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Frontotemporal-Orbitozygomatic Approach

[Original Article]

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Outline

Graphics

Abstract:

The frontotemporal-orbitozygomatic (FTOZ) approach developed by Hakuba in 1977 as an osteoblastic bone flap for tumoral and aneurysmal pathologic findings offers a craniotomy with a wide

shallow working area and optimal brain exposure with minimal brain retraction. This procedure provides a low vantage point with a wide angle of exposure to the contents of the inferior frontal lobe, parasellar region, cavernous sinus, interpeduncular cisterns, and floor of the anterior and middle fossa. Most procedure variations are fashioned in a nonosteoplastic fashion using deep structures such as the inferior orbital fissure and/or the superior orbital fissures. Unfortunately, published articles have drawn little attention to the cosmesis and complexity of the procedure. A simpler and less time-consuming FTOZ craniotomy approach compared with previous reports is recommended here. An osteoplastic technique with improved long-term cosmesis that eliminates the necessity of use of the inferior orbital fissures with no need to expose the malar eminence and, if required, translocation of the temporal process of the zygoma rather than removal with the bone flap is discussed. The authors present techniques with cadaveric and skull models for performing a simplified osteoplastic FTOZ craniotomy via 3 procedures (1-piece, 2-piece, and modified) and discuss the merits and use of each procedure. Although the procedures can be performed in a nonosteoplastic fashion, the osteoplastic method is recommended for long-term cosmesis and good functional outcome. The authors' preference for most pathologic lesions treated is the modified procedure because of its simplicity, ease, adequate exposure, and shorter required operating time.

The frontotemporal-orbitozygomatic (FTOZ) approach was developed in 1977 and first introduced into the neurosurgical armamentarium in 1986 by Hakuba and colleagues.[1] It was a 1-piece osteoplastic bone flap with the intent of providing excellent exposure obliquely of the parasellar region and the interpeduncular fossa with the shortest possible working distance. Many variations have emerged since the original description as a 1-piece or 2-piece procedure.[2-17] Most investigators suggested a nonosteoplastic craniotomy, with the exception of 1 group,[17] and the cosmesis of such interventions, principally of temporal muscle atrophy with asymmetry and slumping, resulting in temporal fossa depression is seldom addressed. In addition, the devascularization of the free bone flap with antecedent atrophy and suboptimal healing along the craniotomy line with a heightened risk of infection is not mentioned.

This article describes the technical details of performing a simple but easy osteoplastic FTOZ via 3 avenues: 1-piece procedure, 2-piece procedure, and modified 1-piece procedure. The simplicity of the technique is attributed to the lack of need for the use of the inferior orbital fissures in the procedure. Furthermore, the zygomatic arch is not removed separately or as part of the bone flap but is rather translocated with the temporalis muscle without removal of the malar eminence.[18] Closure is simplified by the replacement of a vascularized bone flap that fits snugly. With a decreased incidence of bone infections and malpositioning, temporalis atrophy is avoided, which contributes significantly to long-term cosmesis and good functional outcome. The inherent virtues of the 3 different FTOZ approaches are discussed. The authors' preference is to use the modified procedure (modified FTOZ) in comparison to the others as the workhorse for most pathologic lesions treated for reasons of simplicity, ease, adequate exposure, and shorter operating time. Therefore, an expansive description of the modified FTOZ is provided, followed by descriptions of the 1-piece and 2-piece FTOZ procedures in which the salient features are highlighted.

SURGICAL TECHNIQUES

Positioning

The initial preparation and positioning are similar to those used for a routine pterional approach. The patient is placed in the supine position with a shoulder role under the ipsilateral scapula. The head is raised to 15° above the heart to facilitate cerebrospinal fluid drainage. The neck is extended so as to angle the head backward from the frontal lobe to fall away from the orbital roof. The degree of contralateral head rotation from 15° to 60° is dictated by the location of the pathologic findings at hand. The head is secured in a Mayfield 3-pin headholder, and care is taken to ensure that the pins of the

headholder are kept well posterior to the planned incision site. Hair is neither shaved or cropped but groomed away from the planned incision site and stapled to the scalp.

Skin Incision

A curvilinear skin incision is fashioned where it begins 1 cm anterior to the tragus and is at the level of the zygoma for the modified FTOZ. For the 1-piece and 2-piece FTOZ approaches, however, the inferior aspect of the incision is located 1 cm below the inferior border of the zygomatic arch. The incision is maintained behind the hairline for the entire course and ends contralaterally at the midpupillary line or superior temporal line (Fig. 1A). To avoid the risk of injury to the superficially and anteriorly placed superficial temporal artery, the initial part of the incision should be superficial.

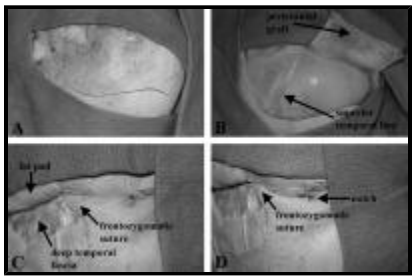


FIGURE 1. A, Left-sided cadaveric specimen highlights the curvilinear incision where it begins 1 cm anterior to the tragus and below the root of the palpable zygoma. The incision is taken to the contralateral midpupillary line or superior temporal line to keep the incision behind the hairline and obtain easy exposure of the ipsilateral orbital rim when the skin flap is retracted anteriorly. B, Largest vascularized pericranium is harvested from the ipsilateral superior temporal line in a medial direction. C, Supraorbital foramen with its named neurovascular bundle (*) is frequently identified along the medial one third of the orbital rim. D, Supraorbital foramen is frequently incomplete anteriorly and is referred to as a notch. The contents can be dissected free. If the foramen is complete, an osteotomy is performed to free its contents.

Scalp Flap and Pericranium

The scalp is elevated in 2 layers. Initially, the scalp flap is dissected in the subgaleal plane with the pericranium remaining on the underlying frontal bone, and the flap overlying the temporalis fascia is exposed in the manner described by Yasargil et al.[19] to avoid injury to the frontotemporal branch of the facial nerve. The dissection is continued until the scalp flap can be reflected anteriorly over the orbit to palpate the superior and lateral aspects of the supraorbital rim under the pericranium. Second, the largest area of pericranium exposed by reflection of the skin flap is dissected carefully off the calvaria and reflected anteriorly along the ipsilateral superior temporal line with a periosteal dissector (see Fig. 1B). Care should be taken to harvest a vascularized frontal pericranial flap at the beginning of the case, because it is more cumbersome to harvest it at the end before closure when it is required to obliterate the frontal sinus or assist in dural repairs.

When dissecting the pericranium off the supraorbital rim, the supraorbital foramen with its nerve and artery is typically encountered along the medial one third of the superior orbital rim (see Fig. 1C). The supraorbital foramen is frequently incomplete anteriorly, and the neurovascular contents can be dissected freely with the pericranium (see Fig. 1D). It is important to preserve this neurovascular bundle because it is the principal blood supply to the pericranial flap. If the supraorbital foramen is complete, the supraorbital nerve and artery can be dissected free by fracturing the foramen with a small osteotome, followed by retraction anteriorly with the pericranium. Along the supraorbital rim, the periorbita is contiguous with the pericranium. The periorbita is firmly attached at the supraorbital foramen and/or notch and the frontozygomatic suture, but it can be easily lifted between these 2 locations. With careful blunt dissection, the supraorbital and lateral orbital rims and the superior and lateral aspects of the orbital roof can be exposed while leaving the periorbita intact. The periorbita is separated for a distance of 2 to 3 cm posteriorly from the orbital rim. If the periorbita is violated, fat rapidly interferes with the exposure of the orbital rim. Bipolar coagulation of the cumbersome periorbital fat can minimize this problem, and/or the rent in the periorbita can be sutured in a fishnet-like fashion to contain the periorbital fat.

Modified Frontotemporal-Orbitozygomatic Approach

A cadaveric model depicts the following soft tissue dissection (Fig. 2). The temporalis fascia and muscle are cut in the direction of the skin incision from the superior temporal line to the root of the zygoma. A periosteal instrument is used to dissect the temporalis muscle off the bone at the root of the zygoma for an area that would encompass a burr hole. This is followed by blunt subperiosteal dissection of the temporalis muscle in a straight line from the root of the zygoma to the superior temporal line. A subperiosteal tunnel is then created from the root of the zygoma to the location of the anatomical keyhole (or MacCarty keyhole) in a retrograde fashion, as described by Oikawa and colleagues.[20] The anatomical keyhole or MacCarty keyhole [21,22] is located 1 cm behind the frontozygomatic suture on the frontosphenoidal suture. Next, the periosteum overlying only the frontal process of the zygomatic bone is elevated to expose 1 cm of the bony surface inferior and lateral to the frontozygomatic suture with no need to expose the entire zygomatic arch. Because the periosteum is contiguous with the periorbita here, elevating the pericranium facilitates separating the periorbita from the lateral orbital rim, particularly at the frontozygomatic suture, where the periorbita is adherent and easily torn. Finally, the insertion of the temporalis fascia to this portion of the zygomatic arch and the most anterior aspect of the superior temporal line is incised. The temporalis muscle is undermined inferiorly in a subperiosteal fashion to elevate the temporalis muscle so as to provide exposure of the anatomical keyhole. This procedure provides a subperiosteal tunnel beneath the temporalis muscle while maintaining the attachment of the belly of the temporalis muscle to the temporal squama and the superior temporal line. Monopolar cauterization should not be used for dissection because it damages the subperiosteum.

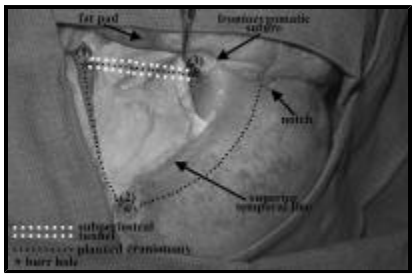
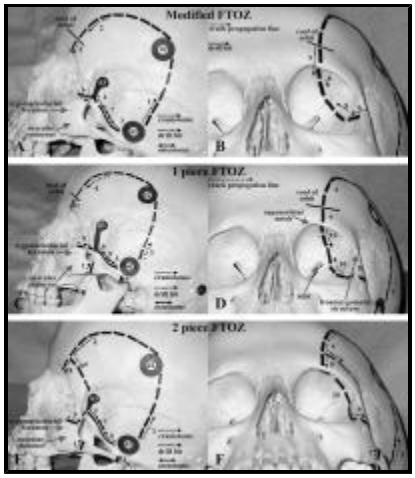


FIGURE 2. Left-sided modified frontotemporal orbitozygomatic cadaveric specimen after harvesting the pericranial flap and releasing the supraorbital nerve from its notch. The temporalis fascia and muscle are cut in line with the incision and cleared off the bone at the root of the zygoma and the anatomical keyhole location by blunt periosteal dissection. The burr holes are numbered as follows: 1 (root of the zygoma), 2 (superior temporal line), and 3 (burr hole at the anatomical keyhole). A subperiosteal tunnel is created beneath the temporalis muscle from the root of the zygoma to the anatomical keyhole (white double-track squares). Planned craniotomy (••••••).

Craniotomy

A skull model (Fig. 3A, B) depicts the necessary bony cuts. Three burr holes are drilled: the first burr hole is placed in the temporal bone above the root of the zygoma, the second burr hole is placed just above the superior temporal line approximately 5 cm behind the keyhole, and the third burr hole is placed at the anatomical keyhole. The keyhole burr hole is then extended inferiorly in a golf club fashion to undercut the sphenoid ridge. A craniotome is used to connect the first burr hole to the second (see Fig. 3A, step 1), and the calvarial cut is advanced toward the orbital rim just lateral to the supraorbital foramen, where its advancement is halted by the roof of the orbit (see Figs. 3A, B, step 2). Next, the craniotome is placed in the first burr hole and advanced toward the inferior limb of golf club-shaped keyhole as limited by the temporalis muscle (see Fig. 3A, step 3). This step is repeated in the opposite direction from the anatomical keyhole (which is shaped like a golf club) toward the first burr hole (see Fig. 3A, step 4).

FIGURE 3. Skull models depict a left-sided frontotemporal orbitozygomatic (FTOZ) craniotomy via the modified (A, B), 1-piece (C, D), and 2-piece (E, F) procedures. Burr holes are numbered as follows: 1 (root of the zygoma), 2 (superior temporal line), and 3 (burr hole at the anatomical keyhole is extended inferiorly in a golf club fashion to undercut the sphenoid ridge). A, B, Modified FTOZ craniotomy. The sequence of the craniotomy is indicated by numbered arrows from 1 to 4 for the craniotome with a footplate attachment, as described in the text. Arrows 5 and 6 continue the sequence and represent bone cuts with a high-speed drill, as described in the text. Step 7 indicates the use of an osteotome, if necessary, to complete the bony cut in the temporal squama. Step 8 involves cracking the thin orbital roof as the bone flap is elevated anteriorly. An osteotome can facilitate propagating a fracture line from burr hole 3 to the osteotomy at the orbital rim, which is completed by step 5. C, D, One-piece FTOZ



craniotomy. The burr hole at the anatomical keyhole is extended further inferiorly compared with the modified FTOZ. Numbered arrows indicate the osteotomy sequence, where 1 and 2 represent sectioning the inferior arch of the zygoma at the temporozygomatic suture anteriorly and at its root, respectively. The sequence of the craniotomy is indicated by numbered arrows from 3 to 6 for the craniotome with a footplate attachment, as described in the text. Arrows 7 and 8 continue the sequence and represent bone cuts with a high-speed drill, as described in the text. Step 9 indicates the use of an osteotome, if necessary, to complete the bony cut in the temporal squama. Step 10 involves cracking the thin orbital roof as the bone flap is elevated anteriorly. An osteotome can facilitate propagating a fracture line from burr hole 3 to the osteotomy at the orbital rim, which is completed by step 7. E, F, Two-piece FTOZ craniotomy. The burr holes are similar to those used in the 1-piece FTOZ craniotomy. Numbered arrows indicate the osteotomy sequence, where arrows 1 and 2 represent sectioning the inferior arch of the zygoma at the temporozygomatic suture anteriorly and at its root, respectively. The sequence of craniotomy is indicated by numbered arrows from 3 to 6 for the craniotome with a footplate attachment, as described in the text. Step 7 indicates the use of an osteotome, if necessary, to complete the bony cut in the temporal squama. Arrows 8 to 10 continue the sequence and represent bone cuts with a high-speed drill to remove the superior and lateral parts of the orbital rim, as described in the text.

A high-speed side-cutting drill bit is then used to section the last uncut 1 cm of the orbital rim while the periorbita and globe are protected (see Fig. 3, step 5; Fig. 4A). Attention is then turned to cutting the frontal process of the zygoma at a location just lateral to the frontozygomatic suture; this cut is extended posteromedially toward the keyhole while the periorbita and globe are protected (see Fig. 3, step 6; Fig. 4B). If necessary, an osteotome can be used to propagate a fracture underneath the temporalis muscle to complete the cut between the anatomical keyhole and the root of the zygoma (see Fig. 3A, step 7; Fig. 4C, D). The bone flap is now attached to the calvaria via the thin orbital roof, which can be cracked.[23] This involves out-fracturing the bone flap using gentle pressure with periosteal elevators. This usually results in 2 cm of the orbital roof fracturing off with the bone flap, as best seen in the intraorbital view (see Fig. 3B, step 8). The cracking of the orbital roof can also be facilitated with the use of an osteotome and may be particularly useful when the frontal sinus extends laterally beyond the supraorbital foramen, lending to an intact posterior wall of the frontal sinus (see Fig. 4E). The osteotome is placed in the anatomical keyhole, and a fracture line is propagated along the roof of the orbit to the previous osteotomy site located just lateral to the supraorbital rim (see Fig. 3B, step 8). The osteoplastic bone flap with its attached temporal muscle is now reflected inferolaterally without any compromise of the operative field (see Fig. 4E).

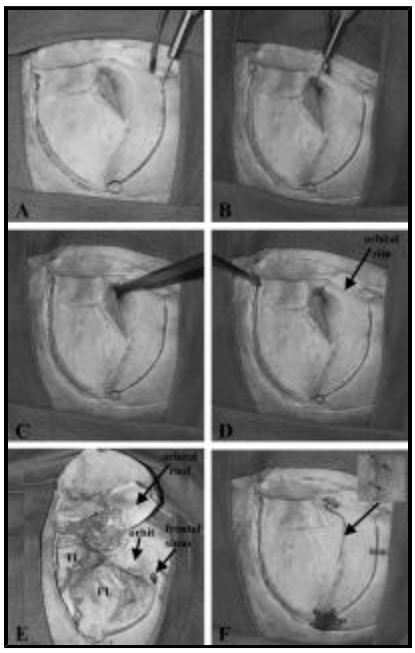


FIGURE 4. Cadaveric specimen on the left side shows the osteotomy sites for the modified frontotemporal orbitozygomatic approach. A, Orbital rim cut is located lateral to the supraorbital notch and/or foramen with protection of the periorbita and globe. B, Zygoma is cut lateral to the frontozygomatic suture and down to the anatomical keyhole. C, D, Osteotome cuts beneath the subperiosteal tunnel in the temporalis muscle to complete the bony cut in the temporal squama (refer to steps 3 and 4 in Fig. 3A). E, Osteoplastic bone flap is reflected inferolaterally by cracking the thin orbital roof. The frontal sinus extends laterally beyond the supraorbital notch and is exposed. FL & TL indicates frontal lobe and temporal lobe covered by dura. F, For closure, the orbital rim is secured with plates and screws with a single burr hole cover at the superior temporal line. Inset, Temporalis fascia is secured to the bone flap for an anatomical reapproximation without any tension.

If difficulty is encountered in elevating the bone flap, the cut across the sphenoid ridge is first inspected and completed. A fracture is then propagated across the roof of the orbit from the anatomical keyhole with an osteotome as previously mentioned (see Fig. 3B, step 8). After the craniotomy, the sphenoid ridge is flattened, and, if necessary, removal of the middle fossa floor and an extradural anterior clinoidectomy 23a are performed as required for the pathologic findings at hand. To prevent accumulation of epidural blood, dural tack-up sutures from the dura mater to the calvaria are routinely placed at the periphery of the bone opening.

Closure

On completion of the procedure, a watertight dural closure is performed; however, if this is not possible, Gelfilm (UpJohn Corporation, Kalamazoo, MI) is placed over the exposed neural tissue to prevent adhesion to the overlying bone. If the frontal sinus is exposed (see Fig. 4E), it is occluded with pieces of Surgicel (Johnson & Johnson Gateway, Irvine, CA) and covered with a pedicled pericranial graft to isolate it from the intracranial cavity. The pericranial graft is secured by suturing it to the dura mater; later, it is sandwiched between the calvaria and the osteoplastic bone flap. The bone flap is affixed to the calvaria with titanium plates and screws (see Fig. 4F), with particular care taken at the frontal area for cosmesis. Calcium phosphate bone cement (Norian SRS Cement; Norian Corporation, Santa Cruz, CA) or polymethylmethacrylate can be optionally used to close the bony defect at the anatomical keyhole location to prevent dimpling of the temporalis muscle as it falls into the bony defect. The temporalis fascia at the most anterior aspect of the superior temporal line is secured to the bone flap for an anatomical reapproximation without any tension (see Fig. 4F, inset). The scalp incision is closed in the usual fashion.

One-Piece Frontotemporal-Orbitozygomatic Approach

For this procedure, the soft tissue dissection is similar to that of the modified FTOZ with 2 additions. First, the entire zygomatic arch (composed of the frontozygomatic process, posterior aspect of the zygomatic bone, and the temporozygomatic process) is exposed by elevating the overlying periosteum without a need to expose the malar eminence and the zygomaticofacial foramen of the zygoma (Fig. 5A). Second, the insertion of the deep temporal fascia is incised along the length of the frontal process of the zygomatic bone to facilitate access to sectioning the frontal process of the zygomatic bone.

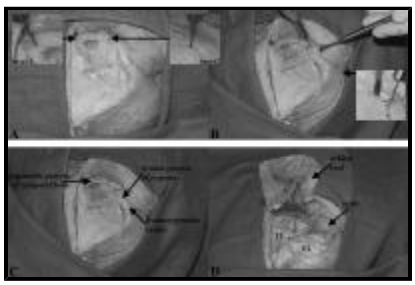


FIGURE 5. Cadaveric specimen on the left side shows the osteotomy sites for the 1-piece frontotemporal orbitozygomatic (FTOZ) approach. A, Zygomatic arch (composed of the frontozygomatic process, posterior aspect of the zygomatic bone, and the temporozygomatic process) is exposed without the need to expose the malar eminence and the zygomaticofacial foramen. A high-speed side-cutting drill is used to section the zygomatic root in front of the tuberculum articulare posteriorly (inset 1) and the zygomatic process of the temporal bone at the temporozygomatic suture anteriorly (inset 2). B, Craniotomy is completed. The inset shows the cut in the orbital rim located lateral to the supraorbital notch and/or foramen with protection of the periorbita and globe. The frontal process of the zygoma is cut superior to the malar eminence. C, Osteotomies are complete, and the osteoplastic bone flap is ready to be out-fractured or cracked along the thin orbital roof. D, Left osteoplastic FTOZ bone flap is reflected inferolaterally. FL & T L indicates frontal lobe and temporal lobe covered by dura.

Craniotomy

A skull model (see Fig. 3C, D) depicts the necessary bony cuts. Three burr holes are drilled as described previously for the modified FTOZ approach. The burr hole located in the region of the anatomical keyhole is extended further inferiorly, however, compared with the modified FTOZ to facilitate cutting the frontal process of the zygomatic bone without having to use the inferior orbital fissure (see Fig. 3C, step 8).

The inferior arch of the zygoma is first sectioned by cutting at the temporozygomatic suture anteriorly (see Fig. 3C, step 1; Fig. 5B) and at its root just in front of the tuberculum articulare posteriorly (see Fig. 3C, step 2; Fig. 5C). The sectioned zygomatic process of the temporal bone remains attached to the temporalis muscle on its medial side. A craniotome is then used to connect the burr holes as previously mentioned (see Fig. 3C, steps 3-6). A high-speed side-cutting drill bit is then used to section the orbital rim as previously illustrated (see Figs. 3C, D, step 7; Fig. 5D, inset) and cut the frontal process of the zygomatic bone just superior to the malar eminence; this cut is extended to the inferior limb of the golf club-shaped keyhole (see Figs. 3C, D, step 8; Fig. 5E). If necessary, an osteotome can be used to propagate a fracture underneath the subperiosteal tunnel of the temporalis muscle to complete the cut between the golf club-shaped anatomical keyhole and the burr hole at the root of the zygoma (see Fig. 3C, step 9). The bone flap can now be cracked (see Fig. 3D, step 10).[23] The osteoplastic bone flap with its attached temporalis muscle is now reflected inferolaterally. This action allows for translocation of the zygomatic process of the temporal bone, which was sectioned earlier. The temporalis muscle can then be further dissected inferiorly to provide enhanced exposure from the infratemporal fossa of the temporal bone forming the floor of the middle fossa without any compromise of the operative field (see Fig. 5F). Dural tack-up sutures are used routinely. Closure is as per the modified FTOZ procedure, and the translocated zygomatic process of the temporal bone is easily attached with titanium plates as well.

Two-Piece Frontotemporal-Orbitozygomatic Craniotomy

A skull model (see Figs. 3E, F) depicts the necessary bony cuts. The soft tissue dissection with the creation of the subperiosteal tunnel below the temporalis muscle for this procedure, the placement of the burr holes, and the sectioning of the zygomatic process of the temporal bone (see Fig. 3E, steps 1 and 2) are similar to the 1-piece FTOZ procedure. An osteoplastic frontotemporal craniotomy is then performed as indicated (see Fig. 3E, steps 3-7), and the bone flap with its attached temporal muscle is now reflected inferolaterally with the translocation of the zygomatic process of the temporal bone (Fig. 6A). The superior and lateral aspects of the orbital rim are removed as a nonosteoplastic second piece (see Fig. 6B). This is performed with a high-speed side-cutting drill bit while the periorbita is protected in the following sequence: 1) the orbital rim just lateral to the supraorbital notch and/or foramen is sectioned (see Figs. 3E, F, step 8), 2) the frontal process of the zygomatic bone superior to the malar eminence is cut (see Figs. 3E, F, step 9), and 3) the superior and lateral orbital roof is sectioned (see Fig. 3F, step 10). Dural tack-up sutures are used routinely. Closure first involves reapproximating and securing the nonosteoplastic orbital rim bone flap with titanium plates and screws to the frontal calvaria and the malar eminence. The remaining procedures involved in closure are similar those used in the 1-piece FTOZ procedure.

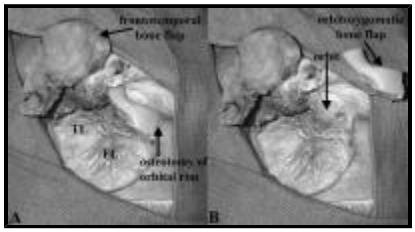


FIGURE 6. Cadaveric specimen on the left side shows the 2-piece frontotemporal orbitozygomatic approach. A, Osteoplastic frontotemporal craniotomy bone flap is reflected inferolaterally with translocation of the zygomatic process of the temporal bone. The next step involves removal of the orbitozygomatic bone flap in a single piece. FL & TL indicates frontal lobe and temporal lobe covered by dura. B, Completed 2-piece procedure.

INDICATIONS AND COMPLICATIONS

The FTOZ craniotomy is a versatile procedure that provides surgical access to a variety of lesions located at the anterior and lateral skull base. The main advantage lies in removal of the superolateral portion of the orbital rim.[8] Our group has verified the efficacy of this maneuver in an anatomical study,[24] which showed that a superolateral orbital osteotomy provided significant and consistent increases in surgical exposure but that removal of the inferior zygomatic arch produced less consistent gains.[24] Clinical correlation for the adequacy of an orbital rim osteotomy over that of an orbitozygomatic craniotomy for a satisfactory surgical corridor was recently reported for various

pathologic findings located in the anterior, middle, and interpeduncular fossa.[25]

The need for removal of the zygomatic process of the temporal bone as commonly performed with most FTOZ craniotomies for additional exposure is seldom required, and its necessity is far outweighed by the increase in length of the operating time and the associated morbidity. This insight led to the development of the modified FTOZ (where the zygomatic process of the temporal bone is not removed), and its worth was clinically verified in 200 cases over a 4-year period at our institution (Balasingam et al., submitted for publication). The modified FTOZ approach offers the following advantages over the 1-piece or 2-piece FTOZ craniotomy: 1) technical simplicity, 2) shorter operating time, 3) decreased incidence of injury to the frontotemporal branch of the facial nerve, 4) excellent exposure of the skull base with a shorter and wider dissection distance, 5) minimal brain retraction, 6) easy replacement of a single bone flap, and 7) decreased postoperative discomfort.

Is there a specific place for the additional exposure provided by displacement of the zygomatic process of the temporal bone? Yes, rarely, and it is specific for 1) the need to access the infratemporal fossa or for a subtemporal approach [8] and 2) the need to reach particularly high-positioned basilar artery aneurysms that are located 10 mm above the baseline connecting the anterior and posterior clinoid processes.[18] In these scenarios, it is recommended that the zygomatic process of the temporal bone be not removed but translocated,[18] because it can easily be osteotomized and rapidly reapproximated during closure.

The frontal craniotomy is taken to a point just lateral to the supraorbital foramen and/or notch to prevent damage to the supraorbital neurovascular bundle and to avoid entering the frontal sinus, which commonly does not extend beyond the supraorbital foramen and/or notch.[26] The location of the frontal sinus can be easily determined during surgery by illuminating the sinus with a light source placed at the ipsilateral inner canthus after the reflection of the pericranium. If the frontal sinus is entered, it is approached as described. If the pathologic findings at hand require a more medial plane of access, however, the orbital rim osteotomy and the craniotomy can be taken medial to the supraorbital foramen and/or notch. In our experience, this is seldom necessary except for lesions extending to and/or involving the medial orbital wall, because the supraorbital foramen and/or notch is located along the medial one third of the superior orbital rim.

The technique of out-fracturing the bone flap by cracking the orbital roof is a safe and simple procedure. Observers of the human skull may note that the orbital roof is triangular in shape and is formed by the frontal bone anteriorly and by the lesser wing of the sphenoid posteriorly to include the superior surface of the optic foramen and the superior orbital fissure. The normal anterior orbital roof is usually translucent, delicate, and thin, with depressions and ridges corresponding to the gyri and sulci of the frontal lobe. In contrast, the posterior orbit, by creative design, is thicker and difficult to fracture. It thus prevents the surgeon from injuring the contents of the optic foramen and the superior orbital fissure when the orbital roof is cracked. The crack usually occurs at the weakest point of the nonpathologic normal orbital roof, which is located approximately 2 to 3 cm from the orbital rim within the anterior portion of the thin orbital roof. If difficulty is encountered, an osteotome should be used as previously described. Opponents [27] of this technique state that the crack may occur over the carotid artery or its associated vascular anomaly and may result in disastrous consequences. In reply, this concern is valid only if the orbital roof is involved with the pathologic findings (eg, fibrous dysplasia, meningioma, metastatic lesion). For such instances, we recommend the 2-piece FTOZ in which the orbital rim is osteotomized under direct vision, although it is more cumbersome and time-consuming to perform.

Interestingly, Zabramski and colleagues [13] promoted the 2-piece FTOZ concept as a modification of the original FTOZ for 2 reasons: to eliminate the need for bone reconstruction of the orbital wall to prevent enophthalmos and to minimize the risk of injury to the frontal branch of the facial nerve. We do not subscribe to this opinion. When the FTOZ procedure is performed for reasons not involving pathologic findings of the orbital roof, the absence of enophthalmos was attributed to the replacement of

the anterior one third of the roof with the 1-piece bone flap. If resection of the orbital roof was performed because of pathologic findings, defects in the orbital roof, whether isolated or in combination with defects in the lateral or medial wall of the orbit, do not require routine reconstruction when the periorbita remains intact.[28,29] This is in contradistinction to the recommendations of others.[30-32] We have not encountered pulsatile enophthalmos during long-term follow-up exceeding 12 months. DeMonte and colleagues [29] report transient orbital pulsations when pulsatile enophthalmos is present but an absence of pulsatile enophthalmos in their series of 56 patients after orbital entry during excision of anterior and anterolateral skull base tumors. Nevertheless, reconstruction is mandated when more than two thirds of the orbital floor is removed, even if the periorbita is intact, to prevent postoperative enophthalmos and hypoglobus.[29]

The skin incision has to be of the appropriate length for exposure of the ipsilateral orbital rim with ease. If this is not accomplished, exposure can still be obtained but with additional skin flap retraction. This usually contributes to transient periorbital swelling and periorbital ecchymosis, which generally resolves within the first 72 hours for the former and within 14 days for the latter. A more significant complication is that of periorbital blistering, which resolves within 6 to 8 weeks. This is a rare but significant painful inconvenience that prevents eye opening, which results directly from prolonged excessive retraction of a skin flap with a shorter than necessary incision length.

After the FTOZ procedure, the extent of further bone removal is dependent on the size and location of the pathologic findings. The sphenoid ridge, anterior clinoid, posterior clinoid, anterior aspect of the middle fossa, and floor of the middle fossa can be removed with the use of high-speed pneumatic drills and rongeurs. Furthermore, when necessary, a craniotomy of the temporal squama can be directed as far posteriorly as required from the root of the zygoma to gain access to the posterior middle fossa.

Why an osteoplastic bone flap? Temporal muscle atrophy is a common sequela of a frontotemporal craniotomy and is contributory to functional and cosmetic complications. The causes have been attributed to denervation, loss of vascular supply, inappropriate muscle tension, and muscle fiber injury.[33] Oikawa et al.[20] noted the avoidance of temporal atrophy by preserving the deep temporal nerve and artery by means of retrograde dissection without damage to the subperiosteum. Despite various temporal resuspension and fixation techniques,[34-39] however, inappropriate reattachment with undue muscle tension and muscle fiber damage from monopolar cauterization [13,20] contributes to postoperative muscle atrophy and contraction, leading to temporal hollowing and possible painful mastication.

The answer to long-term cosmesis and good functional outcome is an osteoplastic bone flap with the following advantages: 1) minimal opportunity for damage to the deep temporal nerve and artery, because the area of subperiosteal dissection is small; 2) simple and easy precise reapproximation of the bone flap at the edge of the craniotomy with only minimal muscle fiber damage (along the craniotome corridor) and the absence of undue muscle tension; 3) minimal risk of injury to the frontotemporal branch of the facial nerve; 4) vascularization provides excellent bone union at its edges and prevents atrophy; and 5) the incidence of infection is also significantly decreased with a vascularized bone flap. The small gap in the posterior aspect of the bone flap and the calvaria as well as the inferior defect, which is dependent on the area of bone removed for access to the middle fossa, is covered by the temporalis muscle and does not contribute to any significant cosmetic issues. This flap is criticized for bulk and obstruction of maximal operative exposure, but this is minimal with the removal of the lateral orbital rim in comparison to an osteoplastic pterional craniotomy in our experience. Furthermore, the overall advantages far outweigh the disadvantages.

The diploic veins of the osteoplastic bone flap can sometimes contribute to troublesome postoperative hematomas; therefore, appropriate hemostasis of the bone edges is important. Asymptomatic epidural hematomas were identified on postoperative computed tomography scans when adequate hemostasis of the osteoplastic bone flap was not performed. These can be easily avoided with appropriate waxing of the bone edges and venous channels in the bone flap. No patients suffered an infection of an osteoplastic

bone flap, and patients were generally satisfied with their long-term cosmesis. Paresis of the frontotemporal branch of the facial nerve was usually witnessed when the interfascial dissection technique described by Yasargil et al.19 was not respected by surgeons-in-training at our institution. Moreover, the risk of injury to the frontotemporal branch of the facial nerve was further decreased with the modified FTOZ, because complete exposure of the zygoma is not warranted.

Transient intraoperative bradycardia attributable to the oculocardiac reflex was witnessed rarely when excessive downward retraction was performed on the globe to obtain visual access to the skull base without brain retraction.

CONCLUSION

The authors present 3 simplified surgical techniques for performing a 1-piece, 2-piece, and modified FTOZ craniotomy. It is recommended that the procedures be performed with an osteoplastic bone flap for reasons of long-term cosmesis and good functional outcome. If access is required to high-positioned basilar artery aneurysms or to the infratemporal fossa, translocation of the zygoma is recommended with a 1-piece FTOZ procedure. The 2-piece FTOZ approach is usually advocated when there are pathologic findings involving the orbital rim or roof and precludes orbital roof cracking for reasons of safety. Furthermore, the 2-piece procedure is more cumbersome and time-consuming to perform. The authors' preference for most pathologic lesions treated is to use the modified FTOZ as the workhorse. The modified FTOZ involves only the removal of the lateral orbital rim with the frontotemporal bone as a single unit and obviates the need for removal of the zygomatic process of the temporal bone while providing all the advantages of a traditional FTOZ procedure.40 Closure is further simplified by the replacement of a vascularized bone flap, with a decreased incidence of malpositioning and bone infections. The osteoplastic component adds to the improved long-term cosmesis and ascribes to the art and our practice of neurosurgery.

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