacent to the proposed parasagittal osteotomy and partially up the contralateral side. The cartilaginous septum is detached from the maxilla and vomer and translocated.

The dissection of the maxilla is performed in a manner similar to that used with a sublabial transsphenoidal approach except that the incision and dissection of the gingivobuccal mucosa are more extensive. A sublabial mucosal incision extends to both maxillary tuberosity. The mucoperiosteal flap is elevated until the inferior border of the infraorbital foramen is visualized bilaterally. The nasal mucosa is elevated, exposing the entire superior face of the hard palate. The anterior nasal spine is preserved in its anatomical position. At this stage of the procedure, the bony elements are completely exposed and prepared for the osteotomy.

The Le Fort I osteotomy

The osteotomy, which reproduces the lines of fractures described by Le Fort, begins bilaterally 1 cm superior to the pyriform aperture and ends at the pterygomaxillary fossa (Fig.5A). Before the osteotomy is started, titanium miniplates are positioned and holes are made at the superior and inferior level of the osteotomy. This maneuver provides the means to return the bony elements to their anatomical positions. Special care must be taken to avoid damage to the apex and denervation of the teeth inferiorly and to the inferior orbital nerve superiorly. When the bilateral osteotomy is complete, an unforced pressure is performed, displacing the maxilla inferiorly, and allowing the bony part of the nasal septum and, inferiorly, the posterior pharyngeal wall to be visualized. The hard and soft palate are preserved intact.

The area of exposure is limited superiorly by the base of the anterior fossa and inferiorly by the anterior border of the foramen magnum.

Le Fort I osteotomies with midline splitting of the hard and soft palate

A midline incision is performed in the hard palate and extends inferiorly through the full thickness of the soft palate paramedian to the base of uvula. A median palatal
osteotomy is made with a Gigli saw. Bilateral Le Fort I osteotomies are performed, and the floating maxillary segments are mobilized inferiorly and laterally (fig 5B). The blood supply to each maxillary segment is maintained by the soft palate with its remaining connections to the pharynx. A work field is created superiorly and inferiorly to the soft palate. The area of exposition extends from the base of the anterior cranial fossa to the body of C2 or C3.

**Unilateral paramedian maxillotomy with preservation of the Soft Palate**

After the maxilla is exposed, the transverse and paramedian osteotomies are marked, titanium compression plates are contoured to fit both sides of the maxillotomy. The drill holes are made, and the plates are secured and then, removed before performing the osteotomies. A unilateral Le Fort I osteotomy is made homolateral to the extension of the tumor. A second osteotomy is performed between the central and lateral incisors or between the lateral incisor and the canine (fig.5C). In some cases, we prefer to extract one of the teeth to avoid bilateral damage while the osteotomy is being performed. The mucosa under the hard palate is carefully dissected at the paramedian, and a small hole between the junction of the soft and hard palate is made to allow crossing of the Gigli saw. After the osteotomies are performed, an unforced digital pressure will displace the maxilla inferiorly and slightly laterally. The soft palate is preserved intact 6.

Frequently, the dura mater of the clivus area is disrupted or injured during the extensive drilling procedure. Hence, special care should be taken to perform a closure that is as watertight as possible. We currently use a combination of fascia lata graft, fat, and fibrin glue, even those cases in which dural tears are not detected. Clear evidence of dural tear during the surgical procedure mandates a lumbar CSF drainage for at least 5 days to prevent CSF leakage. The pharyngeal tissue is approximated as much as possible and the maxillary segments are returned to their anatomical positions and fixed in place by the miniplates using the previously-drilled holes. The soft palate is close in three layers with absorbable sutures. The nasal structures are returned to their original position, and the transfixing incision is closed. The nasal cavity is packed and the sublabial incision is closed. The postoperative care is carefully monitored especially for CSF leak and respiratory care.

**Conclusions**

Approach to and surgery of lesions of the cranial base previously considered inaccessible and inoperable have become routine in the advanced neurosurgical centers around the world. With greater understanding of the surgical approaches and increased interest of the neurosurgical community in the study of the surgical anatomy of the skull base, as well as advances in intraoperative monitoring and modern anesthesiast, skull base surgery is becoming a neurosurgical subspecialty.

We encourage all neurosurgeons with interest in this field to carefully study the surgical anatomy and techniques presented in this report. Certainly, the understanding of this technique, which initially seems quite complex, is facilitated tremendously by previous studies in microsurgical laboratories.

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