TECHNICAL NOTE

Neurologia i Neurochirurgia Polska
Polish Journal of Neurology and Neurosurgery
2022, Volume 56, no. 2, pages: 178–186
DOI: 10.5603/PJNNS.a2022.0023

ISSN: 0028-3843, e-ISSN: 1897-4260

Fronto-orbito-zygomatic (FOZ) approach for infratemporal fossa lesions extending to middle cranial fossa: our experience and review of literature

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ABSTRACT

Aim of the study. Tumours of the infratemporal fossa (ITF) are rare and include primary tumours, contiguity lesions and metastases. Surgical resection is the gold standard. The fronto-orbito-zygomatic (FOZ) approach is commonly used in order to obtain safe access to the lateral skull base and ITF to resect intra- and extra-cranial tumours. We here describe our series of ITF lesions extending to the middle cranial fossa and/or orbit, treated by single- or two piece FOZ.

Material and methods. All cases of single- or two-piece FOZ approach for an infratemporal fossa lesion extending to the middle cranial fossa operated at our Institution from January 2014 to January 2018 were retrospectively reviewed. The follow-up was for a minimum of four months and a maximum of 60 months. The inclusion criteria were lesions involving the ITF with an extension to the middle cranial fossa and/or orbit. Baseline characteristics of patients, tumour localisation, tumour extension, diffusion route, histology, extent of tumour resection, post-operative treatment, and post-operative complications were evaluated.

Results. Nine patients underwent a surgical procedure with a FOZ approach, two of them with a single-piece approach and the remainder with a two-piece one. All patients had an ITF localisation. Gross total removal (GTR) was achieved in 7/9 patients. Only one patient, with non-total removal (NTR), underwent radiotherapy.

Conclusions. For the treatment of ITF fossa tumours extending to the orbit and or middle cranial fossa, we believe that both FOZ techniques are effective and allow a good medial extension toward the cavernous sinus and parasellar region. But a two-piece craniotomy may ensure a more medial extension and a wider angle of work compared to a one-piece craniotomy.

Key words: fronto-orbito-zygomatic approach, infratemporal fossa tumours, middle cranial fossa tumours, FOZ

(*Neurol Neurochir Pol 2022; 56 (2): 178–186*)

Introduction

Tumours of the infratemporal fossa (ITF) are rare entities, with an incidence of less than 3% of all head and neck cancers. ITF include primary tumours, contiguity lesions and metastases [1]. Contiguity lesions arise from surrounding structures such as the paranasal sinus, oral cavity, nasopharynx parotid gland, external ear canal and middle-cranial fossa [2–4]. Primary intrinsic infratemporal fossa tumours include a limited number of primary lesions, and metastases have only rarely been described [5, 6]. Surgical resection is considered the gold standard for the treatment of this tumour, even if the complex anatomical structures of ITF and skull base represent a particular challenge for the surgeon, with a high rate of perioperative morbidity and tumour recurrence, due to the difficulty of obtaining a complete surgical resection [7].

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Received: 27.11.2021; Accepted: 8.12.2021; Early publication date: 18.03.2022

Among these lesions, those extending intracranially to the middle cranial fossa and/or orbit are even more difficult to treat, especially when the medial extension involves the cavernous sinus. Several surgical approaches have been described, all aiming to achieve the maximal surgical exposure concomitantly with sparing the cranial nerve and vessels [8–11].

The fronto-orbito-zygomatic (FOZ) approach is commonly used in order to obtain safe access to the lateral skull base and ITF, considering that it provides a wide working space and a multidirectional surgical corridor to resect these complex intra- and extra-cranial tumours [12–16]. The wide bone resection of the FOZ approach provides a minimal brain retraction and several techniques have been described, including single-piece and two-piece craniotomy. While numerous descriptions of this technique are available for the treatment of pure intracranial or pure ITF fossa lesion, data regarding tumours of the ITF contemporary extending into the middle cranial fossa is lacking.

We here describe our series of ITF lesions extending to the middle cranial fossa and/or orbit, treated by a single- or two-piece FOZ, reporting surgical techniques, anatomy and indications for these two approach variants. An illustrative case of rare ITF metastases by lung adenocarcinoma treated with one-piece FOZ is also described.

Material and methods

From 2014 to 2018, all patients who underwent a surgical procedure with a single- or two-piece- FOZ approach for an infratemporal fossa lesion extending to the middle cranial fossa, were retrospectively reviewed, and all data was collected in the Ospedali Riuniti of Ancona Centre of the Politecnica delle Marche University. The follow-up was for a minimum of four months and a maximum of 60 months. Other than one patient who died after four months, consequent upon his primary tumour, all other patients had a follow-up of at least two years. Our study inclusion criteria were lesions involving the ITF with an extension to the middle cranial fossa and/or orbit; all the patients had complete pre- and post-operative radiological exams, and had a long-term follow-up performed by the same senior surgeons (neurosurgeon and maxillofacial surgeon). The approaches are described and compared in the technical note provided below.

Data regarding age, gender, pre-operative symptoms, tumour localisation, tumour extension (pterygopalatine fossa, lesser sphenoidal wing, orbit, cavernous sinus, paranasal sinus), diffusion route (through oval, spinous and rotundum foramina or the presence of temporal bone erosion), histology, extent of tumour resection (gross total, near total or subtotal surgical resection), post-operative treatment (radiotherapy and/or chemotherapy), post-operative Karnofsky Performance Status (KPS), recurrence requiring surgery, and complications were evaluated. The baseline characteristics of our series are set out in Table 1.

Results

From January 2014 to September 2018, nine patients underwent a surgical procedure with a FOZ approach, two of them with a single-piece approach and seven with a two-piece one. All patients had an ITF localisation (Fig. 1): the orbit was involved in four patients, the cavernous sinus and the lesser sphenoidal wing in six, the paranasal sinuses in three, and the pterygopalatine fossa (PPF) in five. The diffusion was through the oval foramen in one case, rotundum foramen in two cases, a temporal bone erosion was evidenced in two cases, and one patient had a spinous foramen route diffusion. Relative to the histology, one case was a metastasis from adenocarcinoma of the lung, and another was a schwannoma; the remaining cases were meningiomas (WHO grade I in four cases and grade II in three cases). Presenting symptoms and signs included visual deficit, diplopia, trigeminal neuralgia or numbness (V2 and V3), proptosis and palpable mass.

GTR was achieved in all cases except for two in which diffusion through the foramina complicated complete excision. Only one patient, with NTR resection for atypical meningioma, underwent radiotherapy. Another patient had a single dose of chemotherapy for lung metastasis, followed by rapid progression of lung disease and death. The KPS was higher than 80 in all the cases analysed, and notably was 100 in five patients. Three patients had a recurrence, but all of them had a grade II meningioma or NTR. Considering the nasal component as localisation of the recurrence in two patients, they underwent a second surgery by an endoscopic endonasal approach. We report below an illustrative case of a patient who underwent a single-piece FTOZ approach for rare ITF metastases of lung metastasis (Tab. 1).

Case presentation

A 63-year-old man with a four-week history of progressive and resistant to carbamazepine trigeminal neuralgia, involving V2 and V3 territory, presented to our Department with rapid visual deficit and mild proptosis involving the left eye. Neurological examination revealed, in addition to the previously reported neuralgia, left eye blindness and deficit in left eye abduction due to direct involvement of lateral rectus muscle. Brain MRI and CT scans showed a mass in the infratemporal fossa (ITF), extending into the pterygopalatine fossa (PPF), middle cranial fossa and orbit; only the epidural space without apparent invasion of meninges and brain parenchyma was observed (Fig. 2). Considering his long working history of exposure to dyes and dust, a primitive lesion from the parasinuses region was supposed. Anyway, the screening chest

Table 1. Baseline characteristics of patients and operative outcomes according to surgical intervention type

Patient	Sex, age	Location	Diffusion route	Approach	Histology	Extent of resection	Radiotherapy/ chemotherapy	Outcome (KPS)	Recurrence and follow-up
Case 1	M, 58	Orbit Cavernous sinus Sphenoidal sinus IFT LSW	Oval foramen	Two-piece FTOZ	Meningioma grade II	NTR	RT	80	Recurrence at 9 years, nasal component. Treated with EEA
Case 2	F, 48	IFT LSW Cavernous sinus	None	Two-piece FTOZ	Meningioma grade I	GTR	N	100	No recurrence, 3 years FU
Case 3	M, 64	IFT PPF	Temporal bone erosion	Two-piece FTOZ	Meningioma grade II	GTR	N	80	No recurrence, decided for cardiovascular failure, 1 year FU
Case 4	M, 59	Orbit Cavernous sinus IFT LSW PPF	None	Single-piece FTOZ	Adenocarcinoma of lung	GTR	N	80	4 months, progression of lung disease
Case 5	F, 47	Cavernous sinus IFT LSW	Temporal bone erosion	Single-piece FTOZ	Meningioma grade I	GTR	N	90	No recurrence, 4 years FU
Case 6	M, 62	IFT PPF Ethmoidal sinus	Rotundum foramen	Two-piece FTOZ	Meningioma grade II	GTR	N	100	Recurrence at 3 years, nasal component. Treated with EEA
Case 7	M, 64	IFT PPF	Spinous foramen	Two-piece FTOZ	Meningioma grade I	NTR	N	100	Recurrence at 7 years, NED
Case 8	F, 53	Orbit Cavernous sinus IFT LSW PPF	Rotundum foramen	Two-piece FTOZ	Meningioma grade I	GTR	N	100	No recurrence, 6 years FU
Case 9	M, 67	Orbit Cavernous sinus Sphenoidal sinus IFT LSW	None	Two-piece FTOZ	V cranial nerve Schwannoma	GTR	N	100	No recurrence at 2 years, NED

Ch — chemotherapy; EEA — endoscopic endonasal approach; FTOZ —fronto-temporal-orbitozygomatic approach; FU — follow up; IFT — infratemporal fossa; LSW — lesser sphenoidal wing; N — no; PPF — pterygopalatine fossa; RT — radiotherapy; Y — yes

X-ray, completed with total body CT scan, showed a right apical oval lung lesion of approximately 3.5 cm, without any other location of disease.

In this case we attempted surgery. The decision making was based on the progressive and excruciating neuralgia, the need for a histological diagnosis, as well as decompression. Despite the medial extension of the lesion toward the cavernous sinus, a single-piece FOZ approach was chosen having considered the good working angle in a patient with less risk of manipulation on the orbit. The details of the technical note are reported below. Interestingly, an intra-operative specimen deponed for a metastasis. In any case, a gross total removal was attempted due to the patient's symptoms.

Surgical technique

The patient was positioned supinely with head fixed on a head holder (Mayfield®) and turned to the right by around 35 degrees. A reverse question mark skin incision was planned, starting 4 cm below the zygomatic process just in front of the tragus and terminating behind the hairline at the ipsilateral pupillary line; the posterior "C" shape extended immediately behind the auricle (Fig. 3). The skin flap was elevated and reflected anteriorly with fish hooks, exposing the fronto-temporal bone, zygomatic arch and orbital rims. An anterior pericranial flap was elevated starting at the level of the

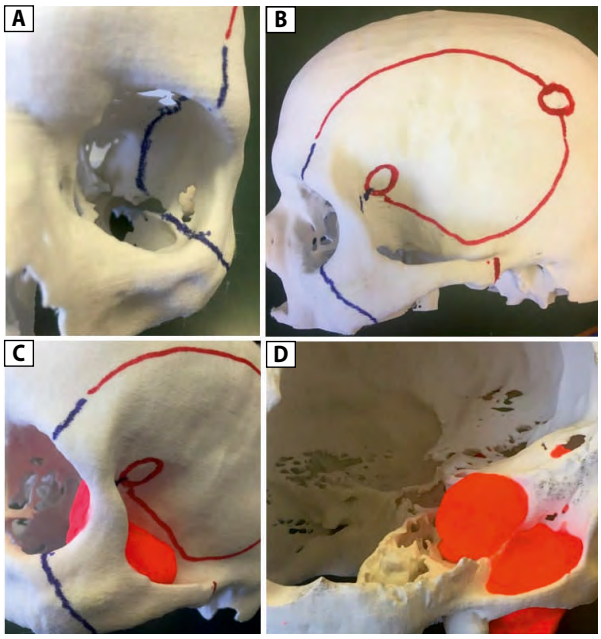

Figure 1. Representation of tumour localisation (ITF, PPF, orbit, middle cranial fossa) and craniotomy (fronto-orbito-zygomatic one--piece). **A.** Intraorbital craniotomy is made with piezoelectric osteotome (blue line) starting at supraorbital rim and going down along posterior wall of orbit and inferiorly to lateral portion of orbital fissure; **B.** 'One-piece' fronto-orbito-zygomatic craniotomy with key--hole and parietal burr-holes using both standard craniotome (red line) and piezoelectric osteotome (blue line); **C.** Tumour mass in ITF invading lateral orbital wall; **D.** Tumour mass involving both ITF and middle cranial fossa with medial extension toward cavernous sinus

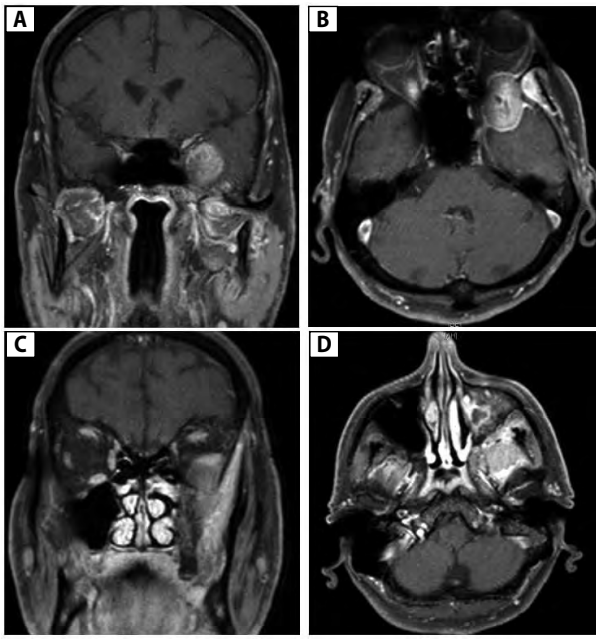

Figure 2. Lesion of left ITF with extension to extra-dural space of middle cranial fossa and lateral wall of orbit

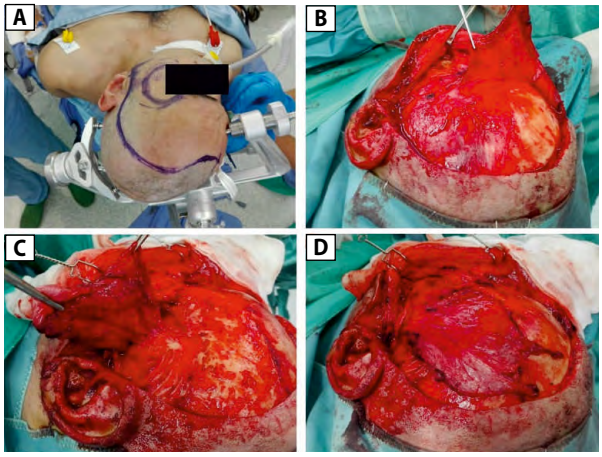

Figure 3. Patient positioning and surgical approach. **A.** Bi-coronal skin incision; **B.** Preparation of galeal flap, **C.** After posterior zygomatic arch osteotomy, temporal muscle is detached and mobilised; **D.** Reconstruction of temporal muscle

coronal suture and extending laterally until the superior temporal line; during anterior dissection toward the supraorbital rims, care must be taken to identify the supraorbital neuro-vascular bundle that is separated and reflected with the flap. Therefore, the peri-orbita was gently dissected from the orbital rim. The subfascial-subpericranial technique was used to protect the frontal branch of the facial nerve and to preserve the continuity between the frontal pericranial flap (medial to the superior temporal line) and the superficial and the deep layers of the temporal fascia (lateral to the superior temporal line). The temporal muscle was mobilised by subpericranial dissection and this was reflected inferiorly, moving his tendon as a pivot through a small osteotomy (about 5 mm) of the posterior root of the zygomatic arch. One burr hole was made just above the posterior root of the zygoma: the first cut started at the burr hole and extended superiorly and anteriorly ending about 10 mm behind the supraorbital rim and 4 mm lateral and 10 mm to the supraorbital notch; the second cut started at the burr hole and ran inferiorly and anteriorly along the squamous temporal bone until a point about 5 mm behind the frontozygomatic suture. The orbital and zygomatic part of craniotomy was then complete with piezoelectric osteotome. The peri-orbit was retracted and the cut was made across the supraorbital rim, lateral to the supraorbital notch, to the posterior and lateral wall of the orbit extending inferiorly to the lateral portion of the inferior orbital fissure and then laterally across the body of the zygoma, just above the zygomaticofacial foramen. The sphenoid bone was fractured with gentle hand movement and the entire

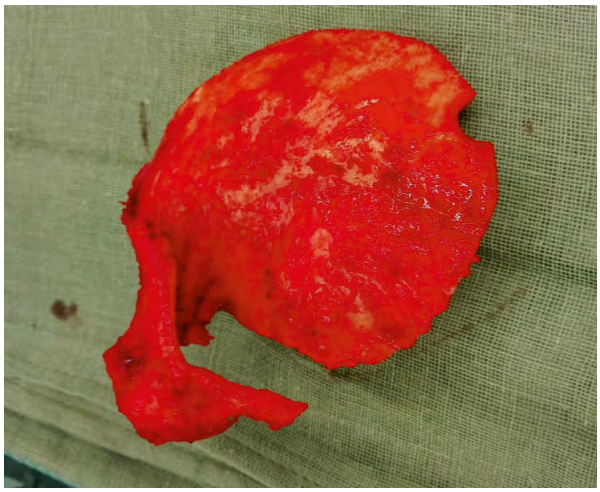

Figure 4. One-piece fronto-orbito-zygomatic bone flap

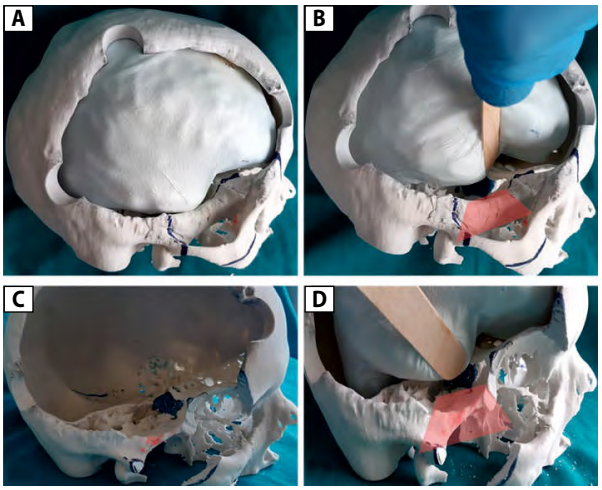

Figure 5. Representation of two-piece FOZ craniotomy. **A.** After pterional craniotomy, both temporal bone and sphenoid ridge are drilled; **B** and **C** — intraorbital and lateral orbit osteotomy are performed under direct vision; **D** — this allows more extensive orbital roof removal compared to one-piece FOZ variety and permits a wider angle of work with better visualisation of basal frontal and cavernous sinus

one-piece bone flap was removed (Fig. 4). A yellow-greyish lesion involving the infratemporal fossa, orbit and the anterior temporal skull-base was easily identified. The extracranial dissection of the tumour was performed in a superior-to-inferior direction until the pterygopalatine fossa, following the interface between a capsule and normal tissue. At the pterygopalatine fossa, the tumour was crossed by the internal maxillary artery that was ligated with a haemoclip and sectioned to achieve a complete tumour resection. With the use of a microscope, we then performed intracranial-epidural dissection of the tumour that was bleeding profusely and, at the temporal pole, the dura mater was infiltrated. Dura was opened and there was no brain invasion by the tumour. Near gross-tumour resection was obtained, with the more medial part of epidural mass toward the cavernous sinus and clinoid process left in place because of infiltration and adherence with the neuro-vascular structure. The bone flap was repositioned, fixed with plate and screw, and the temporal muscle was replaced and sutured to the temporal bone.

Discussion

We reviewed a case series of tumours of the ITF fossa with extension to the middle cranial fossa and/or orbit treated by a fronto-orbito-zygomatic (FOZ) approach.

Historically, this approach was first described in 1912 by McArthur [17] as a removal of the supraorbital ridge in a case of frontal craniotomy and in 1913 by Frazier [18] as a feasible option in a case of pituitary tumours. Afterwards, Jane et al. revised it, describing for the first time a one-piece FOZ craniotomy, including anterior orbital roof osteotomy in a single flap, for the treatment of vascular lesions located in the anterior skull base and orbit.

In the early 1980s, Hakuba [15] and Pellerin [19] revived the orbito-zygomatic-malar craniotomy to obtain access to anterior and middle skull base, upper third of clivus and posterior fossa. Since then, this approach has evolved into a number of technical adaptations by several authors, such as Al Mefty [20–23] and others, who have included a plethora of variations, extending the indication and improving the surgical outcomes. Nevertheless, tumours involving concomitantly extra-cranial (ITF, PPF) and intracranial compartments (middle cranial fossa and/or orbit) are infrequent [23, 24]. In consequence, the vast majority of early papers reported a FOZ approach merely for pure intracranial lesions, in order to increase the working angle of the classical frontal approach.

Tumours of the infratemporal fossa (ITF) comprise a wide range of histological types that include both malignant and benign lesions. Globally, the outcome is poor due to the complex anatomy of this region, which makes surgical excision very challenging concomitantly to the indolent growth of these lesions that leads to delayed diagnosis. Adenoid cystic carcinoma, squamous cell carcinoma, and adenocarcinoma are the most frequent malignant tumours, while among benign lesions, meningiomas, nasopharyngeal fibromas and schwannomas are most frequently encountered [25]. Metastases of the ITF are extremely rare. In a series of 27 patients, Conley [1] reported only two cases of metastases: one was an ovary cancer and one was a melanoma, while Shapshay [26] described two cases of squamous cell carcinomas with unknown primary location. Case reports include metastases from the uterine cervix, colorectal cancer and renal cell carcinoma [6].

Infratemporal fossa tumours were classically managed with a direct approach to this complex anatomical region. These approaches may be classified into two principal varieties: anterior and lateral approaches [27].

Anterior approaches include midfacial degloving, facial translocation and transmaxillary approaches. Compared to lateral approaches, the anterior ones allow a more direct and natural corridor, avoiding craniotomies, as well as remaining extradural, thus reducing the incidence of CSF leakage, decreasing the risk of facial nerve palsy, and preventing lesions to the temporo-mandibular joint (TMJ). Among lateral approaches, the classical lateral access the infratemporal fossa described by Fisch [28] provides a good exposure of concomitantly the middle and anterior skull base and the infratemporal fossa. The approach characteristics include facial nerve transposition, resection of the mandibular condyle, mobilisations of the zygoma and lateral orbital rim, in order to increase the working angle [9, 28]. Another lateral approach is the subtemporal-preauricular one, popularised by Sekhar [11], which is a substantial modification of the Fisch approach and offers some advantages: a decreased incidence of facial nerve damage, preservation of hearing conduction, minimal brain retraction, direct access to the ipsilateral petrous and upper cervical internal carotid artery, and reconstruction of extensive cranial base defects with the use of a muscle flap.

Even if the Fisch and Sekhar approaches are considered to be a milestone, both of them require a wide skin incision and bone destruction, with a full but demolitive access to the ITF. Considering our illustrative case, where the tumour involved the middle skull base and ITF extending to the pterygopalatine fossa (PPF) and orbit, the pre-operative concept was to use a more superior corridor, without the need to remove the mandible; as a consequence, we decided on a less invasive standard approach to the lateral skull base tumours, i.e. the fronto-orbito-zygomatic (FOZ) approach.

The FOZ approach may be considered an extensive modification of the classic pterional craniotomy. Since its original description, it has rapidly evolved and is now considered the gold standard access to lateral skull base lesions [16]. It provides a better exposure with a multidirectional surgical corridor, and a wide working space with minimal brain retraction. Pathologies that may be managed by FOZ craniotomy include spheno-petro-clival meningiomas, trigeminal meningiomas, P1 segment aneurysms, giant sellar and parasellar tumours, and spheno-orbital meningiomas; globally, it may be used for any lesion extending from the orbit to the petrous apex in an anterior-to-posterior direction, and from ITF to cavernous sinus in a lateral-to-medial direction. Cavernous sinus involvement is considered one of the main aspects that could preclude extensive surgical resection, even in cases of wide surgical view.

As previously mentioned, Hakuba [15] first systematically described this approach for the treatment of parasellar and interpeduncular fossa lesions, aiming for a better anatomical exposure of the anterior cranial base compared to the classic pterional and subtemporal approaches [9, 16, 28, 29]. However, some authors recommend a two-piece craniotomy [15, 23] while others prefer a single-piece craniotomy. In two cases of our series, we preferred a single-piece craniotomy that was fashioned with classic craniotomy for temporal, lateral sphenoid and frontal bone and with the piezoelectric osteotome for orbital and medial sphenoid tract; a one-piece craniotomy may ensure a safe and easy reconstruction, while minimising risks for dural tearing during the craniotomy. In addition, after removing the orbits-zygomatic bone, an anatomical study has demonstrated an increase of the working angle, of 75% in sub-frontal, 46% in pterional, and 86% in sub-temporal, approaches [12]. Compared to a one-piece craniotomy, the two-piece FOZ craniotomy ensures greater orbital wall removal, and permits access also to the anterior communicating artery complex and basal frontal. This was required in the two-piece cases of our series where a tumour component was extensively located in the basal frontal lobe [27, 29]. In two-piece FOZ craniotomy, after pterional craniotomy, both temporal bone and sphenoid ridge are drilled and dura is detached from the middle skull base. Thus, intraorbital and lateral orbit osteotomies are performed under direct vision and this allows a more extensive orbital roof removal compared to the one-piece FOZ variety (Fig. 5). When performing a one-piece craniotomy, the intraorbital osteotomy is the key to increasing the amount of orbital roof removal and widening the angle of work.

In our illustrative case of lung adenocarcinoma metastasis, the tumour has a wide medial-to-lateral extension, from the pterygoid muscle in ITF to cavernous sinus medially, and therefore a two-piece craniotomy could ensure a wide angle of work (Fig. 5). Nevertheless, considering the left eye blindness, we could have performed a single-piece FOZ with a mild and safe periorbital and ocular bulb retraction, achieving a more medial intraorbital osteotomy than a usual one-piece craniotomy. As a result, the medial extension of tumour near cavernous sinus was exposed and gross total resection obtained, maintaining the advantages of the one-piece variety, such as a short time for the craniotomy, superior reconstruction, as well as a good cosmetic outcome.

In the other case of WHO grade I meningioma where a single-piece FOZ had been used, the patient's left eye was not impaired but the medial extension of the lesion was limited and there was no cavernous sinuous involvement; in such a condition, the orbital osteotomy ensured by the one-piece FOZ is sufficient to expose the tumour, even with gentle eye retraction aimed at preserving visual function.

Despite progress in surgical techniques, tumours invading both the middle cranial fossa and ITF still remain difficult to manage. In a series of 33 patients, Bao et al. [24] obtained a gross total resection in 23 patients; in 29 patients, the clinical status improved significantly. In our series, gross total removal was achieved in seven patients (77.8%), and a near total in the remaining cases; this high rate of GTR may be related to

the benign nature of most lesions as well as a good selection of the cases eligible to FOZ. The same authors [24] reported complications in 7/33 patients (21.2%) with unremarkable morbidity. In our series, we observed one patient with post-operative enophtalmos.

Recurrence was observed in 3/9 patients (33.3%) and was mainly related to a parasinuses nasal component, successively treated with an endoscopic endonasal approach. Nonetheless, the relationship between recurrence and the presence of a diffusion route in the bone remains unclear. As a matter of fact, these communicating lesions characteristically show route of spread, such as foramina, skull base erosion and, rarely, bone sutures [25]. As a consequence, it is likely that this aspect could lead to an arduous excision and, subsequently, to a recurrence in that area. However, some authors have emphasised the histology as a fundamental factor for bone spread. In fact, bone erosion is generally associated with more aggressive tumours. We can partially confirm this statement: we observed two cases of erosion of temporal bone, one WHO grade II and one grade I meningioma. Moreover, an aggressive tumour such as metastases from lung adenocarcinoma showed no bone erosion while spreading through the oval foramen. Regarding trigeminal neurinomas (TN), we report a single case that spread though the oval foramen. In their series of 27 patents surgically treated for TN, Yoshida et al. found 30% of extra-cranial extension, including ITF, orbit or pterygopalatine fossa and foramen ovale, as the most common route of spread. These lesions are characteristically dumbbell-shaped, and foramina are enlarged at CT scan without bone erosion. Invasion of the orbit can occur in two ways: direct extension from the middle cranial fossa via the superior orbital fissure, and indirect extension firstly from the middle cranial fossa to the pterygopalatine fossa and then via the inferior orbital fissure into the orbit. Surgical techniques to treat these tumours include a combination of zygomatic and orbitozygomatic craniotomy and the zygomatic-infratemporal approach.

Extension into the lateral wall of the cavernous sinus is considered challenging for surgeons. Nevertheless, it is possible to obtain a gross total resection, with a wide anatomical exposure. In their original series of 18 mixed type tumours involving cavernous sinus, Al-Mefty et al. [20, 21] achieved a complete resection in 15 (83%) cases; no tumours with extra-cranial extension was present in their series. A review of surgical outcomes in tumours involving cavernous sinus is difficult because the definition of involvement in not itself clear. Tumours originating in the cavernous sinus are extremely rare, whereas nasopharyngeal carcinoma and metastasis are the most common of those invading the cavernous sinus space; meningiomas often compress, rather than invade, the lateral wall of the cavernous sinus that is composed of two layers. In tumours extending from ITF to the cavernous sinus, this lateral-to-medial extension is the main factor that can limit complete surgical excision.

A surgical approach such as FOZ, both the one- and the two-piece, is very useful in this situation because it ensures a wide angle of work. In our series, 6/9 patients (67%) showed MRI evidence of cavernous sinus involvement; nonetheless, intraoperative evidence of clear invasion of the lateral wall was evident only in one case of WHO grade II meningioma, which was treated by near total surgical resection and radiotherapy, and recurred after nine years of follow-up.

Our illustrative case is characteristic in terms both of the surgical approach and the rarity of the pathology. Lung cancer is the most common malignant cancer worldwide and every year it causes about 1.6 million deaths. Non-small cell lung cancer (NSCLC) represents about 85% of all lung cancers, and lung squamous cell carcinoma (LUSC) and adenocarcinoma (LUAD) are the most common subtypes [30]. At the time of diagnosis, most tumours are unresectable stage IV and globally the five-year survival rate for NSCL is 24%. Lung carcinomas can metastasise through lymphatic and blood vessels. The most frequent sites of metastases are the brain, bones and adrenal glands. A preferential metastatic site among different subtypes has been described: adenocarcinoma tends to metastasise to the brain, while SCLC spreads to both the brain and the liver; specific mutations can predispose to brain metastases [31, 32]. Generally, brain metastases from a hematogenous route, irrespective of histological types, are intra-axial lesions that tend to be located at the junction between grey and white matter, near major arteries and are surrounded by oedema with mass effect. In our case, the tumour invaded the middle cranial fossa by contiguity from infra-temporal fossa (possibly through the foramen) and it was localised only in the epidural space with only focal dural involvement and no brain invasion.

The management of this lesion is different from that of conventional brain metastases from lung adenocarcinoma, but due to the rarity of the pathology no specific indications are known. Chaudhuri et al. have described the case of a 46-year-old woman who presented with proptosis as the only sign of a mass in the infratemporal fossa invading her right orbita. Thoracic CT scan demonstrated a voluminous lung mass, and biopsy of both lung and ITF masses showed a poorly differentiated metastatic adenocarcinoma. Palliative chemotherapy with pemetrexed and carboplatin plus radiotherapy to the orbital mass was started, but a rapid progression of primary disease was observed and the patient died five weeks after the last cycle of chemotherapy.

In our case, surgical intervention was dictated by the need to decompress the neural structure, control intracranial extension and make a histological diagnosis. Despite gross total resection being obtained, even our patient's prognosis was extremely poor and he died only

four months after diagnosis due to the progression of his pulmonary disease.

These kinds of tumour are extremely rare, and, due to the poor prognosis, a complex surgical approach such as FOZ craniotomy should be carefully evaluated compared to a simple biopsy.

Conclusion

For the treatment of ITF fossa tumours extending to the orbit and/or middle cranial fossa, we believe that a two-piece FOZ craniotomy ensures a wider angle of work compared to a one-piece craniotomy and it allows safer and more direct surgical access to the cavernous sinus and paresellar region. A one-piece craniotomy ensures safer and better reconstruction while not requiring extra surgical time.

We believe that the main anatomical feature of the lesion that should dictate which of the two should be used is the medial-to-lateral extension of the tumour, in particular the invasion of the cavernous sinus: for a tumour with limited intracranial extension and not involving the cavernous sinus, we prefer the one-piece FOZ craniotomy, while for a tumour that extends from the pterygoid muscle to the cavernous sinus, a wider angle of work is required and here the two-piece FOZ craniotomy represents the better choice. In some cases, when visual function is irreversibly compromised and an aggressive manipulation of the orbital content should be carried out, a one-piece FOZ craniotomy may be extended medially with a more medial intraorbital cut, allowing resection also of a lesion involving the cavernous sinus.

Funding: *No funding was received for this research.*

Conflicts of interest: *None.*

Ethical approval: *All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki Declaration and its later amendments or comparable ethical standards.*

The ethical review process and approval by our ethics committee was not required for the present study because it is a retrospective study on patients who required a life-saving intervention. Furthermore, the research data analysis has no effect on the participants or their medical care.

Informed consent: *Informed consent was obtained from all individual participants included in the study.*

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