

RHINOLOGY SECTION

The role of the osteoplastic flap in the endoscopic era: a retrospective multicentre experience on revision surgery

Il ruolo del lembo osteoplastico nell'era della chirurgia endoscopica: esperienza retrospettiva multicentrica sulla chirurgia di revisione

Fabio Pagella^{1,2}, Eugenia Maiorano², Mario Turri-Zanoni³, Marco Ferrari⁴, Paolo Carena², Cesare Zoia⁵, Camilla Czaczkes³, Carlo Conti⁶, Alberto Schreiber⁶, Paolo Battaglia³, Enzo Emanuelli^{4,7}, Stefano Pelucchi⁸, Maurizio Bignami^{9,10}, Piero Nicolai⁴, Paolo Castelnuovo³

¹ Department of Surgical Science, University of Pavia, Pavia, Italy; ² Department of Otorhinolaryngology, Fondazione IRCCS Policlinico San Matteo, Pavia, Italy; ³ Division of Otorhinolaryngology, Department of Biotechnology and Life Sciences, University of Insubria, ASST Sette Laghi Hospital, Varese, Italy; ⁴ Section of Otorhinolaryngology - Head and Neck Surgery, Department of Neurosciences, University of Padua, Italy; ⁵ Neurosurgery Unit, Fondazione IRCCS Policlinico San Matteo, Pavia, Italy; ⁶ Unit of Otorhinolaryngology, Head and Neck Surgery, Department of Surgical Specialties, Radiological Sciences and Public Health, University of Brescia, Brescia, Italy; ⁷ Unit of Otolaryngology, AULSS 2 - Marca Trevigiana, Treviso, Italy; ⁸ Ear-Nose-Throat & Audiology Unit, University of Ferrara, Ferrara, Italy; ⁹ Department of Otorhinolaryngology, Department of Surgery, ASST Lariana, University of Insubria, Como, Italy; ¹⁰ Head and Neck Surgery & Forensic Dissection Research Center (HNS&FDRc), Department of Biotechnology and Life Sciences, University of Insubria, Varese, Italy

SUMMARY

Objective. To retrospectively review the experience of five tertiary-care university hospitals on frontal sinus revision surgery with osteoplastic flap (OPF).

Methods. Descriptive analysis of patients who underwent frontal sinus surgery with OPF after one or more endoscopic procedures for benign and inflammatory pathologies from 2000 to 2022. Clinical charts were reviewed for demographics, indications, clinical presentation, previous frontal procedures, OPF technique and outcomes.

Results. Of the 124 patients who underwent an OPF procedure, 33 met inclusion criteria. With a mean of 2.1 previous endoscopic surgeries, Draf III was the most common former procedure. In 30 (91%) cases OPF was part of a combined procedure. The most common indications were inverted papilloma (61%), mucocele (9%) and chronic rhinosinusitis (6%). Frontal outflow stenosis (36%) and mucocele (9%) were the most frequent complications observed. Improvement of overall symptoms and patient satisfaction after the OPF procedure were recorded.

Conclusions. Even in the endoscopic era, OPF still represents a paramount procedure that should be included in the rhino-surgeon's armamentarium, in particular in patients with challenging pathologies and anatomy when previous endoscopic endonasal attempts have failed.

KEY WORDS: OPF, osteoplastic flap, frontal sinus revision surgery, endoscopic surgery, open frontal sinus procedure

RIASSUNTO

Obiettivo. Analizzare l'esperienza di cinque centri universitari sull'utilizzo del lembo osteoplastico (OPF) nella chirurgia di revisione del seno frontale nel trattamento di patologie benigne.

Metodi. Analisi descrittiva sui pazienti sottoposti tra il 2000 ed il 2022 a chirurgia di revisione con OPF.

Risultati. Su 124 pazienti sottoposti a OPF, 33 pazienti hanno soddisfatto i criteri di inclusione. Con una media di 2.1 precedenti trattamenti endoscopici, la Draf III è stata la procedura più comunemente eseguita prima di optare per l'OPF. Le indicazioni più comuni sono state il papilloma invertito, il mucocele e la rinosinusite cronica. Nel 90% dei casi l'OPF è

Received: January 10, 2023

Accepted: January 17, 2023

Correspondence

Eugenia Maiorano

Department of Otorhinolaryngology, Fondazione IRCCS Policlinico San Matteo, piazzale Golgi 19, 27100 Pavia, Italy
E-mail: eugenia_maiorano@libero.it

How to cite this article: Pagella F, Maiorano E, Turri-Zanoni M, et al. The role of the osteoplastic flap in the endoscopic era: a retrospective multicentre experience on revision surgery. *Acta Otorhinolaryngol Ital* 2023;43(SUPPL.1):S34-S40. <https://doi.org/10.14639/0392-100X-suppl.1-43-2023-04>

© Società Italiana di Otorinolaringoiatria e Chirurgia Cervico-Facciale



OPEN ACCESS

This is an open access article distributed in accordance with the CC-BY-NC-ND (Creative Commons Attribution-NonCommercial-NoDerivatives 4.0 International) license. The article can be used by giving appropriate credit and mentioning the license, but only for non-commercial purposes and only in the original version. For further information: <https://creativecommons.org/licenses/by-nc-nd/4.0/deed.en>

stato eseguito in combinazione con una procedura endoscopica. La stenosi della senotomia frontale ed il mucocoele sono state le complicanze post-operatorie più frequenti. Durante il follow-up, i pazienti hanno riferito il miglioramento o la scomparsa dei sintomi e delle condizioni cliniche di partenza, con un importante livello di soddisfazione post-chirurgico.

Conclusioni. Anche nell'era della chirurgia endoscopica l'OPF rappresenta uno strumento fondamentale nell'armamentario otorinolaringoiatrico, in particolare nei pazienti con patologie e anatomia complesse, per i quali il trattamento endoscopico non è stato risolutivo.

PAROLE CHIAVE: OPF, lembo osteoplastico, chirurgia di revisione del seno frontale, chirurgia endoscopica

Introduction

Historically, frontal sinus disease has been treated surgically through external approaches. Among these, the frontal osteoplastic flap (OPF) technique is the principal direct orthodox open approach to address the most anteriorly placed sinus^{1,2}. First described at the end of 19th century by Schonborn³ and Brieger⁴, OPF was popularised by Goodale and Montgomery in the 1950s⁵ and became for decades the gold standard in the surgical treatment of frontal sinus diseases⁶. Since the introduction of endoscopic sinus surgery (ESS) in the 1980s, the use of OPF has decreased significantly, due to the possibility to endoscopically treat and manage a wide variety of paranasal sinus diseases with reduced morbidity for patients^{1,7,8}.

However, despite the recent advances in ESS, OPF still holds its ground in the treatment of selected frontal sinus disorders, where due to the complex anatomy of the frontal recess and its anatomic relationship to vital structures, an open approach provides unparalleled views and access^{2,6,9}. Current indications for OPF include chronic frontal sinusitis which has failed previous endoscopic approaches; acute frontal sinusitis with forthcoming complications, osteogenesis and osteomyelitis of the frontal bone, frontal bone fractures with multiple comminuted bone fragments, and selected pathologies that are inaccessible endoscopically such as benign and malignant frontal sinus lesions, frontal sinus mucocoeles and cerebrospinal fluid (CSF) leak^{2,6,9}.

When an OPF is planned, a combined open and endoscopic frontal sinus procedure has become prevalent in recent years in order to manage the disease with direct access while restoring the endonasal ventilation of the sinus on the nasal side.

The aim of this study was to share the experience of five tertiary-care university hospitals in the management of frontal sinus disease through OPF as revision surgery, after the failure of previous endoscopic procedures, analysing the indications, complications and outcomes during long-term follow-up.

Materials and methods

A retrospective review of a multicentre database on patients who consecutively underwent frontal sinus surgery with OPF in the Otorhinolaryngology Department of five high-volume university hospitals (Otorhinolaryngology Depart-

ment of University of Pavia, Otorhinolaryngology Department of University of Insubria, Varese, Otorhinolaryngology Department of University of Padua, Otorhinolaryngology Department of University of Brescia, Otorhinolaryngology Department of University of Ferrara) from June 2000 to June 2022 was performed.

All consecutive patients who underwent an OPF procedure as a revision surgery after the failure of a single or multiple endoscopic sinus surgeries were enrolled.

Exclusion criteria were considered as follows: previous history of open frontal sinus procedures, OPF performed with obliteration of the frontal sinus, malignant tumours, incomplete clinical and radiological data available.

We collected clinicopathological data regarding gender, age at surgery, indication for OPF, clinical presentation, type of OPF (unilateral vs bilateral), concurrent surgeries, complications, previous and further sinus surgeries including OPF revision and radiological and/or intra-operative evidence of skull base erosion.

A 10-millimeter Visual Analogue Scale (VAS), anchored at each end with verbal descriptors ("no symptom-0" and "extreme symptom-10"), was administered to investigate pain immediately after surgery, overall patient satisfaction, and both pre-operative and post-operative overall sinus discomfort, as well as headache, drainage and congestion.

Qualitative variables were described as absolute frequencies and percentages. Quantitative variables were summarised in terms of mean and standard deviation.

Results

Patient characteristics

A total of 124 patients who underwent OPF from June 2000 to June 2022 were identified. Of these, 33 patients fulfilled the inclusion criteria and were included in the study. Thirteen patients were excluded because the OPF was chosen to manage a malignant tumour, 68 patients were excluded because the OPF was the first line approach to the frontal sinus, 7 patients were excluded because of a history of previous open procedure performed elsewhere and 3 were excluded because an oblitative OPF was performed.

There were 21 males and 12 females (M:F = 2:1). Age at surgery ranged from 24 to 78 years (mean 54.2 years, SD 13.4).

Table I. Indication for OPF.

Indication for OPF	N (%)
Inverted papilloma	20 (60.6%)
Mucocele	3 (9.1%)
CRS	
CRSwNP	1 (3.0%)
CRSSNP	1 (3.0%)
Mucocele and CRSwNP	1 (3.0%)
Other benign tumour	2 (6.1%)
Osteoma	2 (6.1%)
Osteomyelitis	2 (6.1%)
Meningoencephalocele	1 (3.0%)

OPF: Osteoplastic Flap; CRS: Chronic Rhinosinusitis; CRSwNP: Chronic Rhinosinusitis with Nasal Polyps; CRSSNP: Chronic Rhinosinusitis without Nasal Polyps.

Table II. Sign and symptoms at presentation.

Sign and symptoms at presentation	N (%)
Headache	18 (54.5%)
Nasal obstruction	16 (48.5%)
Orbital swelling	3 (9.1%)
Anosmia	2 (6.1%)
None	2 (6.1%)
Frontal swelling	1 (3.0%)
Meningitis	1 (3.0%)
Epistaxis	1 (3.0%)
Periorbital pain	1 (3.0%)

N.B. Some patient presented with more than one sign and symptoms at presentation.

All patients had undergone at least one ESS, with a mean of 2.1 previous endoscopic surgeries (range 1-5). Draf III¹⁰ was the most common former procedure (n = 15; 45.5%), followed by Draf IIB (n = 8; 24.2%). The most common indications were inverted papilloma (n = 20; 60.6%), mucocele (n = 3; 9.1%) and chronic rhinosinusitis (n = 2; 6.1%) (Tab. I). Regardless of the underlying pathology, headache (54.5%) and nasal obstruction (48.5%) were the most complained symptoms (Tab. II).

Surgical strategies

Of the 33 cases, in 30 (90.9%) patients the OPF was part of a combined surgery in which the open approach was coupled with an endonasal endoscopic procedure. Unilateral OPF was carried out in 2 of 33 cases (6.1%). To harvest the OPF, a 6-foot Caldwell X-ray and the CT-image-guided navigation system were used in 18 and 10 cases, respectively. Radiological and/or intra-operative evidence of skull base erosion was recorded in 6 patients (18.2%): 4 cases at posterior frontal table, 1 case at medial orbital wall and 1 case at medial orbital wall and anterior frontal table.

Complication and follow-up

No intra-operative adverse events occurred. There was one case of peri-operative complication, namely a wound infection requiring revision. Forehead contour abnormalities and temporary forehead numbness were reported in 1 and 2 patients, respectively. No further cosmetic or functional complications, such as persistent abnormal forehead sensation, areas of alopecia, bone flap necrosis, or VII cranial nerve injury, were recorded.

The mean follow-up period was 65.13 months (SD 52.67), ranging from 6 months to 15 years.

In the follow-up period, 12 patients developed a frontal outflow stenosis and 3 patients presented with post-operative mucocele (Tab. III). Of the 12 patients with stenosis, 5 patients underwent subsequently a Draf IIB procedure, 7 patients underwent a Draf III procedure. Of the 3 patients developing a mucocele, 2 were managed via Draf III procedure and the remaining one via Draf III followed by OPF revision. Overall, 26 patients (78.8%) required further surgical revision, with Draf III and Draf IIB being the most frequently performed procedures (Tab. IV).

Table III. Complications after OPF.

Complications	N (%)
Bony flap necrosis	0 (0%)
Brain abscess	0 (0%)
CN7 injury	0 (0%)
CSFL	0 (0%)
Forehead abnormalities	1 (3.0%)
Forehead numbness	1 (3.0%)
Frontal outflow stenosis	12 (36.4%)
Hematoma	0 (0%)
Infection	2 (6.1%)
Meningitis	0 (0%)
Mucocele	3 (9.1%)
Orbital haematoma	0 (0%)
Subgaleal seroma	0 (0%)
None	17 (46.2%)

N.B. Some patient presented more than one complication. OPF: Osteoplastic Flap; CN: Cranial Nerve; CSFL: Cerebrospinal Fluid Leak.

Table IV. Frontal sinus procedures performed after the OPF.

Frontal sinus procedures performed after the OPF (n = 26)	N (%)
Draf III	14 (42.4%)
Draf IIB	9 (27.3%)
Draf III and OPF revision	1 (3.0%)
Stenting	1 (3.0%)
Skew removal	1 (3.0%)

OPF: Osteoplastic Flap.

Table V. The comparison between pre-operative and post-operative signs and symptoms using the VAS ("no symptom-0" and "extreme symptom-10").

Signs and symptoms	Pre-OPF (mean \pm SD)	Post-OPF (mean \pm SD)	P-value
Overall sinus discomfort	4.45 \pm 4.57	1.97 \pm 2.83	0.003
Headache	6.83 \pm 3.66	4.24 \pm 4.17	2.01
Drainage	3.45 \pm 4.28	1.38 \pm 2.21	4.15
Congestion	4.00 \pm 4.28	2.28 \pm 2.62	1.01

VAS: Visual Analogue Scale; OPF: Osteoplastic Flap; SD: Standard Deviation.

Patients' perspective and self-evaluation

All symptomatic patients reported improvements or resolution of their primary presenting symptom at the last follow-up visit. The comparison between pre-operative and post-operative values for headache, drainage, nasal congestion and overall sinus discomfort showed an improving trend, even though only the results for sinus discomfort were significant ($p < 0.005$) (Tab. V). The OPF procedure was considered barely painful (mean VAS 1.2 \pm 2.77 SD, range 0-8) with a relevant patient's post-operative satisfaction (mean VAS 8.23 \pm 1.61 SD, range 6-10).

Discussion

Nowadays, evolving experience and dedicated technologies available have made ESS the gold standard for the treatment of the majority of frontal sinus pathologies. However, despite the increasing application of ESS, OPF still has an important role in the rhinologist's surgical armamentarium, above all after the failure of previous endoscopic procedures⁸. The main causes of a failed endoscopic approach leading to OPF are the incomplete achievement of the goal of surgery due to unfavourable anatomy (i.e., narrow anteroposterior distance of the frontal recess, multiple intrafrontal septa, narrow sinuses) and the obstructed frontal sinus outflow caused by the scarring and osteogenesis consequent to the previous surgeries^{2,6,9}.

A recent review by Lee et al. analysed the criteria whereby OPF may be chosen as a primary procedure⁹. Accepted indications for OPF as a first line approach are: pathologies located laterally in the frontal sinus^{7,11-14}, frontal sinus trauma where displaced fractures may cause cosmetic and functional impairment^{7,12,15,16}, osteomyelitis^{11, 15-17} and neurosurgical complications^{15,18}.

Frequently, open and endoscopic frontal sinus procedures are combined in order to achieve surgical success, maintaining the normal aeration/outflow of the frontal sinus^{13,14,17,19,20}. In our case series, the combined procedure was the surgical strategy of choice in the majority of cases, in order to preserve the sinus ventilation.

Numerous variations of OPF have been described in literature, in particular regarding the final restoration of frontal sinus function.

Once the pathology has been addressed, the frontal sinus can be obliterated or left aerated. In case of obliteration, the mucosal lining of the frontal sinus and frontal recess must be meticulously removed. A high-speed diamond drill is generally used to remove the mucosa and to polish the bone surface, with or without microscopic assistance, in order to avoid the potential for delayed mucocele formation, observed up to decades after surgery. The frontal sinus is then obliterated with a variety of alloplastic or autologous materials, including fat, muscle and bone pate^{6,9,21,22}.

Some authors in the past decades described mucosal removal without packing the sinus cavity with any obliterative material, relying on natural obliteration, where the empty sinus cavity is allowed to fill with newly formed fibrous and osseous tissue^{16,23}. However, other authors reported an incomplete auto-obliteration that often resulted in the development of mucocele²⁴.

Once the nasofrontal tract is obstructed, the frontal sinus is excluded from ventilation.

Over the years, data emerging from long-term follow-up with obliterative OPF procedures have demonstrated a non-negligible proportion of cases where the frontal sinus developed complications, related mainly to the superinfection and/or reabsorption of the obliterative materials as well as mucocele formation arising from remnants of mucosa in hidden frontal recesses⁹.

Therefore, even if the original description of the OPF required obliteration of the frontal sinus⁵, it is becoming more common to perform this procedure without obliteration^{9,25-28}. In these cases, the sinus is left aerated, and the frontal recess is not occluded but rather widely opened to ensure the drainage from above to the nasal cavity. Several authors prefer this technique because it restores physiologic function of the sinus and avoids late complications related to fat reabsorption and mucocele formation¹. Moreover, in case of frontal sinus tumours, the obliteration is undesirable given the difficulty of monitoring for recurrence. If the ventilation is preserved, the frontal sinus can be overseen more accurately endoscopically and radiologically²⁶.

One of the most important steps in OPF harvesting is the precise localisation of the frontal sinus boundaries in order

to get the widest access possible to the frontal sinus without breaching into the dural space.

Different techniques have been described to map the frontal sinus anatomy. The 6-foot Caldwell film has historically been used to delineate the borders of the frontal sinus. This technique has an important limitation in case of hyper-pneumatized frontal sinus with irregular margins^{29,30}. After the first report in the late 1990s, CT image guidance is the most commonly used tool, and several studies have shown its accuracy and superiority over other techniques in determining the sinus extent^{29,31}. In our case series, the 6-foot Caldwell X-ray was used in 19 cases, with surgery performed almost entirely in the first decade of 2000. Since that time, OPF harvesting have been mostly guided by a CT image navigation system (image guided navigation system, IGNS).

The use of a three-dimensional printing as an onlay template for OPF has been reported, resulting in a viable, inexpensive and precise tool to identify the boundaries of the frontal sinus^{32,33}.

Recently, the first application of VITOM® 3D-4K (KARL STORZ GmbH & Co, Tuttlingen, Germany) coupled with a dedicated robotic arm (ARTip Cruise™) further enhanced the view of the surgical field in the OPF approach³⁴. This coupled system also improved the ergonomics and safety during surgery and had significant educational value providing the resident and fellows an immersive experience in the theatre³⁴.

Analysing the complications of the open surgery, one must consider that OPF, and OPF with sinus obliteration in particular, are usually the last resort once all other less invasive surgical attempts have failed, creating a patient population with challenging pathology and anatomy^{9,27}. For these reasons, OPF can have significant morbidity. Montgomery and Hardy in their landmark paper of 250 cases, reported a total complication rate of 18%³⁵. Weber et al. in their series of 82 obliterative OPFs reported as the most common intra-operative complications the exposure of orbital fat (19%), bone flap fractures (19%), dural exposure and dural injury (10%)³⁷. Ulualp et al. reported only CSF leak (2%) as an intra-operative complication among 43 cases of OPF with abdominal fat obliteration³⁷. Overall, according to the literature, dural injury, bone flap fracture and orbital fat exposure are the most common intra-operative complications. These types of complications can be avoided with careful flap harvesting and, in our experience, are nowadays fairly infrequent with the support of the IGNS.

Peri-operative and post-operative complications are the commonest^{1,9,38}. Peri-operative adverse events, such as wound infection, meningitis, brain abscess, subgaleal seroma and haematoma, may be ascribed to either the previ-

ous frontal sinus disease with consequent infection of the operative site or to the surgery itself. In our case series, the infection rate was not superior to previous reports by other authors: 2.8% vs 11% according to Catalano et al.³⁹. Depression or embossment of the surgical scar and forehead abnormalities are the most frequent and relatively infrequent aesthetic complications – 3.0% in our experience with similar outcomes in literature (2.6% according to Soyka et al.¹⁵, 8% according to Weber et al.³⁶). Forehead numbness is caused by the distress or injury of the supratrochlear and/or supraorbital branches of ophthalmic nerve during the harvesting of the scalp flap. It usually resolves in 6-12 months, but can be persistent in a considerable percentage of cases (3.0% in our experience, 6-35% in the literature)^{35,36}.

As seen in our results, frontal sinus outflow stenosis and mucocele are common after OPF surgery, with a reported rate in the literature of 6%-31%^{35,40}. Mucocele formation in particular, is the most troublesome complication after OPF, and can be secondary to the scarring of the outflow tract or to the remnant mucosal epithelium in case of obliterative OPF. The reported rate of post-operative mucocele formation is 3%-10%^{1,15}, with a time range from 1 to 42 years^{38,41}. In case of recurrent frontal sinusitis and/or mucocele formation, revision surgery is recommended^{38,42} and, in the last decades, the Draf II and Draf III procedures has been successfully used as salvage procedures⁴²⁻⁴⁴. Endoscopic procedures have demonstrated a success rate of 88% in the literature^{42,43}, avoiding the risks of a revision OPF, preserving mucociliary clearance and making the frontal sinus easily evaluable on an outpatient basis⁴⁴.

Analysing the patients perceived health and satisfaction after OPF, our results are aligned with previously published data⁴⁰. The majority of patients reported improvement of symptoms and were satisfied with the results, in particular regarding the decrease of overall sinus discomfort and overall satisfaction.

Despite the possible limitations due to the retrospective nature of the study, our analysis reports the 20-year experience of five high-volume university hospitals on frontal sinus revision surgery with OPF for pathologies other than malignant tumours.

Our data showed that OPF is still an important tool in frontal sinus surgery, even in centres with the experience and technology to manage a wide variety of pathologies endoscopically. OPF is useful in cases with challenging pathology and anatomy: it enables access to areas that are not reachable by the endoscopic endonasal technique in case of CSF leak and mucocele; it allows to achieve the radicality not gained in the first surgery in case of neoplastic disease (i.e., inverted papilloma's pedicle, residual osteoma); it al-

lows to reach areas where the anatomy is unfavourable (i.e., interfrontal sinus cells, narrow anteroposterior distance, multiple septa) in case of inflammatory disease.

Nevertheless, the OPF technique still carries significant morbidity, exactly as it was when it was introduced more than a century ago, with a high rate of revisions, due to the challenging characteristics of the patient population in which it is employed.

In case of frontal outflow stenosis and/or mucocele, an endoscopic endonasal salvage procedure may be feasible, in selected cases, when performed by an experienced surgical team with the appropriate equipment.

Conclusions

This case series is the first report on the experience of five high-volume university hospitals on frontal sinus revision surgery with OPF for pathologies other than malignant tumours. We analysed the indications, complications and outcomes over long-term follow-up, thus offering insight into a “niche” and complex surgical procedure which is still valuable in the endoscopic era.

Conflict of interest statement

The authors declare no conflict of interest.

Funding

This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

Author contributions

FP: patient care, study design, revision of the manuscript; MTZ, CZ: patient care, patient enrolment, revision of the manuscript; EM: patient enrolment, literature revision, drafting the manuscript; CC, CC: patient enrolment; MF: patient enrolment, revision of the manuscript; EE, SP, PB, AS, MB, PN, PC: patient care, study design revision of the manuscript.

Ethical consideration

This case series was deemed exempt from ethical approval. Informed consent was collected prior to surgery from each participant/patient for study participation and data publication according to the Italian laws. Nevertheless, this study did not affect patients care in any way.

The research was conducted ethically, with all study procedures being performed in accordance with the requirements of the World Medical Association’s Declaration of Helsinki.

References

- 1 Kountakis SE, Senior BA, Draff W. The frontal sinus. Second edition. Berlin Heidelberg: Springer-Verlag; 2016.
- 2 Konstantinidis I, Constantinidis J. Indications for open procedures in the endoscopic era. *Curr Opin Otolaryngol Head Neck Surg* 2016;24:50-56. <https://doi.org/10.1097/MOO.0000000000000219>
- 3 Wilkop A. Ein Beitrag zur Kasuistik der Erkrankungen des Sinus frontalis. Wuerzburg: F. Frome; 1894.
- 4 Brieger. Ueber chronische Eiterungen der Nebenhohlen der Nase. *Arch Ohren Nasen Kehlkopffheilk* 1895;39:213.
- 5 Goodale RL, Montgomery WW. Experiences with the osteoplastic anterior wall approach to the frontal sinus; case histories and recommendations. *AMA Arch Otolaryngol* 1958;68:271-283. <https://doi.org/10.1001/archotol.1958.00730020281001>
- 6 Eloy JA, Marchiano E, Vázquez A. Extended endoscopic and open sinus surgery for refractory chronic rhinosinusitis. *Otolaryngol Clin North Am* 2017;50:165-182. <https://doi.org/10.1016/j.otc.2016.08.013>
- 7 Lee JM, Palmer JN. Indications for the osteoplastic flap in the endoscopic era. *Curr Opin Otolaryngol Head Neck Surg* 2011;19:11-15. <https://doi.org/10.1097/MOO.0b013e3283419453>
- 8 Montgomery WW. State-of-the-art for osteoplastic frontal sinus operation. *Otolaryngol Clin North Am* 2001;34:167-177. [https://doi.org/10.1016/s0030-6665\(05\)70304-2](https://doi.org/10.1016/s0030-6665(05)70304-2)
- 9 Lee YH, Lee JY, Lawson W. Indications and outcomes of the osteoplastic flap procedure with or without obliteration. *J Craniofac Surg* 2020;31:2243-2249. <https://doi.org/10.1097/SCS.00000000000006717>
- 10 Draff W. Endonasal micro-endoscopic frontal sinus surgery: the fulda concept. *Oper Tech Otolaryngol Head Neck Surg* 1991;2:234-240
- 11 Silverman JB, Gray ST, Busaba NY. Role of osteoplastic frontal sinus obliteration in the era of endoscopic sinus surgery. *Int J Otolaryngol* 2012;2012:501896. <https://doi.org/10.1155/2012/501896>
- 12 Hahn S, Palmer JN, Purkey MT, et al. Indications for external frontal sinus procedures for inflammatory sinus disease. *Am J Rhinol Allergy* 2009;23:342-347. <https://doi.org/10.2500/ajra.2009.23.3327>
- 13 Sofokleous V, Maragoudakis P, Kyrodimos E, et al. Management of paranasal sinus osteomas: a comprehensive narrative review of the literature and an up-to-date grading system. *Am J Otolaryngol* 2021;42:102644. <https://doi.org/10.1016/j.amjoto.2020.102644>
- 14 Pietrobon G, Karligkiotis A, Turri-Zanoni M, et al. Surgical management of inverted papilloma involving the frontal sinus: a practical algorithm for treatment planning. *Acta Otorhinolaryngol Ital* 2019;39:28-39. <https://doi.org/10.14639/0392-100X-2313>
- 15 Soyka MB, Annen A, Holzmann D. Where endoscopy fails: indications and experience with the frontal sinus fat obliteration. *Rhinology* 2009;47:136-140. <https://doi.org/10.5167/uzh-19767>
- 16 Bosley WR. Osteoplastic obliteration of the frontal sinuses. A review of 100 patients. *Laryngoscope* 1972;82:1463-1476. <https://doi.org/10.1288/00005537-197208000-00010>
- 17 Thompson HM, Tilak AM, Miller PL, et al. Treatment of frontal sinus osteomyelitis in the age of endoscopy. *Am J Rhinol Allergy* 2021;35:368-374. <https://doi.org/10.1177/1945892420959587>
- 18 Mendians AE, Marks SC. Outcome of frontal sinus obliteration. *Laryngoscope* 1999;109:1495-1498. <https://doi.org/10.1097/00005537-199909000-00025>
- 19 Karligkiotis A, Turri-Zanoni M, Sica E, et al. Role of endoscopic surgery in the management of sinonasal and skull base schwannomas. *Head Neck* 2016;38(Suppl. 1):E2074-E2082. <https://doi.org/10.1002/hed.24383>

- ²⁰ Sama A, McClelland L, Constable J. Frontal sinus mucocoeles: new algorithm for surgical management. *Rhinology* 2014;52:267-275. <https://doi.org/10.4193/Rhino13.103>
- ²¹ Kristin J, Betz CS, Stelter K, et al. Frontal sinus obliteration: a successful treatment option in patients with endoscopically inaccessible frontal mucocoeles. *Rhinology* 2008;46:70-74.
- ²² Anand VK, Hiltzik DH, Kacker A, et al. Osteoplastic flap for frontal sinus obliteration in the era of image-guided endoscopic sinus surgery. *Am J Rhinol* 2005;19:406-410. <https://doi.org/10.1177/194589240501900415>
- ²³ Macbeth R. The osteoplastic operation for chronic infection of the frontal sinus. *J Laryngol Otol* 1954;68:465-477. <https://doi.org/10.1017/s0022215100049884>
- ²⁴ Walsh TE. Experimental surgery of the frontal sinus: the role of the ostium and nasofrontal duct in post-operative healing. *Laryngoscope* 1943;53:75-92. <https://doi.org/10.1288/00005537-194302000-00001>
- ²⁵ Banks CG, Garcia JAP, Grayson J, et al. Osteoplastic flap without obliteration: how i do it. *Am J Rhinol Allergy* 2018;32:346-349. <https://doi.org/10.1177/1945892418782222>
- ²⁶ Smith TL, Han JK, Loehrl TA, et al. Endoscopic management of the frontal recess in frontal sinus fractures: a shift in the paradigm?. *Laryngoscope* 2002;112:784-790. <https://doi.org/10.1097/00005537-200205000-00004>
- ²⁷ Ochsner MC, DelGaudio JM. The place of the osteoplastic flap in the endoscopic era: indications and pitfalls. *Laryngoscope* 2015;125:801-806. <https://doi.org/10.1002/lary.25014>
- ²⁸ Chiu AG, Schipor I, Cohen NA, et al. Surgical decisions in the management of frontal sinus osteomas. *Am J Rhinol* 2005;19:191-197. <https://doi.org/10.1177/194589240501900213>
- ²⁹ Carrau RL, Snyderman CH, Curtin HB, et al. Computer-assisted frontal sinusotomy. *Otolaryngol Head Neck Surg* 1994;111:727-732. <https://doi.org/10.1177/019459989411100605>
- ³⁰ Melroy CT, Dubin MG, Hardy SM, et al. Analysis of methods to assess frontal sinus extent in osteoplastic flap surgery: transillumination versus 6-ft Caldwell versus image guidance. *Am J Rhinol* 2006;20:77-83. <https://doi.org/10.1177/194589240602000114>
- ³¹ Volpi L, Pistochini A, Bignami M, et al. A novel technique for tailoring frontal osteoplastic flaps using the ENT magnetic navigation system. *Acta Otolaryngol* 2012;132:645-650. <https://doi.org/10.3109/00016489.2012.654854>
- ³² Daniel M, Watson J, Hoskison E, et al. Frontal sinus models and onlay templates in osteoplastic flap surgery. *J Laryngol Otol* 2011;125:82-85. <https://doi.org/10.1017/S0022215110001799>
- ³³ Roy R, Goyal S, Roy KN, et al. Use of three-dimensional printing for the osteoplastic flap approach: a viable technique. *Med J Armed Forces India* 2021;77:363-366. <https://doi.org/10.1016/j.mjafi.2021.01.022>
- ³⁴ Bignami M, Arosio AD, Dalfino G, et al. First experience of AR-Tip cruise VITOM-assisted OPF removal of frontal fibro-osseous lesion: operative video. *Laryngoscope* 2021;131:2219-2223. <https://doi.org/10.1002/lary.29546>
- ³⁵ Hardy JM, Montgomery WW. Osteoplastic frontal sinusotomy: an analysis of 250 operations. *Ann Otol Rhinol Laryngol* 1976;85:523-532. <https://doi.org/10.1177/000348947608500414>
- ³⁶ Weber R, Draf W, Keerl R, et al. Osteoplastic frontal sinus surgery with fat obliteration: technique and long-term results using magnetic resonance imaging in 82 operations. *Laryngoscope* 2000;110:1037-1044. <https://doi.org/10.1097/00005537-200006000-00028>
- ³⁷ Ulualp SO, Carlson TK, Toohill RJ. Osteoplastic flap versus modified endoscopic Lothrop procedure in patients with frontal sinus disease. *Am J Rhinol* 2000;14:21-26. <https://doi.org/10.2500/105065800781602939>
- ³⁸ Schneider JS, Day A, Clavenna M, et al. Early practice: external sinus surgery and procedures and complications. *Otolaryngol Clin North Am* 2015;48:839-850. <https://doi.org/10.1016/j.otc.2015.05.010>
- ³⁹ Catalano PJ, Lawson W, Som P, et al. Radiographic evaluation and diagnosis of the failed frontal osteoplastic flap with fat obliteration. *Otolaryngol Head Neck Surg* 1991;104:225-234. <https://doi.org/10.1177/019459989110400211>
- ⁴⁰ Alsarraf R, Kriet Jd, Weymuller EA Jr. Quality-of-life outcomes after osteoplastic frontal sinus obliteration. *Otolaryngol Head Neck Surg* 1999;121:435-440. [https://doi.org/10.1016/S0194-5998\(99\)70234-2](https://doi.org/10.1016/S0194-5998(99)70234-2)
- ⁴¹ Javer AR, Alandejani T. Prevention and management of complications in frontal sinus surgery. *Otolaryngol Clin North Am* 2010;43:827-838. <https://doi.org/10.1016/j.otc.2010.04.021>
- ⁴² Wormald PJ, Ananda A, Nair S. Modified endoscopic lothrop as a salvage for the failed osteoplastic flap with obliteration. *Laryngoscope* 2003;113:1988-1992. <https://doi.org/10.1097/00005537-200311000-00025>
- ⁴³ Stankiewicz JA, Wachter B. The endoscopic modified Lothrop procedure for salvage of chronic frontal sinusitis after osteoplastic flap failure. *Otolaryngol Head Neck Surg* 2003;129:678-683. <https://doi.org/10.1016/j.otohns.2003.07.011>
- ⁴⁴ Langton-Hewer CD, Wormald PJ. Endoscopic sinus surgery rescue of failed osteoplastic flap with fat obliteration. *Curr Opin Otolaryngol Head Neck Surg* 2005;13:45-49. <https://doi.org/10.1097/00020840-200502000-00011>