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Reconstructive

Decompression Surgery for Frontal Migraine Headache

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Introduction: Migraine headache (MH) is one of the most common diseases worldwide and pharmaceutical treatment is considered the gold standard. Nevertheless, one-third of patients suffering from migraine headaches are unresponsive to medical management and meet the criteria for "refractory migraines" classification. Surgical treatment of MH might represent a supplementary alternative for this category of patients when pharmaceutical treatment does not allow for satisfactory results. The goal of this article is to provide a comprehensive review of the literature regarding surgical treatment for site I migraine management.

Methods: A literature search using PubMed, Medline, Cochrane and Google Scholar database according to Preferred Reporting Items for Systematic Reviews and Meta-Analysis guidelines was conducted using the following MeSH terms: "frontal neuralgia," "frontal trigger site treatment," "frontal migraine surgery" and "frontal headache surgery" (period: 2000 -2020; last search on 12 March 2020).

Results: Eighteen studies published between 2000 and 2019, with a total of 628 patients, were considered eligible. Between 68% and 93% of patients obtained satisfactory postoperative results. Complete migraine elimination rate ranged from 28.3% to 59%, and significant improvement (>50% reduction) rates varied from 26.5% to 60%.

Conclusions: Our systematic review of the literature suggests that frontal trigger site nerve decompression could possibly be an effective strategy to treat migraine refractory patients, providing significant improvement of symptoms in a considerable percentage of patients. *(Plast Reconstr Surg Glob Open 2020;8:e3084; doi: 10.1097/GOX.0000000000003084; Published online 15 October 2020.)*

INTRODUCTION

Migraine headache (MH) is one of the most common diseases worldwide, reportedly afflicting more than 11% of the adult population, approximately 35 million Americans in the United States.[1] MH affects working-aged female patients (25- to 50-year-olds), resulting more commonly in an annual economic loss of approximately $14 billion in the United States.[2,3] Pharmaceutical and behavioral treatment is considered the gold standard. Despite this, between 5% and one-third of MH patients meet criteria for "refractory migraines" demonstrating unresponsiveness to medical management or intolerance to pharmacological side effects.[4–6] Surgical treatment of MH might represent a supplementary alternative for this category of patients when pharmaceutical treatment does not allow for satisfactory results. Surgical strategy is based on the decompression of peripheral sensory nerve branches considered to be migraine trigger points. Since 2000,[7] the efficacy and cost-effective modality of surgical deactivation has been confirmed in over 40 scientific studies published by various centers.[8–19] The migraine trigger points correspond to branches of the trigeminal and the greater occipital nerves in 3 different craniofacial regions (frontal, temporal, and occipital) corresponding to 6 different sites (Table 1).

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Trigger site I migraine is most common[20] and originates from the irritation of the supraorbital (SON) and supratrochlear nerves (STN), as well as the terminal branches of the frontal nerve. Different anatomical studies have been conducted to better understand supraorbital and supratrochlear nerve anatomy and to identify their possible irritation points.[21–24] The supratrochlear nerve exits the orbit medially, runs along its medial roof, and penetrates into the corrugator at about 1.8 cm from the midline, exiting the muscle approximately 2 cm from the midline.[24,25] In most cases, the nerve splits into 2 branches in the retro-orbicularis oculi fat pad before penetrating the muscle.[25] The supraorbital nerve exits the orbit via a supraorbital notch or via a foramen, splitting in a superficial and in a deep branch.[21–23] Four different patterns of branching were identified based on their interaction with the corrugator muscle.[24] However, different studies show that the mean distance of supraorbital nerve entrance into the brow and the midline is about 2.7 cm.[21,22,25] The irritation mechanism depends on the compression of the nerve structures by either their arteries, the glabellar muscles group (procerus, depressor, and corrugator supercilii), the supraorbital foramen, or by a fascial band present at the supraorbital notch.

Clinically, patients affected by trigger site I MH usually report pain starting above the eyebrows and show deep frown lines and corrugator muscles hypertrophy or eyelid ptosis.[26] Often, clinical history and clinical examination (tenderness of the trigger point at manual compression) are sufficient to clearly identify the MH trigger site.[19] Complementary signs can be an audible vessel signal using a handheld Doppler on the trigger point, botulinum toxin-A injection[27] (useful only in case of “non-vascular” etiology), or local anesthetic injection if the patient examination is contextual to a pain episode.[26]

Currently, frontal trigger site deactivation is performed through a transpalpebral or an endoscopic approach, under local anesthesia, sedo-analgesia, or general anesthesia, including different surgical procedures. The goal of this article is to provide a comprehensive review of the literature about surgical treatment for site I migraine management.

METHODS

A literature search using PubMed, Medline, Cochrane, and Google Scholar database according to Preferred Reporting Items for Systematic Reviews and Meta-Analysis (PRISMA) guidelines was conducted to perform a review of the different surgical techniques and to evaluate the outcomes of surgical deactivation of frontal trigger site migraines. The following MeSH terms were used: “frontal neuralgia,” “frontal trigger site treatment,” “frontal migraine surgery,” and “frontal headache surgery” (period: 2000–2020; last search conducted on March 12, 2020). Two independent reviewers performed two-stage screening and data extraction. Abstracts were screened to identify eligible papers. Reference lists of relevant articles were searched for additional studies. The search strategy is shown in the form of a flow chart (Fig. 1).

Table 1. Six Different Migraine Trigger Sites Corresponding to Branches of the Trigeminal and the Greater Occipital Nerves in 3 Different Craniofacial Regions

Trigger Site	Trigger Site	Corresponding Nerve
Site I	Frontal	Supratrochlear and supraorbital nerves
Site II	Temporal	Zygomatico-temporal branch of the trigeminal nerve
Site III	Septo-nasal	–
Site IV	Occipital	Great occipital nerve
Site V	Auricolo-temporalis	Auriculo-temporal nerve
Site VI	Lesser occipital	Lesser occipital nerve

Inclusion and Exclusion Criteria

Studies were selected based on the following inclusion criteria: (i) studies selectively investigating surgical treatment of frontal headache; (ii) studies that include more than 10 patients; (iii) full text available in English. Studies were excluded due to any one of the following criteria: (i) review articles; (ii) case report; (iii) articles reporting only radiologic anatomic data; (iv) studies that included fewer than 10 patients; (v) studies investigating simultaneous decompression of multiple sites surgical site I decompression (vi) contextual to other sites decompression; (vii) non-referenced articles; and (viii) expert opinion (Level V).

Data Collection

Extracted data included: number of patients, sex, mean age, surgical strategy (incision type, myotomy versus muscle, foraminotomy, fasciotomy, and vessel obliteration), mean follow-up time, method of outcome measurements used, outcomes after surgical treatment (including resolution of migraine headache and postoperative complication).

Statistical Analysis

Statistical analyses were performed using SPSS statistical software (version 24.0; IBM Corporation, Somers, N.Y.).

RESULTS

After duplicate exclusion, 1266 articles were identified. Two different reviewers analyzed all the records by titles and abstracts. Forty full-text articles were examined for eligibility. Eighteen studies published between 2000 and 2019 were considered eligible and included in this systematic review based on appropriateness, relevance, and actuality[7, 28–44] (Fig. 1).

From the 16 selected studies, 6 were retrospective studies,[7,32–34,37,39] 11 were prospective studies,[28–31,35,36,38,40–42] of which 1 was a blinded randomized cohort study,[41] 1 was a double-blind, sham surgery, controlled clinical trial,[30] and 1 was a cross sectional study.[40] A total of 628 patients were included in the review, and the sample size of each study ranged from 10 to 132 patients. Ten of 16 studies reported patient gender showing female prevalence ranged from 68.14% to 100%. Twelve of 16 studies reported the age of patients (as mean or as range). Moreover, two additional studies investigating supraorbital region anatomy were included[43,44]: one study[43] described the supraorbital

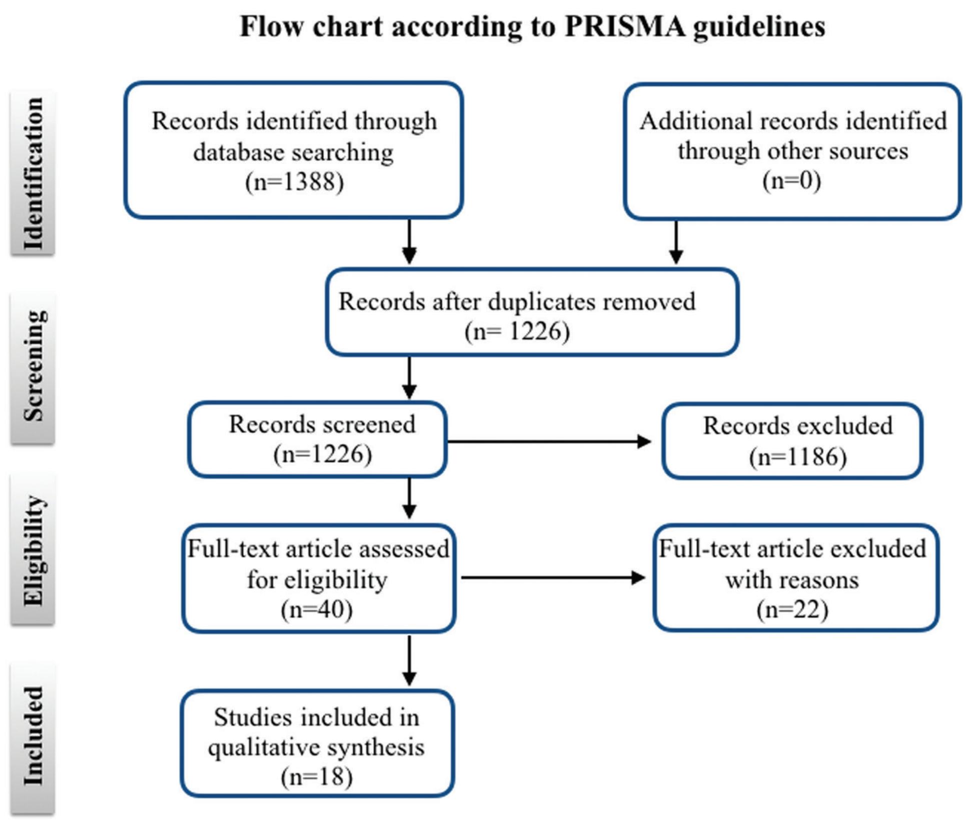

Fig. 1. PRISMA guidelines.

anatomy in 30 cadavers and the other[44] reported the intraoperative findings in 61 patients who had undergone multiple site deactivation surgery.

Concerning surgical techniques, 2 different approaches were mentioned. Seven studies reported a transpalpebral approach[28–30,39,40,43,44]; 6 studies reported an endoscopic approach[31,35–38,42] and 5 studies reported both.[27,31–34,41] Studies further mentioned that among endoscopic techniques from 1 single incision (1.5 cm) to 5 incisions, all were positioned behind the hairline. Moreover, the tip to place three surgical sutures bilaterally in the superciliary region to lift the frontal skin allowing for better visualization of the SON, STN, and the surrounding muscles[36–38] was given. Among transpalpebral approaches, 5 studies referenced the transposition of fat from the medial compartment of the upper eyelid to fill any defect left by the excised muscles.[31–34,40] One paper[34] consisted of a comparative study between the two approaches and reported significantly higher success and elimination rates in the endoscopic decompression group than in the transpalpebral decompression group (89% versus 79%, $P < 0.05$ and 67% versus 52%, $P < 0.03$, respectively). In any case, the surgical approach corrugator and depressor supercilii resections or myotomies and careful preservation of SON and STN were described in all the procedures. Procerus muscle weakening was reported in 10 articles.[29,30,32–38,40] Three articles expressly mentioned vessels coagulation or arterectomy.[28,34,41] Three articles[32,34,41] expressly mentioned foraminotomy using a percutaneous 2 mm osteotome to perform a supraorbital foramen release,[32] and 2 articles expressly mentioned fasciotomy.[34,41]

The anatomical cadaveric study included in the review[43] reported the presence of a supraorbital foramen or a supraorbital notch in 26.6% and 83.3% of the sample, respectively. Moreover, this study[43] documented the existence of a fascial band encasing the supraorbital neurovascular bundle in 86% of the supraorbital region that contained a notch. A recent study[44] describing the intraoperative anatomy of the supraorbital region on 118 sites reported a supraorbital nerve foramen and a supraorbital nerve notch prevalence pair to 41% and 49%, respectively. In addition, SON or STN compression appeared macroscopically evident in 95% of cases. Another interesting finding was the presence of nerve edema, nerve flattening, or nerve discoloration in 74% of patients.

Table 2 shows the study characteristics and data collection regarding surgical strategies (surgical approach, incision type, glabellar muscle resection, formaninotomy, fasciotomy, or arterectomy).

With respect to outcome measurements, the most frequently used methods were migraine headache index (MHI)[32,33,38,41] and the headache questionnaire.[36–39,42]

Follow-up period varied from 6 months to 126 months. The majority of the studies defined a successful migraine treatment as migraine attack elimination or at least a 50% reduction of its symptoms.

Eleven studies[27–29,31,33–39] reported the success rate as a percent value. Overall, 68.3%–93.3% of patients presented satisfactory results. Specifically, the complete elimination of migraine attacks varied from 28.3% to 59.1%, and the rate of significant improvement (at least a 50% reduction of symptoms) varied from 26.5% to 60.5%.

A double-blind controlled clinical trial[30] compared two groups of patients who had undergone actual surgery and sham surgery (placebo), expressing the result as an absolute score using the Migraine Disability Assessment, the Migraine-Specific Quality of Life, and the Medical Outcomes Study 36-Item Short Form Health Survey, where significantly better results were observed in the actual surgery group. Another comparative study[32] investigated the difference between performing only glabellar myectomy and performing glabellar myectomy combined with supraorbital foraminotomy. This study used MH severity, frequency, and duration, as well as the MHI and the forehead pain score and reported significantly better results in the group of patients who had undergone a glabellar myectomy combined with supraorbital foraminotomy compared with the group who had only undergone a myectomy (postoperative migraine frequency: 7.8 per month versus 4.1 per month; postoperative migraine severity: 5.6 versus 4.4; MHI: 26.5 versus 11.12; persistent forehead pain: 48.8% versus 25.6%). Punjabi et al[40] analyzed the appearance of secondary trigger sites after decompression primary surgery showing that the most frequent unmasked secondary trigger after site I surgery is in site III (20.83%). Another article[41] suggested that patients who had undergone arterectomy obtained better outcomes in terms of MHI (51.71 versus 5.55), MFD (18 versus 24), and frequency (12 versus 6.11) compared with patients who had not undergone arterectomy. Moreover, 31% of patients who had not undergone arterectomy needed a second surgery consisting of a revision arterectomy and after the procedure showed a statistically equivalent improvement in MFD (20.75 versus 24, $P = 0.178$) compared with the patients who had undergone arterectomy as primary surgery. Finally, the most recent study included in the review[37] showed a decrease in VAS headache intensity from 8.10 before surgery to 1.09 after surgery ($P < 0.001$).

Seven of 16 studies mentioned postoperative complications.[27–31,39,42] The most common complication reported in 6 studies[27–29,31,39,42] was transient paresthesia, followed by pruritus reported in 2 studies,[30,39] and eyebrow asymmetry or uneven movement,[27,30] frontal muscle paralysis,[27] eyelid ptosis[39] and hematoma formation reported in one patient.[31] Many authors suggest wearing a compressive bandage for 24–48 hours after surgery.

Table 3 reports in detail the outcomes after the surgical treatment of each study (outcome measures method, MH elimination or improvement, patient satisfaction, and postoperative complications).

DISCUSSION

Since the unexpected finding of frontal headache amelioration consequent to glabellar muscle resection and periosteal release performed during brow-lift procedures,[27] the field of migraine surgery has rapidly progressed. Our study evidences the positive effects of frontal nerve decompression surgery and underlines how the migraine surgical field is still evolving. In our review, seven studies reported a transpalpebral approach, 6 studies reported an endoscopic approach, and 5 studies reported both. This proportion denotes that there is still no consensus as to what the best approach to treat frontal migraine is. The transpalpebral approach consents the direct visualization and the excision of the glabellar muscles, leaving the periosteal and the fascial structures undamaged. This can be considered as an extension of an upper eyelid blepharoplasty. The anatomical findings that emerged from the two studies included in the review[43,44] reported a relatively high prevalence of supraorbital foramen, supraorbital notch, and fascial band encasing the supraorbital neurovascular bundle, which may suggest that a transpalpebral approach allows for better visualization and treatment of nerve compression. Conversely, some authors argue that the endoscopic technique, at the same time allowing a complete periosteal release on the orbital ridge and a wide glabellar muscles dissection, should be considered as the best choice whenever anatomically possible. The endoscopic approach is not recommended for patients with a forehead length greater than 8 cm or patients presenting with a protruding forehead.[45] A retrospective study[34] included in our review reported significantly higher success rates in cases of endoscopic approach than in the transpalpebral option. As aforementioned, among the described endoscopic techniques, surgical access varies from 1 single incision of 1.5 cm to 5 incisions, all of which are positioned behind the hairline. The minimally invasive technique described by Raposio,[36–38,46–48] in addition to the single midline incision, requires the use of a modified endoscope and the placement of 3 surgical sutures bilaterally in the superciliary region to have a better visualization of the anatomical structures lifting the frontal skin.

Regardless of the approach, another noticeable difference among the studies is related to surgical procedures. All the authors agree that glabellar muscles group excision and SON and STN preservation are mandatory. The necessity to perform an arterectomy, a fasciotomy, and a foraminotomy is still a matter of debate. Gatherwright,[41] in a prospective blinded randomized cohort study, demonstrated the role of arterectomy in frontal migraine surgery showing that patients who undergo arterectomy obtain better outcomes. Moreover, the study reported that in about 30% of cases, patients who had not undergone arterectomy needed a revision consisting of an arterectomy; after which, a statistically equivalent improvement was achieved when compared with patients who had undergone arterectomy as the primary surgery. Another retrospective comparative study[32] investigated the role of supraorbital foraminotomy proving a reduction of migraine frequency, migraine severity, MHI, and forehead pain in patients who had undergone foraminotomy. This clinical finding is supported by recent radiological and anatomical evidence[49] showing that SON and especially supraorbital foramen contribute significantly to MH symptoms. This radiological study suggests that an analysis

Table 2. Study Characteristics and Data Collection Regarding Surgical Strategies

Study	Type	Sample (patients)	Surgical Incision	Surgical Strategy
Guyuron et al[7]	Retrospective analysis	39	TP or E or open	Resection of the corrugator and depressor muscles
Dirnberger and Becker[28]	Prospective	60 Female: 78.3%	TP	Resection of the corrugator and depressor muscles, vessels coagulation by bipolar diathermy
Bearden and Anderson[29]	Prospective	12	TP (combined with blepharoplasty)	Resection of the corrugator and depressor muscles, procerus muscle weakening
Guyuron et al[30]	Double-blind, sham surgery, controlled clinical trial	29 Actual surgery: 19 Sham surgery: 10	TP	Resection of corrugator, depressor and procerus muscle + fat from medial compartment of the upper eyelid to fill any defect left by the excised muscles
de Ru et al[31]	Prospective	10 Mean age: 30.7 y Female: 100%	E 3 small incisions above the hairline	Cleavage of the corrugator muscle
Chepla et al[32]	Retrospective analysis	86 Mean age: 42.5 y versus 46.4 y Female: 97.67%	TP or E	Group 1: glabellar myectomy Group 2: glabellar myectomy + supraorbital foraminotomy
Lee et al[33]	Retrospective analysis	132 Mean age: 44.6 y versus 44.7 y	TP or E	Resection of corrugator, depressor, and lateral portion of the procerus + fat from medial compartment of the upper eyelid to fill any defect left by the excised muscles
Liu et al[34]	Retrospective analysis	35 Mean age: 45.3 y versus 44.7 y Female: 89.3%	TP or E	– Resection of corrugator, depressor and lateral portion of the procerus + fat from medial compartment of the upper eyelid to fill any defect left by the excised muscles – Removal of the vessels accompanying the nerves – Foraminotomy when a foramen was present – Release of the fibrous bands across the supraorbital notch when a notch was present
Caruana et al[35]	Prospective	54 Age range: 18–75 y	E	Frontal bilateral selective myotomy procedure of procerus, depressor, and corrugator muscles
Caruana et al[36]	Prospective	16 Age range: 27–72 y Female: 80%	E 2 incisions (1.5 cm) above the hairline, positioned 4 cm from the midline Placement of 3 surgical sutures in the superciliary region to lift the frontal skin	Resection of corrugator, depressor, and procerus muscles
Polotto et al[37]	Retrospective analysis	43 Age range: 18–72 y Female: 88.3%	E One midline scalp incision (length: 1.5 cm)	Selective myotomies of corrugator, depressor, and procerus muscles
Raposio and Caruana[38]	Prospective	43 Age range: 18–72 y Female: 88.3%	E 3–5 incisions (length: 1.5 cm) behind the hairline using a specifically modified endoscope Placement of 3 surgical sutures in the superciliary region to lift the frontal skin	Corrugator, depressor, and procerus muscles section performing one myotomy (full-thickness to reach the subcutaneous tissue) per side parallel and approximately 2 mm medially and laterally to each nerve
Kurlander et al[39]	Retrospective analysis	34 Age range: 20–70 y Female: 89.6%	TP	Corrugator resection
Punjabi et al[40]	Cross- sectional study	185	TP	Corrugator, depressor, and procerus resection + fat from medial compartment of the upper eyelid to fill any defect left by the excised muscles
Gatherwright et al[41]	Prospective, blinded randomized cohort study	13 Mean age: 41.8 y Female: 100%	TP	4 groups: 1. Myectomy 2. Myectomy + foraminotomy/fasciotomy 3. Myectomy + arterectomy 4. Forminotomy/fasciotomy
Filipovic et al[42]	Prospective	22 Mean age: 42 y Female: 68.1%	E	Complete release of STN and SON by cutting the periosteum at the level of the supraorbital ridge Glabellar muscles were not removed
Fallucco et al[43]	Cadaveric study	30	TP	Transpalpebral bilateral approach
Ortiz et al[44]	Prospective	61	TP	Transpalpebral bilateral approach

E, endoscopic approach; TP, transpalpebral approach.

Table 3. Outcomes of Surgical Deactivation of Frontal Trigger Site Migraine

Study	Sample (patients)	Outcomes Measurements	Follow-up (mo)	Results	Complications
Guyuron et al[7]	39	–	46.5	79.5% positive response 38.4% → elimination 41% → significant improvement	–Paresthesia –Eyebrow asymmetry –Frontalis muscle paralysis
Dirnberger[28]	60	% reduction of MH days, drugs, side effects, and severity of MH Patient satisfaction using a scale from 1 to 5 (1 = elimination; 5 = any change)	6 and 18	68.3% positive response 28.3% → elimination 40% →significant improvement 31.7% → minimal or no change	Paraesthesia, disappeared in all patients within 3–9 months.
Bearden and Anderson[29]	12	Onset, frequency, severity, and duration of MH episodes; headache medications; and botulinum toxin	6–19	92% →improvement	Any
Guyuron et al[30]	29 Actual surgery 19 Sham surgery 10	–Migraine Disability Assessment –MSQEM –Medical Outcomes Study 36-Item Short Form Health Survey	12	*Baseline actual surgery versus sham surgery*: –Frequency: 9.8 versus 7.6–Intensity: 5.9 versus 6.1 –Duration: 0.56 versus 1.1–MHI: 24.3 versus 27.5 –MSQEM: 48.8 versus 37.2–Study 36-Item –Short Form Health Survey: 45.4 versus 46.7 *1 year postoperative actual surgery versus sham surgery* –Frequency: 6.37 ($P < 0.001$) versus 1.5 ($P < 0.18$) –Intensity: 2.5 ($P = 0.005$) versus 2.1 ($P = 0.51$) –Duration: 0.24 ($P = 0.01$) versus 0.18 ($P = 0.57$) –MHI: 15.4 ($P = 0.003$) versus 12.2 ($P = 0.03$) –MSQEM: 24 ($P = 0.02$) versus 0.46 ($P = 0.97$) –36-Item Short Form Health Survey: 5.9 ($P = 0.002$) versus 1.5 ($P = 0.51$)	–Temporary intense pruritus →11% –Uneven brow movement →5% –Residual corrugator muscle function →5%
de Ru et al[31]	10	Pain severity scoring verbal numerical rating scale (NRS): from 0 (no pain) to 10 (severe pain)	3–30	90% → lowered pain score (from 8.1 to 0.8) 10% → any change	Numbness in 3 patients Paresthesia and hematoma formation in 1 patient
Chepla et al[32]	86	MH severity, frequency, and duration MHI Forehead pain	12	*Glabellar myectomy versus Glabellar myectomy + supraorbital foraminotomy* Postoperative migraine frequency: 7.8 versus 4.1 per month Severity: 5.6 versus 4.4 MHI: 26.5 versus 11.1 Persistent forehead pain: 48.8% versus 25.6%	Not reported
Lee et al[33]	132	MHI (success defined as >50% of reduction) 2 groups: a) preoperative BTA responsive (109 patients) b) preoperative BTA NON responsive (23 patients)	>12	*Total*: 83.3% → positive response 56.8% → elimination 26.5 → >50% reduction *BTA responsive versus BTA NON responsive group*: Migraine elimination: 33.7% versus 7.6% >50% reduction: 92.5% versus 69.2%	Not reported
Liu et al[34]	35	MH frequency, duration and intensity	12–126 (mean: 34)	77% → positive response	Not reported
Caruana et al[35]	54 Age range: 18–75 y	36-item short questionnaire (before surgery) 29-item short questionnaire (6 months and 2 years after surgery)	24	*6 months* (51 patients): 84.3% → positive response 41.2% → elimination 43.1% → significant improvement 2 *years* (29 patients): 89.6% → positive response 31% → complete elimination 58.6% → significant improvement	Not reported
Caruana et al[36]	16	Headache questionnaire	–	81.5% → positive response 31.5% → elimination 50% → significant improvement	Not reported
Polotto et al[37]	43	Headache questionnaire	24	93.3% → positive response to the surgery: 33.3% → complete elimination 60% → significant improvement	Not reported

(*Continued*)

Table 3. (*Continued*)

Study	Sample (patients)	Outcomes Measurements	Follow-up (mo)	Results	Complications
Raposio and Caruana[38]	43	Headache questionnaire	6 and 24	*6-month-long follow-up* (43 patients): 81.4% → positive response 39.5% → elimination 41.9% → significant improvement *2-year-long follow-up* (15 patients): 93.3% →positive response 33.3% → elimination 60% →significant improvement	Not reported
Kurlander et al[39]	34	Frontal-specific MHI Reduction in migraine days (duration × frequency)	12	88% → positive response 59% → elimination	Numbness →32.1% Pruritus →8.9% Hypersensitivity →8.9% Eyelid Ptosis →3.6%
Punjabi et al[40]	185	Migraine headache questionnaire	13	17.8% of the cohort reported new postoperative migraines Site I: 20.83% → Site III (septo-nasal) unmasked after surgery	Not reported
Gatherwright et al[41]	13	Migraine headache severity and duration MHI MFDs	21.6 (7.6–34.1)	MHI: from 52.6 (3.8–85) to 4.7(0–21.3), *P = 0.0001* *Arterectomy group* (9 patients): MHI: from 51.71 to 5.55 Frequency: 12 versus 6.11 Improvement MFDs: from 18 to 24 *No arterectomy* (4 patients): Improvement MFDs: 13.25 *Less than arterectomy group* (13.25 versus 24 MFDs): 31% required a site I revision that included an arterectomy. Following revision, both groups had statistically equivalent improvement in MFDs (20.75 versus 24 MFDs)	Not reported
Filipovic et al[42]	22	Daily headache diary (4 points only) Headache questionnaire	12–107 (mean: 29.5)	VAS headache intensity from 8.10 to 1.3 at 3 months after surgery and to 1.09 at 12 months after surgery Accompanying headache symptoms (photophobia, phonophobia, nausea, and vomiting) were completely abolished in all patients, except in 1 case	–Transient paresthesia → 2 patients (3 months duration) –Temporary hair loss above the incision → 1 patient (12 months duration)
Fallucco et al[43]	30	–	–	–Supraorbital foramen → 26.6% of cases –Supraorbital notch → 83.3% of cases –Fascial band → 86% of supraorbital region that contained a notch and classified into 3 types	–
Ortiz et al[44]	61	–	–	–Supraorbital foramen → 41% of cases –Supraorbital notch → 49% of cases –Supraorbital foramen and notch → 9.3% of cases SON (66%) or STN (29%) Compression → 95% of cases. Nerve edema, flattening, or discoloration → 74%	–

BTA, botulinum toxin type A; MFD, migraine-free days; MSQEM, Migraine-Specific Quality of Life.

of all available face or perinasal sinus CT images could be helpful in preoperative planning, possibly including foraminotomy and fasciotomy.

An important criticism in frontal migraine management is the lack of consensus among clinicians regarding the methods to measure surgical outcomes. In our review the most frequently used methods were MHI[7,28,34,36] and the headache questionnaire.[36–38,40,42] Quality of life documentation before and after a migraine surgery is exiguous, mirroring the literature regarding trigger site decompression surgery. In our opinion, to improve the migraine surgery effect reporting, future investigations should spotlight what is the most complete evaluation method to universalize outcome measurements.

Patient follow-up period varied from 6 to 126 months; results were considered as stable three months after surgery by most of the authors. Overall, 68.3%–93.3% of patients presented satisfactory results. Complete migraine elimination rate ranged from 28.3% to 59% and significant improvement (>50% of reduction) rate varied from

26.5% to 60%. The wide range can be justified by the fact that different surgical techniques were performed. One double-blind controlled clinical trial[30] compared actual surgery and sham surgery (placebo), showing significantly better results in the actual surgery group. Consensus about why some patients remain refractory to frontal migraine surgery has yet to be reached. The frontal migraine crisis pathogenesis remains unclear and additional clinical and anatomical studies have to be accomplished to improve surgical outcomes.

Undeniably, some authors are not convinced that decompression surgery represents an effective treatment for headaches[50,51] and the neural entrapment theory is still a matter of debate. Certainly, the lack of clarity regarding patient selection criteria, the scarcity of controlled studies, the lack of consistent outcome measures, and the relative brevity of follow-ups represent weak points that can lead to prejudiced results. However, recent studies have described intraoperative findings of SON and STN compression, nerve edema, flattening, or discoloration, thus demonstrating the concreteness and the anatomical-clinical correlation of the neural entrapment theory. In our opinion, standardization of patient selection and outcome measures after decompression surgery are the most critical points needed to convince neurologists of the effectiveness of this type of treatment in selected patients. In fact, the MHI represents a non-validated instrument that may increase the possibility of obtaining positive results.[49] A constructive and open discussion between surgeon and neurologist would surely improve the management of these patients and allow for the building of an integrated therapeutic algorithm to better evaluate the postoperative results.

Postoperative complications were relatively rare and a few were reported. The most common complication was a transient paresthesia, followed by pruritus, eyebrow asymmetry or uneven movement, frontal muscle paralysis, eyelid ptosis, and hematoma formation.

CONCLUSIONS

Our systematic review of the literature suggests that frontal trigger site nerve decompression may be an effective strategy to treat migraine refractory patients, allowing for the resolution or at least a significant improvement of symptoms in a considerable percentage of patients. However, the poor quality of the included studies, the scarcity of controlled trials, the lack of consistent outcome measures, and the multitude of varied surgical techniques do not permit the conclusion of efficacy with respect to frontal migraine surgical treatment. Certainly, higher level studies need to be conducted to confirm the effectiveness of this treatment. Moreover, why some patients are still unresponsive to surgical treatment is still a matter of discussion.

Nowadays, there is not a standard surgical technique. Prospective studies to compare excision or blunt dissection of the glabellar muscles, periosteum release, vessel coagulation and foraminotomy would be helpful to reach a better understanding as to what is the best surgical strategy to treat these patients.

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