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Review Article

Esthetics outcomes in patients submitted to pterional craniotomy and its variants: A scoping review

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ABSTRACT

Background: Highly performed nowadays, the pterional craniotomy (PC) has several widespread variants. However, these procedures are associated with complications such as temporalis muscle atrophy, facial nerve frontal branch damage, and masticatory difficulties. The postoperative cranial aesthetic is, nonetheless, the main setback according to patients. This review aims to map different pterional approaches focusing on final aesthetics.

Methods: This review follows the Preferred Reporting Items for Systematic Reviews and Meta-Analyses statement. Studies were classified through the Oxford method. We searched PubMed/MEDLINE, EMBASE, and Cochrane Library from January 1969 to February 2021 for cohorts and randomized clinical trials that met our inclusion criteria.

Results: 1484 articles were initially retrieved from the databases. 1328 articles did not fit the inclusion criteria. 118 duplicates were found. 38 studies were found eligible for the established criteria. 27 (71.05%) were retrospective cohorts, with low evidence level. Only 5 (13.15%) clinical trials were found eligible to the criteria. The majority of the studies (36/38) had the 2B OXFORD evidence level. A limited number of studies addressed cosmetic outcomes and patient satisfaction. The temporal muscle atrophy or temporal hollowing seems to be the patient's main complaint. Only 17 (44.73%) studies addressed patient satisfaction regarding the aesthetics, and only 10 (26.31%) of the studies reported the cosmetic outcome as a primary outcome. Nevertheless, minimally invasive approaches appear to overcome most cosmetic complaints and should be performed whenever possible.

Conclusion: There are several variants of the classic PC. The esthetic outcomes are poorly evaluated. The majority of the studies were low evidence articles.

Keywords: Esthetic outcomes, Patient reported outcomes, Pterional craniotomy

INTRODUCTION

Pterional craniotomy (PC) is a classic approach for all anterior circulation aneurysms, suprasellar tumors (i.e., pituitary adenomas and craniopharyngiomas), and neurosurgeries where the opening of the Sylvian fissure is a crucial step.[1] Described for the 1st time by Yasargil *et al.*, PC continues to be one of

the most used nowadays.[2,46] PC has several variants such as the orbitozygomatic (OZ) approach, first proposed by Hakuba *et al*.[18] Nevertheless, complications such as temporalis muscle atrophy, facial nerve frontal branch damage, and masticatory difficulties are not seldomly observed.[14] However, the low patient satisfaction regarding the pterional approach is mainly a result of postoperative cranial esthetic. These drawbacks have challenged neurosurgeons to improve the original technique to minimize such complications. Thus, novel variants that diminish the exposed area named "mini-pterional" and "nano-pterional" draw increasing attention. Although the neurosurgical field is familiar with the different techniques, few studies have thoroughly assessed them, comparing outcomes. This scoping review aims to address the situation, evaluating the varied forms of PC when it comes to final esthetics.

MATERIALS AND METHODS

Search strategy

This scoping review was made using the Preferred Reporting Items for Systematic Reviews and Meta-Analyses statement extension for scoping reviews.[42] A scoping review was conducted using MEDLINE/PubMed (NLM), EMBASE and Cochrane Library, the selected articles were from 1969 to February 2021. The MeSH and keywords used in the databases were: "pterional" OR "supraorbital" OR "frontolateral" OR "craniotomy" AND "approaches."

Study selection

This study intended to gather randomized clinical trials and cohort studies that compared different types of PC from the esthetics point of view. Inclusion criteria were: (a) studies that evaluated PC and its variants, in terms of aesthetics outcomes, (b) randomized clinical trial and cohort studies, and (c) articles written in English, Spanish, and Portuguese. Conversely, we excluded review articles, editorials, letters, comments, and articles that had no related theme to this study, case/series reports, or studies that evaluated the reconstructive surgeries for esthetic repair.

Data extraction

Two researchers (D.B.G and M.I.A.S) selected the studies. Divergences among the article selection as well as to the quality assessment were evaluated by the senior author. The following data were extracted from the studies: (1) general details on the study (author, year of publication, country, study type, time of follow-up, number of patients); (2) type of pterional approach; (3) baseline disease; (4) esthetic outcomes; and (5) complications.

Quality assessment

Studies were classified according to the Oxford method. The quality of the only randomized clinical trial that met the final criteria was assessed trough the JADAD score.[21]

RESULTS

One thousand four hundred and eighty-four articles were retrieved. 38 studies were found eligible for the established criteria (27 retrospective cohort studies, one outcome research, four prospective cohorts, one case–control, and five clinical trials).[1,5-8,10,11,13,17,18,20,21,23-25,28-31,33,34,36-38,41,44,45,48] 118 duplicates were found. 1328 papers were excluded as determined by the exclusion criteria [Figure 1].

Among the cohorts, four were prospective studies. Most of the articles studied the cosmetic/aesthetic outcomes in intracranial brain aneurysms (27/38). The primary outcomes analyzed were the temporal muscle atrophy (TMA) and frontal nerve palsy, evaluated quantitatively or qualitatively (through patients or health professionals reported outcomes). Over 50% of the studies (31/38) considered aesthetic as a secondary outcome. All main information from each included study are summarized in [Table 1].

We have identified five studies that compare PC and minimally invasive surgery (MIS) understood as minipterional craniotomy (MPC) and supraorbital variants approach.[26,32,40,43,49] Among these articles, 2 compared PC versus MPC and 3 compared PC versus supraorbital approach. 183 patients were submitted to PC, with 117 (63.93%) good outcomes. 59 patients were submitted to MPC, with 50 (84.74%) good outcomes. 116 patients were submitted to the supraorbital approach, with 109 (93.96%) good outcomes. Main adverse cosmetic events are summarized in [Table 2].

DISCUSSION

At present, PC is still the most widely used craniotomy to approach vascular and neoplastic diseases in neurosurgical practice.[1,46] Nonetheless, this method is associated with a series of cosmetic and functional issues, such as TMA, facial nerve frontal branch injury, and masticatory difficulties. In light of this, it became of utmost importance to compare different types of PC [Figure 2], from an esthetic point of view. In this scoping review, it was noted that a reduced number of studies addressing cosmetic outcomes and patient satisfaction. Only 10 (26.31%) of the studies addressed patient satisfaction regarding the esthetics, and only 7 (18.42%) of the studies reported the cosmetic outcome as a primary outcome.

Due to the heterogeneity of the esthetic evaluations carried out among the studies analyzed, we identified that for the purposes of evaluating of aesthetic outcomes, it is important that the evaluation is standardized and that it considers the patient's evaluation. We identified that the most important

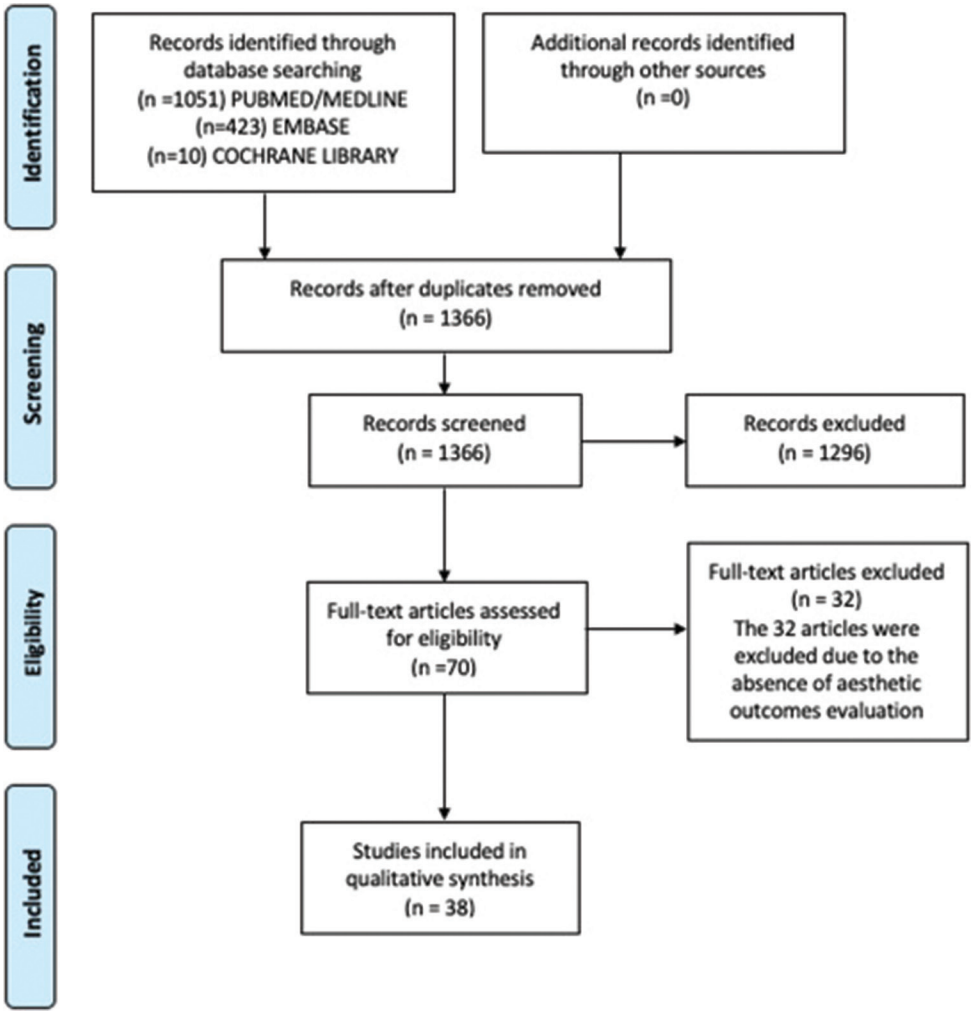

Figure 1: Flowchart of the study.

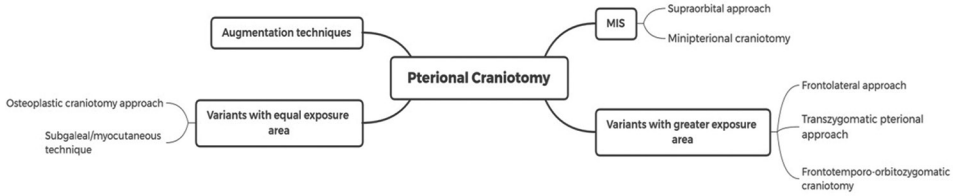

Figure 2: Pterional craniotomy and its variants.

aspects to be assessed by the researcher are: temporal hollowing, paresis of the frontal branch of the facial nerve, temporo-mandibular dysfunction, and patient's visual analogue scale proposed in [Table 3].

TMA

The TMA or temporal hollowing seems to be the chief complaint of the patients regarding the esthetics issue. Temporal hollowing can cause significant craniomaxillofacial asymmetry, esthetic deformity, and serious cosmetic concern in patients, even when there is an excellent postoperative functional outcome [Figure 3]. Several methods to prevent temporal hollowing have been introduced, all with specific drawbacks. The most straightforward technique to prevent TMA without lesion of the frontalis branch nerve seems to combine subgaleal/myocutaneous technique, described by Youssef *et al*. (2012).[47] However, a clear description of the methods regarding cosmetic assessment is not described.

Table 1: Characteristics of the studies assessing different pterional craniotomies.

Author	Approaches	Design of study	Evidence level (Oxford)	Number of patients	Baseline disease	Aesthetic outcome	Results
De Andrade *et al.* (1998)[10]	1. PC using myocutaneous flap 2. Conventional PC using interfascial dieresis	Randomized clinical trial	2B (JADAD 1)	68	Brain aneurysms	1. Temporal muscle atrophy 2. Mastigatory Pain 3. Dysfunction of the TMJ	Favorable to the myocutaneous flap. The risk of moderate and severe temporalis muscle atrophy and TMJ imbalance (pain and movement limitation) was prevalent, worse and long-lasting in interfascial dieresis than in myocutaneous flap
Kim and Delashaw Jr. (2011)[23]	1. Osteoplastic PC 2. Conventional PC	Prospective cohort	2A	40	Anterior circulation aneurysms	Temporal hollowing evaluated by the degree of frontozygomatic fossa depression (unremarkable, mild, moderate and severe)	Favorable to the osteoplastic craniotomy (92.5% vs. 6.7%, P=0.001, had unremarkable depression at the frontozygomatic fossa)
Grajeda-García and Mercado-Caloca (2011)[17]	1. PC 2. Osteomyoplastic pterional flap	Retrospective cohort	2B	26	Neoplasic and vascular supratentorial pathologies	Patient perception of temporal depression graded from 0 to 6	Patients perceived less temporal depression in the osteomyoplastic group
Youssef *et al.* (2012)[47]	1. Pterional 2. Orbitopterional 3. Fronto-orbital Combined with Subgaleal/ Myocutaneous Technique	Retrospective cohort	2B	71	Comprised aneurysms, arteriovenous malformations, sphenocavernous meningiomas, and pituitary adenomas	1. Cosmetic adverse events: frontalis/ orbicularis palsy 2. Subjective evaluation of cosmetic outcomes	There was one case of transient postoperative partial frontalis palsy (1.4%). Postoperative clinical evaluation of cosmetic outcome performed during follow-up clinic visits did not reveal any noticeable difference between the operative and the normal side in all patients.
Kim *et al.* (2018)[24]	1. PC with temporal augmentation 2. PC without temporal augmentation	Retrospective cohort	2B	100	Brain tumor	1. Temporal muscle thickness 2. Patient satisfaction using the VAS – from 0 (no deformity) to 10 (severe temporal hollowing)	Favorable to the pterional approach with temporal augmentation. The temporal thickness on the operated side was significantly reduced in the conventional approach (13.75±3.05 vs. 5.80±3.48 mm, P<0.001). And patient satisfaction was greater in the intervention group (1.77±1.26 vs. 6.85±2.2, P<0.001)

(*Contd...*)

Table 1: *(Continued).*

Author	Approaches	Design of study	Evidence level (Oxford)	Number of patients	Baseline disease	Aesthetic outcome	Results
Welling *et al.* (2015)[43]	1. PC 2. MPC	Randomized clinical trial	2B (JADAD 1)	58	Anterior circulation aneurysms	1. Patient satisfaction using a scale from 0 to 100, in which 0 meant the best result and 100 the worst result (primary outcome) 2. Temporal muscle thickness	There was a trend for the primary outcome to the MPC group. 19 patients (79%) and 13 patients (52%) in the MPC and PC groups, respectively, were satisfied with their cosmetic results (P=0.07). Thickness of the temporal muscle was significantly reduced in the PC group.
Sturiale *et al.* (2017)[40]	1. PC 2. MPC	Retrospective cohort	2B	68	Middle cerebral artery aneurysms	1. Overall patient satisfaction ranked as poor, regular, good, or excellent 2. Disorders of mastication graded as complete restoration, pain persistence during mastication, and functional limitation.	There was trend of excellent satisfaction in the MPC group (P=0.16). And complete restoration of the mastication was also more common on the MPC group (P=0.003).
Alkhalili *et al.* (2017)[1]	MPC	Retrospective cohort	2B	57	Ruptured and unruptured anterior circulation aneurysms	1. Frontal temporal nerve damage 2. Temporal muscle atrophy 3. Pain during mastication (There were no objective assessments of those outcomes)	None of the 57 treated patients experienced frontal temporal nerve damage, temporalis muscle atrophy, craniotomy site depression, or pain.
Genesan *et al.* (2018)[12]	1. PC 2. Supraorbital approach	Retrospective cohort	2B	123	Anterior circulation aneurysms	1. Scar tenderness 2. Cosmetic satisfaction Both outcomes were measured using the VAS, scored between 1 and 5 (scar tenderness: 1 = no pain, 5 = severe pain; cosmetic satisfaction: 1 = very satisfied, 5 = not satisfied).	There was no significant difference between the supraorbital and pterional groups in terms of scar tenderness (P=0.719). Cosmetic satisfaction was significantly higher in the supraorbital group (100% very satisfied in supraorbital approach vs. 76.8% in PC (P=0.001)).

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Table 1: *(Continued).*

Author	Approaches	Design of study	Evidence level (Oxford)	Number of patients	Baseline disease	Aesthetic outcome	Results
Yu *et al.* (2018)[49]	1. Supraorbital approach 2. PC	Retrospective Cohort	2B	140	Ruptured anterior communicating artery aneurysms	A 10-point scale for the patient to self-reporting their perception of esthetic outcomes. • Poor or bad (1–3 score); • Acceptable (4–6 score); • Favorable (7–10 score).	There was a tendency of better satisfaction in the supraorbital approach (94.0% vs. 86.2%, P=0.129).
La Rocca *et al.* (2018)[26]	1. Supraorbital Approach 2. PC	Retrospective cohort	2B	46	Unruptured anterior communicating aneurysm	1. Cosmetic outcome was evaluated by the patient in poor, regular, good or excellent. 2. Disorders of mastication an pain	In 23 of the 25 patients (92%) in the supraorbital approach group and 17 of 25 patients (68%) in the PC group had an excellent aesthetic result (P=0.03). Persistence of pain and disorders of mastication were more seen in the PC group.
Park *et al.* (2018)[32]	Pterional approach and contralateral supraorbital approach in the same group of patients	Retrospective cohort	2B	21	Bilateral intracranial aneurysms	1. Patient satisfaction questionnaire covering 5 complaints related to the surgical approaches: craniotomy-related pain, sensory symptoms, cosmetic complaints, palpable cranial irregularities, and limited mouth opening 2. Cosmetic satisfaction using the VAS	The super-ciliary approach showed better outcomes regarding the incidence of craniotomy-related pain, cosmetic complaints, and palpable irregularities, with a significant between-approach difference (P<0.05). VAS score for patient satisfaction was significantly higher for the superciliary approach (mean 95.2±6.0 [SD], range 80–100) than for the pterional approach (mean 71.4±10.6, range 50–90).
Eroglu *et al.* (2019)[11]	Supraorbital approach	Retrospective cohort	2B	106	Orbitofrontal meningioma; sellar-suprasellar mass; olfactory groove meningioma; glial mass; metastasis; aneurysm; hematoma; abscess; cavernoma; frontal fracture; osteoma; dermoid-epidermoid tumor.	Cosmetic satisfaction in a 5 point scale.	The best satisfactory result was obtained in 85% of the patients for this approach. There was no control group.
Steiger *et al.* (2001)[39]	Transorbital keyhole approach	Retrospective cohort	2B	33	Anterior communicating artery aneurysm	Adverse cosmetic events in short-term and 2 months follow-up.	Good outcomes compared to PC regarding long term aesthetic outcomes.

(Contd...)

Table 1: *(Continued).*

Author	Approaches	Design of study	Evidence level (Oxford)	Number of patients	Baseline disease	Aesthetic outcome	Results
Mori *et al.* (2007)[27]	Pterional Keyhole Approach	Outcomes research	2C	20	Middle Cerebral Artery Aneurysms	1. Patient satisfaction; 2. Cosmetic adverse events: frontalis muscle weakness.	Good cosmetic outcome regarding the approach
Mori *et al.* (2018)[28]	Pterional keyhole approach through a outer canthal skin incision	Retrospective cohort	2B	149	Unruptured middle cerebral artery aneurysms	1. Patient reported cosmetic outcomes: satisfied, moderately satisfied, moderately dissatisfied, and dissatisfied; 1. Frontalis muscle weakness.	The patients were satisfied in 85.6% of cases, moderately satisfied in 10.6%, and moderately dissatisfied in 3.8%. 5 patients experienced frontal weakness within 3 months. 1-year-follow-up showed just one patient with persistent deficit
Yang *et al.* (2014)[45]	1. Frontolateral approach 2. PC	Retrospective cohort	2B	30	Anterior circulation aneurysms	Temporal muscle thickness (primary outcome)	The mean and standard deviation of muscle thickness of group submitted to PC was 5.81 ± 3.48 versus 9.37 ± 3.44 for the group submitted to frontolateral approach
González-Darder *et al.* (2012)[15]	Transzygomatic Pterional Approach	Retrospective cohort	2B	77	Brain tumors in sphenoid wing, temporal lobe and cavernous sinus	Cosmetic adverse events: frontalis muscle weakness and temporal muscle atrophy.	3 (9.7%) had transitory muscle weakness and 5 (16.2%) had temporal muscle atrophy
Shapey *et al.* (2019)[38]	1. Modified mini-orbitozygomatic craniotomy 2.Orbitozygomatic craniotomy 3. PC	Retrospective cohort	2B	18	Spheno-orbital meningiomas	Patient-reported outcome measure of postoperative appearance using a five-point VAS (1 = very poor, 2 = poor, 3 = neutral, 4 = good, 5 = excellent).	There were no differences between the three techniques probably due to the small sample size
Amirjamshidi *et al.* (2015)[4]	1. PC 2. Modified LO	Retrospective cohort	2B	88	Spheno-orbital meningiomas	1. Amelioration of exoftalmos 2. Temporal Muscle atrophy	Both techniques reduced exoftalmos without statistically difference. Temporal muscle atrophy was seen in 2/12 (16.6%) in the PC group and 4/76 (5.2%) in the LO group. No patient reported outcome was analyzed.

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Table 1: *(Continued).*

Author	Approaches	Design of study	Evidence level (Oxford)	Number of patients	Baseline disease	Aesthetic outcome	Results
Ji and Ahn (2010)[22]	PC using calcium phosphate cement with and without augmentation of the temporal bone	Case-control study	2B	17	Anterior circulation aneurysms	Cosmetic outcome based on a grade system (A-well preservation of temporal fossa, B-Slight depression of temporal fossa, C-prominent depression of temporal fossa)	1 out of 5 was classified as Grade A in the without augmentation group; and 7 out of 12 were classified as grade A in the augmentation group. No statistical inference could be made due to the small sample size.
Im *et al.* (2018)[20]	PC using Medpor® implants	Retrospective cohort	2B	92	Unruptured aneurysms	1. Temporalis muscle thickness and volume; 2. Patient satisfaction	The ratio between the affected and non-affected side was 1.15±0.02 for the thickness and 1.18±0.02 for the volume. Overall patient satisfaction (excellent and good) was observed in 83 of 92 patients (90.2%). No complications were reported.
Goh *et al.* (2009)[13]	PC and supraorbital aproach with Medpor implants	Retrospective cohort	2B	107	Not described in the text	Cosmetic outcomes: linear depression in the forehead, anterior temporal hollow, preauricular depression, and parietal burr hole defect in the patients who underwent the PC; linear depressions in the forehead and a dimple at the keyhole site in the patients with the superciliary approach.	No linear depressions and dimples were visible on the forehead. No focal hollow in the anterior temporal area due to a keyhole defect was noticed, whereas nine patients showed a slight, diffuse hollow in the temporal area due to atrophy of the temporalis in cases of PC.
Chandra *et al.* (2020)[6]	f-SOKHA	Retrospective cohort	2B	75	Anterior circulation aneurisms	The subjective satisfaction data was collected in the form of a questionnaire, which took pain, sensory, cosmetic, eye/mouth complications, and overall satisfaction. Thus, a score was obtained (out of 50) called the subjective satisfaction score.	Cosmetic outcome was better for f-SOKHA group (P<0.001)

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Table 1: *(Continued).*

Author	Approaches	Design of study	Evidence level (Oxford)	Number of patients	Baseline disease	Aesthetic outcome	Results
Reisch and Perneczky (2005)[34]	Supraorbital subfrontal approach	Clinical trial	2B	450	1. Brain aneurisms 2. Cranial base meningiomas 3. Craniopharyngiomas 4. Pituitary adenoma 5. Astrocytoma 6. Epidermoid 7. Metastasis 8. Cavernoma 9. Arachnoidal and colloid cysts 10. Arteriovenous Malformation 11. Germinoma 12. Plexus papilloma 13. Amygdalohippocampectomy	Quantitative description of aesthetic adverse events	Permanent partial supraorbital hypesthesia related to a lesion of the supraorbital nerve was observed in 34 patients (7.5%); permanent palsy of the frontal muscle related to a lesion of the frontal branch of the facial nerve appeared in 25 cases (5.5%). Problems with closing of the eyelids was not noted; problems with chewing were observed in 3 patients (0.6%), but atrophy of the temporalis muscle was not observed in any of them; wound healing disturbances occurred in 6 cases (1.3%);
Wiedemayer *et al.* (2004)[44]	Supraorbital keyhole craniotomy	Clinical trial	2B	9	1. Meningiomas 2. Craniopharyngioma 3. Rathke's cleft cyst 4. Hypophysitis	The cosmetic result was judged by visual inspection	Considering the surgical wound, the osteotomy site and the state of the temporalis muscle the overall cosmetic result was very satisfying in all cases
Sarmento *et al.* (2019)[36]	1. Minimally invasive craniotomy (nummular craniotomy) 2. Standard frontotemporal craniotomy	Retrospective cohort	2B	73	Mesial temporal lobe epilepsy	Quantitative description of aesthetic adverse events	Postoperative complications in the standard frontotemporal craniotomy group included temporal muscle atrophy (4 patients), cerebrospinal fluid leakage (1 patient) and wound infection (1 patient), whereas there were no complications related to the access route in the "keyhole" group.
Gosal *et al.* (2018)[16]	1. Kawase's approach 2. The half-and-half (trans-Sylvian with subtemporal) 3. Frontotemporal craniotomy with orbitozygomatic osteotomy 4. RMSO	Prospective cohort	2B	33	Large-to-giant petroclival meningiomas	Quantitative description of esthetic adverse events	7 (21.2%) patients developed transient facial nerve paresis in the post-operative period. One patient developed permanent facial nerve paralysis (grade 4). 2 patients had worsening of facial nerve functional status from the House Brackmann Grade 2 to Grade 4 in the postoperative period while four patients had improvement in their facial nerve function.

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Table 1: *(Continued).*

Author	Approaches	Design of study	Evidence level (Oxford)	Number of patients	Baseline disease	Aesthetic outcome	Results
Nakamura *et al.* (2006)[30]	1. Frontolateral approach 2. Pterional/ fronto- temporal approach 3. Bifrontal approach	Retrospective cohort	2B	72	Tuberculum selae meningiomas	Quantitative description of aesthetic adverse events	A paresis of the frontal branch of the facial nerve was noted in one patient after surgery (bifrontal craniotomy group). Local wound infection was observed in three patients, all of whom underwent a bifrontal approach.
Cheng *et al.* (2006)[8]	Pterion keyhole approach	Clinical trial	2B	40	MCA and ICA aneurysms	Quantitative and subjective description of aesthetic adverse events	The post-operative cosmetic result was excellent and the patients were satisfied with it. After 7–50 months of follow-up, we found that only 3 patients had temporomandibular dysfunction or signs of atrophy at the site of the craniotomy.
Mori *et al.* (2018)[29]	Supraorbital keyhole approach w/titanium plate	Retrospective cohort	2B	63	Anterior communicating artery aneuryms	The patients were asked about the cosmetic results including the surgical scar at 1 yr, and opinions were classified as complete satisfaction, moderate satisfaction, moderate dissatisfaction, and complete dissatisfaction.	Mild frontalis muscle weakness was noticed in 3 patients at 3 mo after the operation, but had resolved at 1 yr in 2 patients. Temporal halo due to temporal muscle atrophy was recognized in 4 patients. Overall, 56 patients were completely satisfied, 7 were moderately satisfied with their cosmetic results, and no patient was dissatisfied.
Chen *et al.* (2010)[7]	Supraorbital keyhole surgery	Prospective cohort	2B	21	1. Ruptured intracranial aneurysms 2. Tumors of anterior fossa	Each patient's cosmesis was evaluated after the operation using a VASC.	Of the 19 patients who were followed-up, 89% of patients, and 84% by physician evaluation, were satisfied with the cosmetic result, noting >75 mm on the VASC.

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Table 1: *(Continued).*

Author	Approaches	Design of study	Evidence level (Oxford)	Number of patients	Baseline disease	Aesthetic outcome	Results
He *et al.* (2019)[19]	1. Supraorbital eyebrow approach 2. Pterional approach	Retrospective cohort	2B	25	Cranio-orbital lesion that communicated via the supraorbital fissure	During the follow-up period, the patients performed a rough subjective evaluation of their surgical aesthetic appearance, which was divided into 3 levels: satisfaction, neutrality, and dissatisfaction.	The patient-rated satisfaction scores obtained during the final visit showed that 92.3% (12 of 13) were satisfied, 7.7% (1 of 13) were neutral, and none were unsatisfied with the outcome after surgery in the SEA group. However, in the PA group, 41.7% (5 of 12) were satisfied, 50% (6 of 12) were neutral, and 8.3% (1 of 12) were unsatisfied. The SEA group reported greater patient satisfaction with the aesthetic appearance than the PA group (P=0.024). The incision in the SEA group (4.3±0.4 cm) was also significantly shorter than that in the PA group (13.6±0.8 cm; P 1⁄4 0.001).
Reisch *et al.* (2014)[33]	Supraorbital craniotomy	Retrospective cohort	2B	375	1. Cerebral aneurysms 2. Brain tumors 3. Cystic lesions 4. Miscellaneous pathological conditions	Patient satisfaction according to a postoperative cosmesis questionnaire on a scale from 1 to 5 (1 = very pleasant, 5 = very unpleasant), difficulty chewing, frontal weakness, frontal hypesthesia, and hyposmia.	Outcome was a score of 1 for 315 patients (84.0%), 2 for 33 (8.8%), 3 for 14 (3.7%), 4 for 10 (2.7%), and 5 for 3 (0.8%). Postoperative chewing difficulty was reported for 8 patients (8 [2.1%] temporary, 0 permanent); palsy of the frontal muscle for 21 patients (5.6%; 13 [3.5%] temporary, 8 [2.1%] permanent); frontal hypesthesia for 31 patients (8.3%; 18 [4.8%] temporary, 13 [3.4%] permanent)
Tang *et al.* (2013)[41]	Supraorbital keyhole approach	Retrospective cohort	2B	76	Anterior circulation aneurisms	Quantitative description of aesthetic adverse events	Five patients experienced permanent partial supraorbital hypesthesia as a result of lesion of the supraorbital nerve, but there was no depression of the operated site and palsy of the frontal muscle. Permanent unilateral hyposmia occurred in 6 patients. There was no frontalis branch palsy of the facial nerve. Wound healing disturbances were not observed.

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Table 1: *(Continued).*

Author	Approaches	Design of study	Evidence level (Oxford)	Number of patients	Baseline disease	Aesthetic outcome	Results
Ansari *et al.* (2020)[5]	Supraorbital eyebrow craniotomy w/modified pericranial flap	Retrospective cohort	2B	117	Tumors/cysts	Quantitative description of aesthetic adverse events	The modified pericranial flap technique used in 18 recent patients resulted in a shorter duration of transient frontalis paresis and forehead hypesthesia with complete functional recovery in all 18
Al-Otaibi *et al.* (2014)[3]	1. Minicraniotomy approach 2. Standard frontotemporal craniotomy	Retrospective cohort	2B	38	Standard temporal lobectomy	Quantitative and subjective description of aesthetic adverse events	Cosmetic outcome was excellent in group I while 4 patients in group II developed disfiguring depression at lateral sphenoid wing and anterior temple
Youssef *et al.* (2012)[48]	FTOZ approach	Prospective cohort	2B	75	1. Petroclival meningioma 2. Basilar aneurysm 3. P2 aneurysm 4. Pituitary adenoma 5. Trigeminal schwannoma 6. Sphenoid meningioma	Objective evaluation was conducted in the outpatient clinic setting. Subjective evaluation was based on the self-evaluation by the patients in regard to their postoperative appearance. Patients were assessed with a five-question survey that was sent in a delayed fashion from 6 months–6 years after surgery.	Overall, 22 patients (78.5%) were satisfied with the cosmetic outcome of surgery

PC: Pterional craniotomy, MPC: Minipterional craniotomy, f-SOKHA: Fronto-orbital variant of supraorbital keyhole approach, RMSO: Retromastoid suboccipital craniectomy, FTOZ: Frontotemporal-orbitozygomatic, TMJ: Temporomandibular joint, VAS: Visual Analog Scale, MCA: Middle cerebral artery, ICA: Internal carotid artery, VASC: Visual analog scale for cosmesis, LO: Lateral mini orbitotomy

Table 2: Complications related to different surgical approaches.

Approach	Related complication
MPC	Pain during mastication Functional limitations (mouth opening); Temporal muscle, subcutaneous tissue, and skin atrophy
Medpor® implants after PC	Not reported
Supraorbital approach	Frontal muscle weakness and frontal numbness
Pterional approach with temporal augmentation	Temporal muscle atrophy
Superciliary keyhole approach	Temporal muscle hollowing; Patient complaints; Partial ptosis.
Modified LO	Enophtalmy, cranial nerve palsy
FTOZ	CN-V palsy; CN-III palsy
Lateral supraorbital approach	Pain during mastication
Modified mini-orbitozygomatic craniotomy	Not reported
Orbitozygomatic craniotomy	Not reported
Frontolateral approach	Not reported
Osteoplastic craniotomy approach	Frontozygomatic fossa depression; Pain during mastication
PC with brushite CPC repair	Not reported
Transzygomatic pterional approach	Transient frontalis weakness
Transorbital keyhole approach	Frontal branch of the facial nerve weakness
Pterional keyhole approach	Weakness of the frontalis muscle
Subgaleal/myocutaneous technique	Transient postoperative partial frontalis palsy

PC: Pterional craniotomy, MPC: Minipterional craniotomy, LO: Lateral mini orbitotomy, FTOZ: Frontotemporal-orbitozygomatic, CN: Cranial nerve, CPC: Calcium phosphate cement

Moreover, there was no control group. The "myocutaneous flap," the "osteoplastic craniotomy" and the "osteomyoplastic craniotomy" are similar techniques that preserve the temporal muscle attached to the bone flap. There was just one randomized control trial and 2 observational studies showing significant differences regarding TMA compared to the conventional PC. However, the operative time may be a drawback of these techniques, which was just explored in one study and favored the conventional PC.[13] Some authors described using autologous bone or cement to "cover" and prevent the temporal hollowing seen postoperatively. Furthermore, the drawback of using the autologous temporal bone is related to the operative time. The mean operative time for temporal augmentation was 45 min in one study. The most

Table 3: Aesthetic outcomes evaluation proposal regarding the main analyzed variables.

Aesthetic criteria analyzed by the researcher	Classification
Temporal hollowing	0 – No temporal hollowing in the clinical evaluation 1 – Partial hollowing in the clinical evaluation 2 – Severe temporal hollowing
Frontal branch of the facial nerve weakness	0 – No paresis in the clinical evaluation 1 – Partial motor deficit 2 – Complete paresis
TMD	0 – No TMD 1 – TMD
Aesthetic criteria reported by the patient	Classification
VAS regarding personal aesthetic satisfaction	0 ←→10

TMD: Temporo-mandibular disfunction, VAS: Visual analogue scale. TMD was defined by patient reports or presentation with at least one of the three cardinal signs or symptoms of TMD: Jaw pain, limited mouth opening, or temporo-mandibular junction noise.[37]

cement used is the calcium phosphate cement, but also the use of Medpore is described. The advantage of such techniques is that it probably increases the costs of the surgery.

With the increasing concept of minimally invasive surgeries, techniques such as mini PC, supraorbital, and frontolateral approaches emerged. It seems logical to think that no or less temporal muscle handling, lesser would be the temporal hollowing. The MPC seems to be an excellent option for unruptured anterior circulation aneurysms,[1,39,43] but there are also reports on its use for ruptured aneurysms.[15] These studies showed a decrease in temporal hollowing, pain, and masticatory dysfunctions. The use of a supraciliary incision to perform a supraorbital approach, highly performed and described in the literature by Prof. Romani *et al*.,[35] may be a matter of discussion regarding the incision esthetics outcome. However, it is non-inferior to the conventional Yasargil *et al*.[46] incision when it comes to scar tenderness. Moreover, as expected, temporal hollowing is prevented by more conservative approaches.

Temporomandibular dysfunction (TMD)

TMD is one the most described adverse aesthetic event among the studies. However, no adequate quantification of the event was made by the authors. Costa *et al*.[9] showed a high incidence of muscle pain and temporomandibular joint (TMJ) pain in patients after surgery. This result indicates that the surgery, and most likely the post-operative inflammation, affects the TMJ function of surrounding areas, including the masticatory

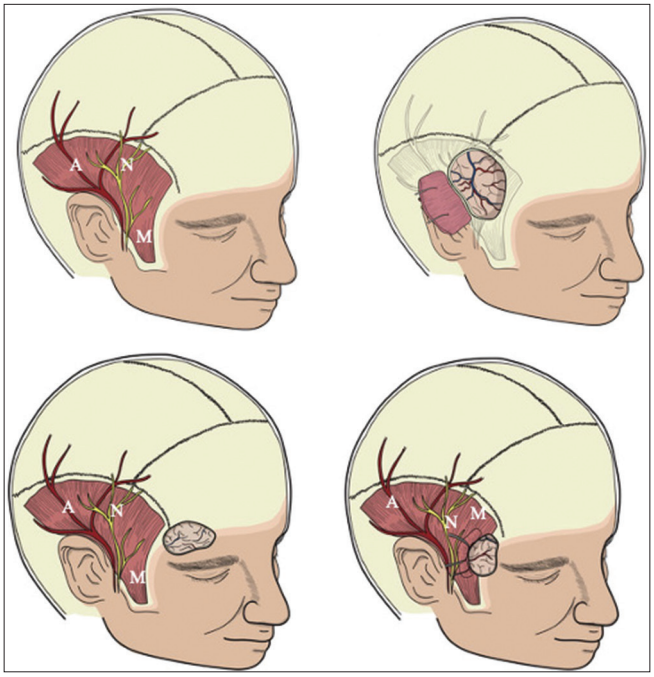

Figure 3: Schematic representation of the minimally invasive approaches compared with standard pterional craniotomy. A – Superficial Temporal Artery; N – Frontal Branch of Facial Nerve; M – Superficial Temporal Muscle. (a) Preoperative illustration of the main affected structures potentially damaged in surgery. (b) Schematic illustration of the standard pterional craniotomy and structures potentially damaged in surgery. (c) Schematic illustration of the supraorbital craniotomy. Note that due to the location of the approach, the main complaints are frontal muscle weakness and frontal numbness. (d) Schematic illustration of the minipterional craniotomy and structures potentially damaged in surgery. This technique aims to minimize temporal hollowing and adverse effects related to the superficial temporal artery and the frontal branch of facial nerve.

muscles, which contribute to developing TMD. MIS can possibly minimize the incidence of TMJ related complications.[26,32,49]

Skin incision

Other incisions, such as those to perform the modified miniorbitomy or the pterional keyhole approach, generate concerns since the incision is out of the hairline. However, the patients submitted to the later were overall satisfied with the final esthetic result. As the patients submitted to the miniorbitomy had orbital meningiomas, the central concern was exophthalmos. This study did not evaluate scars.[4]

Patient-reported outcomes (PRO)

PRO are highly relevant. This tool is a regularly used indicator for measuring health care quality.[25] The patient-centered treatment guides the majority of the guidelines today. The esthetic outcomes from the patient's opinion should be taken into consideration whenever possible. In this scoping review, we found only ten articles evaluating PRO.

Among the 38 articles gathered in this study, 27 (71.05%) were retrospective cohorts, with low evidence levels. Only 5 (13.15%) clinical trials met the criteria with a JADAD score of 1 in 2 studies. The remaining three clinical trials had the JADAD score of 0.4 (10.52%) prospective cohorts were included in the study. These articles had a poor description of the methods used to assess cosmetic outcomes, jeopardizing our analysis. More studies should be performed to properly evaluate PRO and the impacts of the different types of craniotomy in patients' overall satisfaction.

An important limitation observed in practically all studies is that the analysis of aesthetic aspects in the postoperative period of brain surgery is superficial. This results mainly from the severity of the diseases treated, presenting life-threatening, and risk to functional neurological sequelae. However, components that involve the patient's quality of life have progressively gained relevance more recently. The use of non-surgical treatments with radiosurgery and embolization of aneurysms requires an improvement in PC techniques.[43] Subjective evaluation of cosmetic outcomes is relevant,[31] but it has a limitation in the evaluation of minimally invasive techniques. The development of scales for esthetics outcomes analysis maybe can bring more precision for comparing surgical techniques. For other surgeries, its possible use of modified Stony Brook Scar Evaluation Scale and Manchester Scar Scale.[25] For PC maybe development of specific cosmetic outcome scale analyzing scar, muscle atrophy and bony deformation can be an interesting idea.

CONCLUSION

This review showed that the prime esthetic outcomes were TMA, frontal branch weakness, and scar. Several alternative techniques to the PC can be adopted to minimize the drawbacks mentioned above, which appear to be successfully overcome by minimally invasive approaches. The use of one procedure over another must consider the baseline disease, area of exposure, and surgeon expertise. Furthermore, temporozygomatic region primary augmentation with bone or other materials safely prevents temporal hollowing. Finally, an adequate evaluation of the various pterional surgeries is still lacking due to the limited prospective high-quality researches.

Study limitations

This article is not a systematic review; therefore it was not submitted in the PROSPERO database. Furthermore, the studies included did not provide a uniform and systemic method to evaluate the aesthetic outcomes when comparing

different approaches. This applies also to a viable quantitative analysis since most articles had no specific quantification of the aesthetic adverse events.

Declaration of patient consent

Patient's consent not required as patients identity is not disclosed or compromised.

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Conflicts of interest

There are no conflicts of interest.

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