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Original Article

Anterior rotation of the temporalis muscle for prevention of temporal hollowing in cranial surgeries: Esthetic and patient-reported outcomes

Ignacio J. Barrenechea[1], Micaela Clerici[2], César Cordero Ramírez[2], Luis Márquez[1], Sabrina C. Miralles[3], Ernesto Adrian Moretti[2]

Departments of [1]Neurosurgery, [2]Plastic and Reconstructive Surgery, [3]Neuroradiology, Hospital Privado de Rosario, Rosario, Argentina.

E-mail: *Ignacio J. Barrenechea - ijbarrenechea@gmail.com; Micaela Clerici - clerici.micaela.2@gmail.com; César Cordero Ramírez - corderocirugiaplastica@gmail.com; Luis Márquez - marquezbirocco@gmail.com; Sabrina C. Miralles - sabrinamiralles@hotmail.com; Ernesto Adrian Moretti - doctormorettiuniversidad@gmail.com

***Corresponding author:**
Ignacio J. Barrenechea,
Department of Neurosurgery,
Hospital Privado de Rosario,
Rosario, Argentina.

ijbarrenechea@gmail.com

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ABSTRACT

Background: Temporal hollowing is a common cosmetic complication following pterional craniotomies. To address this issue, we evaluated the efficacy of anterior rotation of the temporalis muscle at closure. Although this technique is not new and has been generally reported, no research studies have been conducted to evaluate its objective and patient-reported outcomes in the long term.

Methods: We retrospectively reviewed 22 patients treated with pterional, fronto-orbitozygomatic, or fronto-temporo-zygomatic craniotomies from March 2021 to 2023. A 12-month postoperative magnetic resonance imaging was used to evaluate the degree of temporal hollowing. To quantify temporal hollowing, we measured the distance of depression at the level of the temporal fossa. This distance, or "temporal thickness," was defined as the widest distance between the skull's outer cortical bone and skin surfaces at the level of the anterior clinoid process (D1) and foramen of Monro (D2). Furthermore, pre and postoperative cosmetic results were evaluated using the Rostock Functional and Cosmetic Cranioplasty (RFCC) Score. For reasons of objectivity, RFCC was tested by two independent plastic surgeons against the patient's rating.

Results: After a year or more follow-up, 54.5% of patients exhibited no hollowing, while 31.8% had mild or moderate hollowing. Moreover, 91% reported good esthetic outcomes. No cases of severe hollowing were observed. Importantly, temporomandibular joint dysfunction was not observed.

Conclusion: These results suggest that anterior rotation of the temporalis muscle is an effective primary strategy to mitigate cosmetic deformities without compromising masticatory function. Further studies with larger sample sizes are warranted to confirm these findings.

Keywords: Etiology, Magnetic resonance imaging clinical score, Prevention, Rostock functional and cosmetic cranioplasty, Temporal hollowing, Temporal muscle rotation, Temporal anatomy, Temporal fat pad

INTRODUCTION

Neurosurgical practice has understandably evolved over the past 20 years. These changes include a trend toward endovascular procedures for vascular lesions, an increasing number of metastatic or skull base tumors treated with stereotactic radiosurgery, or the application of minimally invasive tubular techniques to resect intraaxial tumors. Nevertheless, certain brain

or skull base tumors still require "conventional approaches" (pterional, orbitozygomatic, etc.). However, the current trends and patient's expectations require special attention to cosmetic results. Considering that these approaches sometimes require extensive temporalis muscle detachment to expose the temporal fossa, surgeons have developed various techniques to avoid temporal hollowing, a frequent cosmetic problem reported to occur in 87–100% of pterional craniotomies.[4,9,10,14,15,17-19,21] Moreover, some authors consider hollowing an unavoidable result after pterional craniotomy, leading to the facial asymmetry between the operated and nonoperated sites. In fact, this complication can cause the patient to experience a lack of confidence and psychosocial problems.

Several techniques have been proposed to address this problem, such as split myofascial bone flap, interfascial pterional craniotomy, or avoidance of dissection beneath the superficial layer of deep temporal fascia or through the temporal fat pad. To overcome this issue, the authors have been utilizing anterior rotation of the temporalis muscle at closure to counterbalance the unavoidable muscle atrophy. Although this technique is not new and has been generally reported elsewhere,[3] no research studies have been conducted to evaluate its objective and patient-reported outcomes in the long term. We describe here our experience with this technique in 22 cases and evaluate the long-term cosmetic and masticatory results.

MATERIALS AND METHODS

This retrospective case series study has been reported in line with the PROCESS guidelines.[1] We retrospectively reviewed the cases of patients with intracranial lesions surgically treated at the Hospital Privado de Rosario Neurosurgery department from March 2021 to 2023 using a pterional, fronto-orbitozygomatic (OZA), or fronto-temporo-zygomatic craniotomy, in whom an anterior rotation of the temporalis muscle was performed at closure [Table 1]. Written consent was obtained from all patients. Medical charts were reviewed for data on demographic characteristics, presenting symptoms, pre and postoperative images, and perioperative complications. In all cases, magnetic resonance imaging (MRI) studies were obtained to evaluate and characterize the lesion (tumor, vascular lesion, etc.). Patients who received radiotherapy postoperatively were excluded from this series. A 12-month postoperative MRI imaging was used to evaluate the degree of temporal hollowing. To quantify the severity of temporal hollowing, we measured the distance of depression at the level of the temporal fossa from the axial T1 contrast-enhanced MRI. This distance, or "temporal thickness," was defined as the widest distance between the skull's outer cortical bone and skin surfaces at the level of the anterior clinoid process (D1) and at the level of the foramen of Monro (D2). To avoid measurement errors between pre and postoperative measurements, we used the same angle drawn from the intersection of the midline and the sella turcica in D1. In D2, the center of the angle was the intersection of the midline and the foramina of Monro [Figure 1]. To assess our results, we used a previously described grading system[11] that categorizes temporal hollowing from 0 to 3: the difference of less than 10% between the temporal thickness of the operated side and nonoperated side was designated to grade 0 (no hollowing), a difference of 10–25% was designated to grade 1 (mild hollowing), and a difference of 25–50% was designated to grade 2 (moderate hollowing). Grade 3 (severe hollowing) was used if the difference was more than 50%. All the patients were able to communicate properly, express their experiences, and have a self-perception of their cosmetic results. The final functional and cosmetic results were evaluated with the Rostock Functional and Cosmetic Cranioplasty (RFCC) Score.[7] For reasons of objectivity, RFCC was tested by two independent plastic and reconstructive surgeons against the patient's rating. This score consists of four equally rated items covering the functional and cosmetic results after a cranioplasty. Each item consists of three answers, judged with ascending points given (one, two, or three). All answers were added up, so possible scores ranged from 4 (best) to 12 (worst) points. The score results were classified as good postoperative results (4–6 points), acceptable results (7–9), and poor postoperative results (10–12 points). The institutional review board approved this study (IRB approval # 1/0151).

Surgical technique

After general anesthesia was induced, the patient was placed in a supine position, with their head rotated and secured in a Mayfield head holder. The skin incision began 1.0–1.5 cm anterior to the ear at the level of the zygomatic arch, extending superiorly across the temporal region. Afterward, it curved anteriorly (posterior to the hairline) to end at the midline or the contralateral pupillary line, depending on the required exposure. Preservation of the frontotemporal branch of the facial nerve was achieved through an interfascial dissection technique, as described by Yasargil *et al*.[20] The temporalis muscle was then incised and dissected from the temporal fossa with a periosteal elevator through the muscle incision, beginning inferiorly to the inferior temporal line. By performing a retrograde dissection,[14] the subperiosteum was preserved, thereby protecting the deep temporal nerve and artery. After releasing the temporalis muscle, the skin flap and temporalis muscle were reflected antero-inferiorly. A frontotemporal craniotomy was then performed with a free bone flap. Once the intradural procedure had ended, the bone flap was replaced and secured with titanium mini plates and screws. To avoid long-term cosmetic scalp defects, burr holes and bone gaps were filled with methylmethacrylate

Table 1: Summary of patient demographics and measurements.

# Patient	Sex	Age (years)	Diagnosis	Approach	Postsurgery THG	Patient-reported RFCC score	Plastic Surgeon reported RFCC score	Follow-up (months)
#1	F	55	ACoA aneurysm	Pterional	D1: 0 D2: 0	5	5	24
#2	F	54	ACoA aneurysm	Pterional	D1: 1 D2: 0	4	4	24
#3	M	57	SW meningioma	OZA	D1: 0 D2: 0	4	4	22
#4	F	32	Tubercullum Sella Meningioma	OZA	D1: 0 D2: 0	4	4	21
#5	F	44	Trigeminal schwanoma	OZA	D1: 1 D2: 0	4	4	21
#6	F	65	SW meningioma	Pterional	D1: 2 D2: 0	6	6	20
#7	F	55	Frontal meningioma	Pterional	D1: 0 D2: 1	5	4	20
#8	M	26	Suprasellar Craniopharyngioma	Pterional	D1: 0 D2: 0	4	5	19
#9	F	35	MCA aneurysm	Pterional	D1: 0 D2: 0	4	5	19
#10	F	53	SW meningioma	TZA	D1: 0 D2: 1	4	4	18
#11	F	41	SW meningioma	Pterional	D1: 1 D2: 0	5	5	18
#12	F	49	PCoM aneurysm	Pterional	D1: 0 D2: 0	5	5	18
#13	F	28	MCA aneurysm	Pterional	D1: 1 D2: 0	7	5	17
#14	F	57	Frontal meningioma	Pterional	D1: 0 D2: 0	5	5	16
#15	F	70	ACoA aneurysm	Pterional	D1: 1 D2: 0	5	6	16
#16	F	73	SW meningioma	Pterional	D1: 0 D2: 0	7	6	16
#17	F	60	Tubercullum Sella meningioma	Pterional	D1: 0 D2: 0	4	4	15
#18	F	73	Tubercullum Sella meningioma	Pterional	D1: 0 D2: 0	5	5	15
#19	F	14	SW meningioma	Pterional	D1: 0 D2: 0	4	4	15
#20	F	37	Cavernoma	Pterional	D1: 1 D2: 0	5	4	13
#21	M	23	MCA giant aneurysm	Pterional	D1: 0 D2: 0	6	5	12
#22	F	14	Clinoidal meningioma	Pterional	D1: 0 D2: 0	5	5	12

THG: Temporal Hollowing grading (as described by Kim *et al.*[11]); RFCC Score: Rostock functional and cosmetic Cranioplasty Score; D1: Temporal thickness between the skull's outer cortical bone and skin surface at the level of the anterior clinoid process; D2: Temporal thickness between the skull's outer cortical bone and skin surface at the level of the foramen of Monro, AcomA: Anterior communicating artery, SW: Sphenoid Wing, MCA: Middle cerebral artery, PCom: Posterior communicating artery.

(Subiton Bone Cement®, Laboratorio SL, S.A, San Fernando, Buenos Aires, Argentina). Before reattaching the temporalis muscle, several v-shaped tunnels were drilled in the outer cortex along the superior temporal line, through which a 2-0 Ethibond® (Ethicon, Inc.) passing through the muscle was tied. When the zygomatic process of the frontal bone was exposed, holes were also drilled in this structure. Once neat hemostasis had been achieved, the temporalis muscle was rotated anteriorly and sutured to the v-shaped tunnels and zygomatic process of the frontal bone [Figure 2]. Although this anterior rotation left a posterior gap in the temporal fossa, no stitches were placed to suture the posterior border to the remaining temporalis muscles (to avoid tearing the muscle fibers). Finally, the periosteum, galea aponeurotica, and skin were closed in the usual manner.

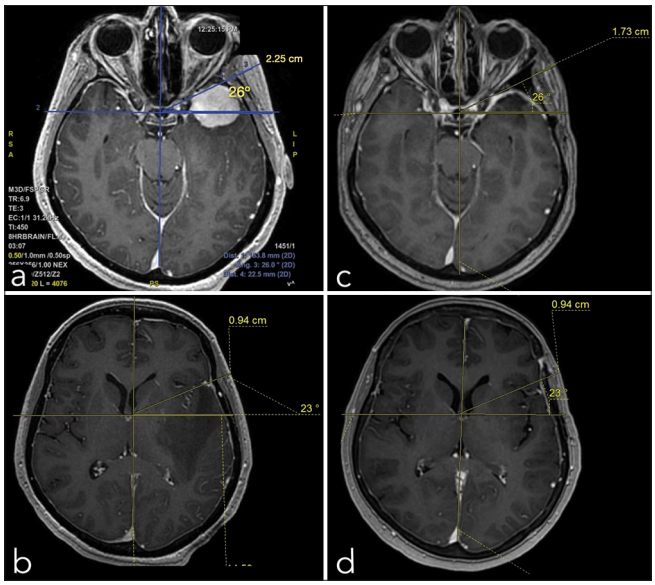

Figure 1: Pre (a;b) and postoperative (c;d) temporal thickness magnetic resonance imaging measurements (example case # 11). This distance was defined as the widest distance between the skull's outer cortical bone and skin surfaces at the level of the anterior clinoid process (D1) and at the level of the foramen of Monro (D2). To avoid errors between pre and postoperative measurements, we used the same angle drawn from the intersection of the midline and a horizontal line (in the x plane) crossing the sella turcica in D1. In D2, the center of the angle was the intersection of the midline and a horizontal line (in the x plane) crossing the foramina of Monro.

RESULTS

Twenty-two patients were operated using this cosmetic technique at closure. The patient group consisted of 19 female and 3 male patients with an average age of 46.1 ± 3.2 years (±Enhanced Surveillance Measures) and a median follow-up of 18 months (range 12–24 months). Details of the cohort are detailed in Table 1. Eighty-two percent of cases (18/22) were operated through a pterional approach, 14% (3/22) were performed through a fronto-orbito-zygomatic craniotomy (OZA), and 4% (1/22) through a fronto-temporo-zygomatic craniotomy (TZC). Histological diagnosis reported 10 (45,4%) meningiomas, 7 aneurysms (31.8%), 1 suprasellar craniopharyngioma, 1 temporal lobe cavernoma, 1 trigeminal schwannoma, and 2 low-grade gliomas.

At the last follow-up, among 22 patients, 54.5% (12 patients) showed grade 0 for both D1 and D2 measures. In addition, 7 patients (31.8%) exhibited grades 1 and 2 for D1 measures (6 with "mild hollowing" and 1 with "moderate hollowing"), while their D2 measures were classified as grade 0 (""no hollowing"). Only 3 patients (13.6%) displayed grade 2 ("moderate hollowing") for D2, which was worse than their D1 distance indicating no hollowing; 19/22 patients (86.4%) were classified as "no hollowing" at D2 measure, and no cases of "severe hollowing" were registered neither at D1 or D2 measures; Kappa index: −0.222/1.0 (95% confidence interval

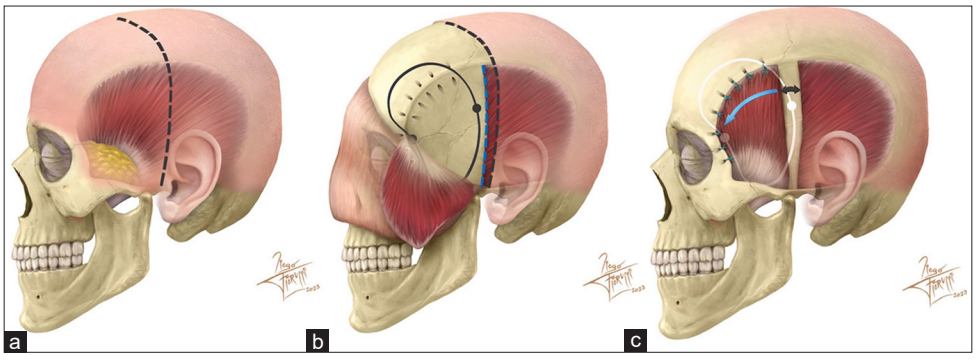

Figure 2: Original artistic drawing of the reported technique. (a) Classic left pterional approach incision. (b) Flap and temporalis muscle reflection. Note the v-shaped tunnels drilled in the outer cortex along the superior temporal line. (c) Final temporalis muscle position. The muscle is rotated anteriorly (blue arrow), leaving a gap behind (double head black arrow). Several 2-0 Ethibond stitches are placed through the v-shaped tunnels to anchor the muscle back to the superior temporal line. Bone cement is used in burr holes and bone gaps to avoid long-term cosmetic scalp defects.

[CI]: −0.782 to 0.337). The inclusion of a 0 value within the 95% CI suggested no relationship [Table 2].

The surgeons and patient RFCC scores were measured; 20/22 (91%) patient scores and 20/22 (91%) plastic surgeon scores stated as "good postoperative results" in terms of appearance; in only 2/22 (9%) cases and plastic surgeon qualified as "acceptable results." Specifically, Figure 3 shows the relationship between patient and plastic surgeon RFCC scores. In 14 out of 22 cases (64%), both the patient and the plastic surgeon shared similar satisfaction qualifications. In 3 out of 22 cases (14%), the patient's score was lower than the plastic surgeon's, indicating that the patients felt more satisfied with the esthetic/cosmetic results than the surgeon did. In the remaining 5 out of 22 cases (23%), the plastic surgeons' scores were higher than the patients,' suggesting that the plastic surgeons were more satisfied than the patients. The Kappa concordance index was calculated to be 0.423 out of 1.0 (95% CI: 0.104–0.742), indicating a "regular relationship."

In all cases, the operated temporalis fossa showed a discrete bulging for several months (compared to the nonoperated side). After that time, both sides remained nearly even. Of note, no external defects were seen at the muscle gap level [Figure 4]. Finally, no patient developed signs of temporomandibular joint dysfunction at the last evaluation.

Table 2: "Temporal thickness" grading system according to Ji Hyun Kim.

***n*=22 patients**		**D2**		
		No hollowing	**Mild hollowing**	**Moderate hollowing**
D1	No hollowing	12	3	-
	Mild hollowing	6	-	-
	Moderate hollowing	1	-	-

Kappa index: −0.222 (95% confidence interval: −0.782–0.337)

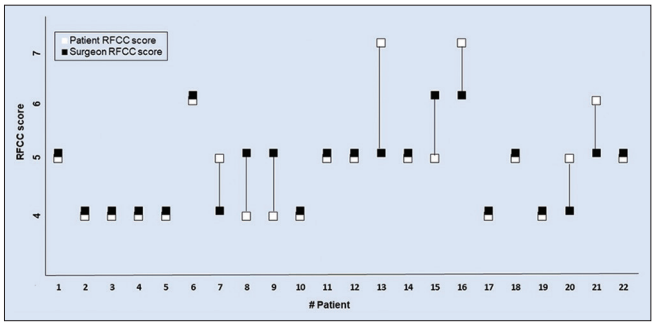

Figure 3: Correlation of postoperative results between patients and plastic surgeons RFCC scores (overlapping squares correspond to similar scores between the patient and plastic surgeon).

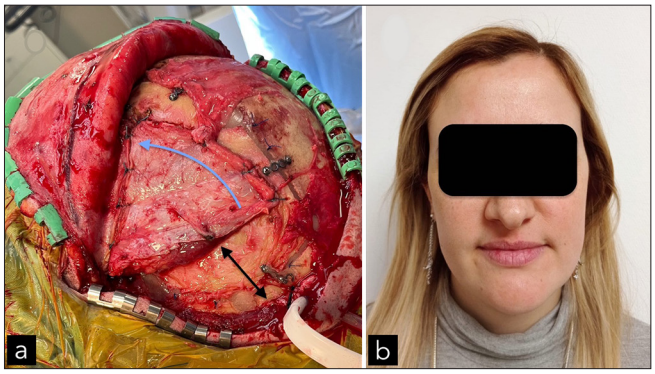

Figure 4: Case # 9. (a) Intraoperative picture of the final reconstruction before scalp closure. The muscle is thoroughly sutured to the superior temporal line. In this case, the zygoma was not exposed. However, the anterior cut over the temporalis fascia was closed with Ethibon. The muscle is rotated anteriorly (blue arrow), leaving a gap behind (double head black arrow). (b) At the 19-month follow-up, the patient was satisfied with the temporal contours.

DISCUSSION

Pterional or orbitozygomatic craniotomies are commonly used surgical procedures to access the intracranial compartment and treat various conditions, such as tumors, aneurysms, and arteriovenous malformations. One of the main complications of these procedures is temporal hollowing, which occurs due to retraction, denervation, or devascularization of the temporalis muscle during the surgery. Besides, injury to the superficial temporal fat pad (a quadrangular fan-shaped structure) contributes to this problem.[12] This complication is not only a cosmetic concern, but it can also lead to functional impairment in the temporomandibular joint.[16] To avoid this issue, many techniques have been described, such as native tissue augmentation[4] and synthetic fillers.[5,13] However, many of these procedures require a second operation. Therefore, primary prevention is of paramount importance. In this sense, different methods have been suggested over the years to avoid muscle atrophy in the index operation.[4,9,10,14,15,17-19,21] Spetzler and Lee[18] proposed leaving a cuff muscle and fascia attached to the skull at the superior temporal line. This technique allows reattaching the muscle to its original position. However, it requires another incision across the fibers of the temporal muscle, with the risk of devascularization and denervation of the remaining cuff. Therefore, other authors prefer anchoring the temporalis muscle to the superior temporal line with microscrews,[21] plates,[2] or suturing it directly to the bone.[8,9] However, since hollowing is reported to occur following 87–100% of pterional craniotomies,[6,10,15] all these techniques are insufficient most of the times. Hence, anterior rotation is a useful primary prevention strategy to improve long-term esthetic results. The mainstay of this technique is to create a temporary bulk of muscle anteriorly,

which compensates in time for the inevitable muscle atrophy. This procedure must be performed together with a neat retrograde dissection during detachment to avoid injuring the deep nerves and vessels. Furthermore, as previously mentioned, it is important to anchor this muscle back to the superior temporal line at the end of surgery. Even though this anterior rotation leaves an inevitable posterior gap, no patient has noticed it in this initial series.

Although the temporalis muscle is anchored back in a different position, no patient reported temporomandibular pain and/or functional jaw limitations. This finding further emphasizes the utility of this technique since some authors reported these symptoms after pterional approaches.[16] However, considering the evaluations were conducted at least 1 year after the surgery, it is plausible that some patients may have experienced these symptoms during the early months following the surgery. Finally, it is worth mentioning that we still employ this technique in all our cases, most of them being gliomas. Since these cases are irradiated early after surgery, most patients end up developing temporal muscle atrophy. However, it is important to note that not all patients who undergo radiation therapy will experience muscle atrophy, and the severity of the condition can vary widely. Indeed, these patients experience satisfactory esthetic outcomes that persist throughout their unfortunately short lifetimes.

CONCLUSION

In this initial series, 91% of patients reported good postoperative results, with no cases of severe hollowing registered. We conclude, therefore, that anterior rotation of the temporalis muscle at closure remains a useful primary prevention strategy for mitigating temporal hollowing following pterional, OZA, or TZC approaches. However, it would be important to extend the follow-up period for these patients and proceed with the development of case series studies involving larger sample sizes. Subsequently, comparative studies with other established techniques should be undertaken for a comprehensive evaluation.

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