Université de Montréal

Facial artery musculomucosal flap for reconstruction of skull base defects

par

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English abstract

Facial Artery Musculomucosal Flap in Skull Base Reconstruction

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Introduction: Failure in skull base defects reconstruction can have serious consequences such as meningitis and pneumocephalus. The nasoseptal flap is usually the first choice but alternatives are necessary when this flap is not available. The facial artery musculomucosal (FAMM) flap has proven to be successful in head and neck reconstruction but it has never been reported in skull base reconstruction.

Objective: To show that the FAMM flap can reach some key areas of the skull base and be considered as a new alternative in skull base defects reconstruction.

Methods: We conducted a cadaveric study with harvest of modified FAMM flaps, endoscopic skull base dissection and maxillectomies in 13 specimens. Measures were taken for each harvested FAMM flap.

Results: The approximate mean area for reconstruction from the combination of the distal FAMM and the extension flaps is 15.90 cm^2. The flaps successfully covered the simulated defects of the frontal sinus, the ethmoid areas, the planum sphenoidale, and the sella turcica.

Conclusion: The FAMM flap can be considered as a new alternative in the reconstruction of skull base defects. Modifications add extra length to the traditional FAMM flap and can contribute to a tighter seal of the defect as opposed to the FAMM flap alone.

Keywords: Skull base reconstruction, FAMM flap, musculomucosal flap, facial artery, cerebrospinal fluid leak

French Abstract

Le lambeau musculomuqueux de la joue dans la reconstruction de la base du crâne

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Introduction: Un échec dans la reconstruction de la base du crâne peut avoir des conséquences graves telles que la méningite ou la pneumocéphalie. Le premier choix de la reconstruction est le lambeau nasoseptal. Lorsque ce dernier n'est pas disponible, d'autres alternatives sont nécessaires. Le lambeau musculomuqueux de la joue (FAMM) a une place établie dans la reconstruction des déficits de la tête et du cou, mais il n'a pas jamais été décrit dans la reconstruction de la base du crâne.

Objectif: Démontrer que le lambeau de FAMM peut atteindre des zones clés de la base du crâne et être considéré comme une nouvelle option de reconstruction de cette région.

Méthode: Nous avons entrepris une étude cadavérique avec prélèvement de lambeaux de FAMM modifiés et une dissection endoscopique de la base du crâne sur 13 spécimens. Des mesures ont été prises pour chaque lambeau prélevé.

Résultats: L'aire de reconstruction moyenne du lambeau de FAMM et des extensions est de 15.90 cm^2. Les lambeaux couvrent totalement les déficits simulés du sinus frontal, des ethmoïdes, le toit du sphénoïde et la selle turcique.

Conclusion: Le lambeau de FAMM peut être considéré comme une nouvelle alternative dans la reconstruction des déficits de la base du crâne. Les modifications apportent une longueur additionnelle et contribuent à une couverture plus étanche du déficit que le lambeau de FAMM seul.

Mots-clés: Reconstruction de la base du crâne, lambeau de FAMM, lambeau musculomuqueux, artère faciale, fuite de liquide céphalo-rachidien

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List of abbreviations

a-FAMMIF: arterialized-facial artery musculomucosal island flap

cm: centimeters

CRCHUM: Centre de Recherche du Centre hospitalier de l'Université de Montréal

CSF: cerebrospinal fluid

EEA: endoscopic endonasal approach

EES: endoscopic endonasal surgery

ESBS: endoscopic skull base surgery

ESS: endoscopic sinus surgery

FA: facial artery

FAB: facial artery buccinator

FAMM: facial artery musculomucosal

FV: facial vein

FOM: floor of mouth

HMR: Hôpital Maisonneuve-Rosemont

MF: masseteric fascia

MP: mandibular periosteum

NSF: nasoseptal flap

SB: skull base

SBD: skull base defect

SBR: skull base reconstruction

SBS: skull base surgery

t-FAMMIF: tunnelized facial artery musculomucosal island flap

UQTR: Université de Québec à Trois-Rivièves

VT: ventral tongue

I dedicate this master's dissertation to my family: my parents, my brother, and my fiancé. Thank you for your infinite support and your trust in me in everything that I do.

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CHAPTER ONE: INTRODUCTION

Introduction

Endoscopic endonasal approaches (EEA) to the skull base (SB) have gained popularity since the late 1990's. The advent of new technologies and various surgical advancements have led to the resection of larger tumors, but have resulted in larger skull base defects (SBD). Major complications, such as cerebrospinal fluid (CSF) leak, ascending meningitis, and tension pneumocephalus, can ensue from skull base defects if the barrier separating the brain and the sinonasal tract is not robust enough.[1] One of the most challenging tasks in endoscopic skull base surgery (ESBS) is the reconstruction of the defect in order to prevent these complications. Many reconstructive options have been described in the literature, such as free grafts (cartilage, fascia, fat, titanium mesh)[2,3], loco-regional vascular flaps (palatal, septal, pericranial, temporoparietal)[4-7], and sometimes, even free flaps for larger defects (rectus abdominis, anterolateral thigh fasciocutaneous, latissimus dorsi)[8-10].

Loco-regional flaps with reliable vasculature are usually preferred over other reconstructive options for larger defects or when the vascularization of the recipient site has been compromised by previous surgeries or radiation therapy. A vascular flap contributes to faster healing, prevents infections at the operative site and is robust enough to withstand post-operative radiotherapy. Zanation et al. have published a systematic review of 38 articles comprising a total of 609 patients who have undergone skull base reconstruction (SBR) with free grafts and vascular flaps. They reported a global rate of 11.5% for CSF leak, 15.6% for free grafts and 6.7% for vascular flaps[11].

The nasoseptal flap (NSF) developed in 2006 has shown to decrease the rate of CSF leak from 20% to less than 5%[12], a rate comparable to that of open craniotomy reconstruction. However, this flap is not available in patients who present with septal perforation (previous posterior septum surgery, chronic cocaine drug users) or nasopharyngeal tumors. In such cases, it is necessary to look for an alternative flap with a robust vascularization. The superiorly-based FAMM flap is a potential alternative in the reconstruction of the skull base because of its length and its wide rotation axis.

Recently, Rivera-Serrano et al. have shown in a cadaveric study that the pedicled facial artery buccinator (FAB) flap (actually a FAMM flap) is a possible flap which can be used in the reconstruction of SBD[13]. The main objective of our project is to reinforce this statement through a cadaveric study. Our secondary objectives are to describe the maximal defect size that can be reconstructed with this flap and assess the possibilities to lengthen the FAMM flap with an extension.

Literature review

History and evolution of endoscopic skull base surgery

Before the era of endoscopic endonasal surgery (EES), SB tumors were removed through extensive open craniofacial approaches.[14] These surgeries had considerable intraoperative and postoperative morbidity and mortality in addition to the presence of disfiguring scars. The occurrence of complications can be as high as 36% and mortality rate can reach up to 5%.[15]

Endoscopic sinus surgery (ESS) was first introduced in the treatment of chronic rhinosinusitis by Austrian surgeon Walter Messerklinger in 1970. Under his guidance, Stammberger further developed ESS in 1975. It was only ten years later, in 1985, that David Kennedy introduced the ESS in the United States.[16] For the management of anterior SB tumors, ESS played an important role in assisting tumor removal through a combined open craniofacial approach with endoscopic assistance to achieve en bloc tumor resection.[17] The first endoscopic surgery treating sellar lesions was performed by Jankowski et al. in 1992.[18] It was Jho and his team who perfected the transsphenoidal approach for resection of pituitary tumors in 1997.[19] The first case of purely endoscopic endonasal removal of an anterior SB tumor was for an esthesioneuroblastoma, and was accomplished in 2001 by Casiano et al.[20]

Endoscopic endonasal SBS, compared to open craniofacial surgery, requires a shorter stay at the hospital and intensive care unit, decreases blood loss and the transfusion rate, and promotes a faster recovery with no significant difference in survival, recurrence, and metastasis.[21,22] Better cosmetic outcomes are other benefits of the minimally invasive endoscopic approach.

With more advanced technology being developed, such as wide angled endoscopes, high definition camera and image guided neuronavigation, endoscopic endonasal SBS is continuously improving over time. SB surgeons have acquired better knowledge of the ventral SB anatomy and have also perfected their skills in manipulating the endoscopes. All these advancements have allowed the surgeons to gain confidence in resecting larger tumors with resulting larger defects. As a consequence, dural opening became more common, as well as complications such as CSF leak.

Skull base reconstruction

The main critique of ESBS is the high rate of CSF leak. Kassam et al. reviewed their personal experiences of ESBS in 800 patients and have found that their most common complication was CSF leak, at a rate as high as 16%.[23] Some studies have even reported a CSF leak rate as high as 40% in endoscopic resection of anterior SB meningiomas.[24]

Small defects (< 1 cm) can be successfully repaired using multilayer free grafts with a success rate superior to 95%.[12,25] For larger defects, the success rate is much lower using the same reconstruction technique and CSF leak can be as high as 20% to 30%.[11] This type of complication discouraged the SB surgeons to perform large SB tumor resection through EEA. Moreover, the use of pedicled flaps harvested through a transcranial open approach, such as the pericranial, the temporoparietal and the galeal flaps, were not in line with the minimally invasive endoscopic approach. That is why research on the development of new reconstructive options which can be harvested endoscopically started to become popular.

It was only in 2006, with the advent of the NSF, that the rate of CSF leak has dramatically decreased to 5.4%.[26] This flap is still considered to be the workhorse flap in SBR today.[12] Harvey et al. conducted a systematic review of the literature on endoscopic SBR of large dural defects and found an average CSF leak of 11.5%, 15.6% for free grafts and 6.7%

for vascularized reconstruction.[27] Other authors later developed other reconstructive options, such as endoscopically harvested pericranial flap, and pedicled turbinate flaps (Table I).[5,28-31]

Table I. Endoscopic flaps for reconstruction of skull base

TABLE V.
Intranasal and Regional Vascular Flaps Available for Skull Base Reconstruction.

Location	Vascular Tissue Flap	Pedicle	Comments/Limitations
Intranasal vascular tissue flap	NSF[13,54]	Sphenopalatine artery	Ideal for all skull base reconstructions
	ITF[14]	Inferior turbinate artery*	Good for small clival defects, cannot reach ACF or sella
	MTF[55]	Middle turbinate artery*	Good for small ACF or transphenoidal defects, small in size, thin mucosa, difficult to elevate
Regional vascular tissue flap	PCF[44]	Supraorbital and supratrochlear artery	Hearty flap with versatile dimensions, extends from ACF to sella but not to posterior skull base
	TPFF[30]	Superficial temporal artery	Good for clival or parasellar defects, 90° pedicle rotation limits reconstruction of ACF
	PF[34]	Greater palatine artery	Theoretical flap that reaches all areas of skull base, 3-cm pedicle but difficult to dissect, experience

*Terminal branch of posterior lateral nasal artery of the sphenopalatine artery.
NSF = nasoseptal flap; ITF = inferior turbinate flap; ACF = anterior cranial fossa; MTF = middle turbinate flap; PCF = pericranial flap; TPFF = temporoparietal fascia flap; PF = palatal flap.

Source: Harvey et al. *Endoscopic skull base reconstruction of large dural defects: a systematic review of published evidence*. Laryngoscope 2012. [27]

FAMM flap

Anatomy of the facial vessels

The facial artery (FA) is a branch of the external carotid artery exiting at the neck level. After a cervical course, it passes from the medial side of the mandible to its external side by grooving through the submandibular gland as it rounds the lower border of the mandible. It follows a very tortuous pathway as it reaches the internal canthus to become the angular artery. With respect to the buccal mucosa, it passes deep to the buccinator muscle and superficial to the risorius, the zygomaticus muscles and the superficial lamina of the orbicularis oris muscle. The FA has a variety of branching patterns and terminal branches as reported in many studies[32-36]. According to Lohn's latest classification, the final branches of the FA are as depicted in figure 1.[36]

The frequency of the terminal branches of the FA ending as the superior labial artery and that of the terminal branches terminating past the alar base was respectively 10% and 85% in Lohn's study,[36] and respectively 6.6% and 88% in Koh's study.[33] Zhao et al.[37] also demonstrated using Doppler ultrasonography that the mean diameter of the FA was 2.6 mm at the lower border of the mandible, 1.9 mm at the oral commissure and 1.6 mm under the nasal alar base[37]. The facial vein (FV) is almost always located posterior to the FA[36]. It starts at the internal canthus as the angular vein and becomes the FV as it runs down the nasogenian fold. Near the mandible, the artery and vein travel very closely to each other and diverge as they travel up towards the nose[37,38]. The average distance between the artery and the vein was found to be 13.6 mm at the oral commissure and 16.3 mm under the nasal alar base[37].

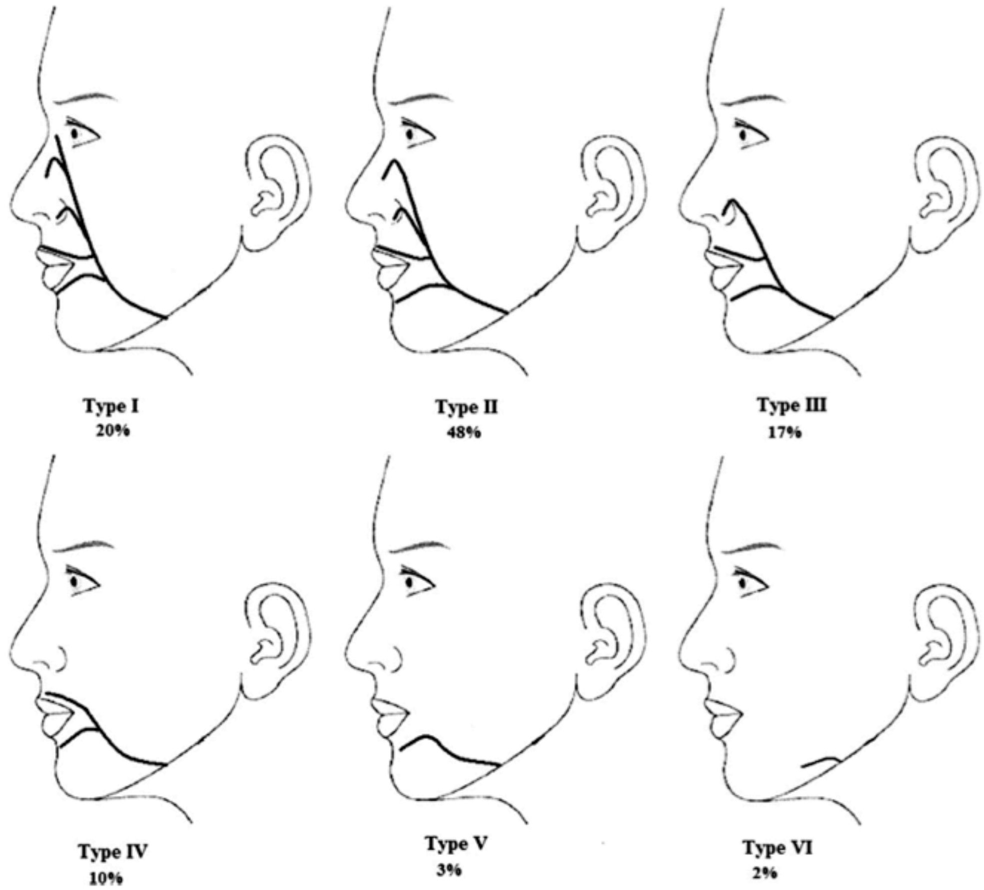

Figure 1. Classification of facial arterial terminal branching and their frequency of occurrence in Lohn et al.'s study: type I, angular; type II, lateral nasal; type III, alar; type IV, superior labial; type V, inferior labial; type VI, undetected

Source: Lohn et al. *The course and variation of the facial artery and vein: implications for facial transplantation and facial surgery*. Annals of plastic surgery 2011. [36]

Anatomy of the FAMM flap (figures 2 and 3)

The FAMM flap was first described by Pribaz in 1992.[39] It is an intra-oral cheek flap made up of mucosa, submucosa, a portion of the buccinator muscle, and the deeper plane of the orbicularis oris muscle. It can be superiorly pedicled on the angular artery with a retrograde flow or inferiorly pedicled with an anterograde flow on the FA. The pivot point of the inferior FAMM flap is located in the area of the last molar tooth and that of the superior FAMM is located at the gingival labial sulcus, or anywhere in between, depending on the reconstructive needs. The location of the defects will determine the use of either the superiorly based or the inferiorly based FAMM flap. The superiorly based FAMM flap can reach the nasal fossa through an incision at the level of the superior gingivobuccal junction. The branches of the facial nerves lie deeper to the FA and are usually not reached during the harvest, therefore preventing facial paresis.

The width of the flap varies from 2.5 to 3 cm in order to allow for primary closure of the donor site. The facial vein is rarely incorporated in the flap considering that, according to histologic studies conducted by Dupoirieux,[38] venous drainage also occurs through a buccal plexus found in the submucosa. However, when the facial vein is not identified, the pedicle base should be kept to at least 2 cm to ensure optimal venous drainage. Some reports have described a purely “arterialized-island FAMM flap” without the presence of the facial vein or the pedicle.[40,41]

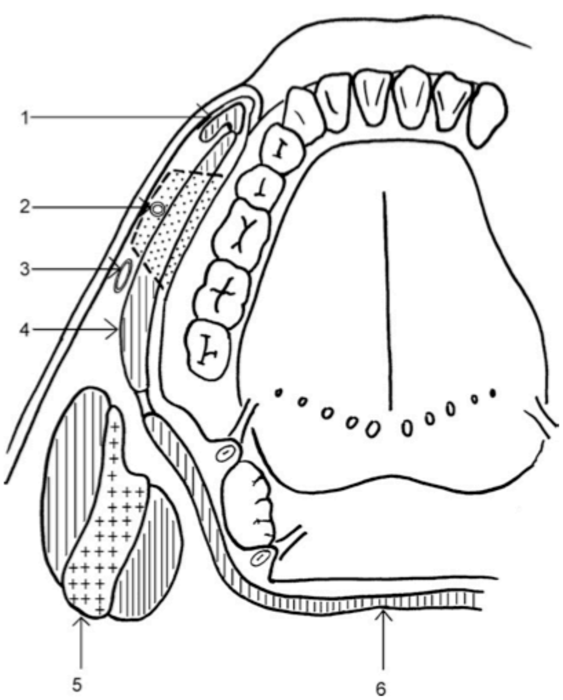

Figure 2. Axial view of the oral cavity at the level of intermaxillary commissure. 1: orbicularis ori; 2: facial artery; 3: facial vein; 4: buccinator muscle; 5: mandible; 6: superior constrictor muscle

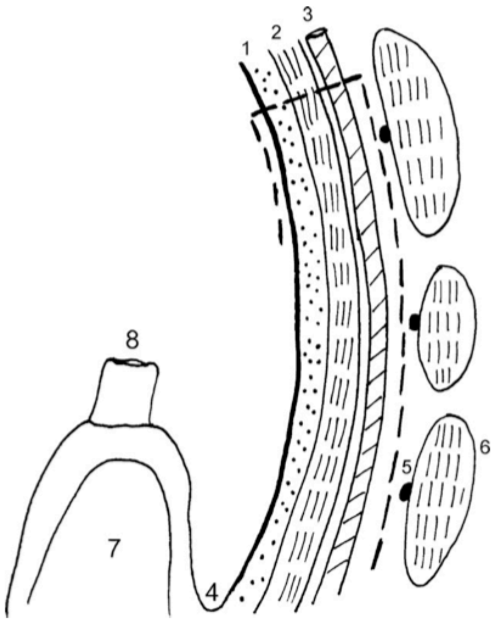

Figure 3. Coronal view of the oral cavity at the level of the cheek. 1: mucosa and submucosa; 2: buccinators muscle; 3: facial artery; 4: gingivo-buccal sulcus; 5: branches of facial nerve; 6: muscles of facial expression; 7: mandible; 8: molar tooth

Source: Ayad et al. *The musculo-mucosal facial artery flap: harvesting technique and indications*. Ann Chir Plast Esthet 2008. [42]

Surgical technique in harvesting the superiorly-based FAMM flap

An outline of the flap is marked on the buccal mucosa while respecting defined limits (figure 1 from article). Anteriorly, the flap is drawn 1 cm posterior to the oral commissure in order to avoid distortion of the labial commissure. Posteriorly, the flap is limited by the orifice of the Stensen's duct. The base of the superiorly-based FAMM flap is located at the superior gingival labial sulcus, close to the alar margin. The distal portion of the flap lies at the level of the retromolar trigone inferiorly. If the superior labial artery is the terminal branch of the FA, the FAMM flap could be based on it instead of the angular artery, provided that the retrograde flow is sufficient. The length of the flap is to be adjusted according to the location of the defect which requires reconstruction. The width of the flap is usually around 2.5 cm at the distal portion and gets thinner at the base. A doppler is sometimes used to confirm the location of the FA but is not mandatory as the vessel will invariably be found within the previously described anatomic limits.

The first step of the harvest requires identifying the FA. In order to find the FA from the distal part, the area is incised through the mucosa, submucosa and buccinator muscle. When found, it is clipped and sectioned distally. Alternately, the FA can also be found anteriorly. The incision is made at 1 cm posterior to the oral commissure through the mucosa, submucosa, and the orbicularis oris muscle in order to identify the superior labial artery. The latter is then followed in a retrograde fashion to finally lead to the FA. Careful dissection often shows the “Y shaped” junction of the 3 vessels (facial, superior labial and nasal lateral arteries) except when variations of the FA end course is present. Ligation of the superior labial artery should be performed only when the angular artery has been identified.

The flap is harvested in a plane deep to the FA by including the overlying part of the buccinator muscle along its length, and part of the orbicularis oris in the area of the oral commissure. The FA must be kept attached to the overlying tissues in its entire length. During elevation, collateral vessels are clipped and sectioned as the dissection progresses distal to proximal. As mentioned previously, the venous drainage relies on a submucosal plexus and inclusion of the FV is not necessary. In the latter case, it is recommended that a 2 cm soft tissue base be maintained in order to allow adequate venous drainage.

The donor site can be closed primarily if the flap is under 3 cm wide. If there is concern about a potential contracture because of excessive tension, the donor site can be skin-grafted or left to granulate[43].

Indications

FAMM flaps have been widely used for small and medium-sized defects of the oral cavity and other head and neck regions. Their clinical applications are diverse. They are mostly used to reconstruct defects from tumor ablation, but other indications include repair of cleft palate, septal perforation and osteoradionecrosis. Table II provides an exhaustive list of indications of the FAMM flap. Table III illustrates the different sites and subsites reconstructed using the FAMM flaps. The most common reconstruction site is the oral cavity.

Table II. Indications of the FAMM flap reported in the literature

Defects post tumor ablation
Cleft palate
Osteoradionecrosis
Trauma with defects other than septum (MVA, gunshot, bite, fall)
Arteriovenous malformation
Nasal perforation (blunt trauma, cocaine abuse, submucosa resection, Wegener granulomatosis)
Iatrogenic (tooth extraction)
Buccal mucosa contracture release
Facial microsomia (lip)

Table III. Sites of reconstruction of the FAMM flap reported in the literature

Floor of mouth (FOM)
Palate
Alveolar ridge
Lip
Oropharynx
Tongue
Nose
Buccal mucosa
Retromolar trigone
Orbit

Rivera-Serrano et al. recently demonstrated through a cadaveric study that the pedicled FAMM flap, referred in their article as the pedicled FAB flap, is a possible option in the reconstruction of SBD.[13] This new indication of the FAMM flap was never reported in a living patient up until very recently by Patel and colleagues.[44] The authors successfully used the FAB flap for CSF leak in a patient previously operated and irradiated for a sinonasal mucosal melanoma.

CHAPTER TWO: METHODS

Methods

Considering the fact that the FAMM flap has never been used as a SB reconstructive option in living human beings, the best approach was to undertake a cadaveric feasibility study. We have chosen fresh cadavers over formalin preserved cadavers because the pliability of the tissues in fresh cadavers is closer to that of the living human beings, which is more suitable for the objectives of this study. Animal studies were not an option for this research because the craniofacial anatomy of animals is too different from that of the human. This would not have been in line with the purpose of our study.

We have judged it was sufficient to include 10 cadaveric specimens with bilateral flaps harvest totalizing 20 FAMM flaps for such a feasibility study. During the course of our research, an additional 3 specimens which had been preserved using the Thiel embalming technique were offered to us by the anatomy dissection laboratory of Université de Québec à Trois-Rivière (UQTR), bringing our total number of cadaveric specimens to 13 and the number of flaps studied to 26. This research project was approved by the Research Ethics Committees of the Hôpital Maisonneuve-Rosemont (HMR) and the CRCHUM (appendices I and II).

All 13 specimens underwent bilateral superiorly-based FAMM flap harvest, endoscopic endonasal SB dissection and bilateral maxillectomy for flap transfer. Two new modifications using extensions to the masseteric fascia (MF) and the mandibular periosteum (MP) were developed to elongate the traditional FAMM flap for a more complete coverage of the SBD.

Specific measures were taken for each flap and the results were collected in an Excel spreadsheet. Qualitative findings on SB coverage by the flaps were video-recorded using a Karl Storz endoscopy system.

Details pertaining to the surgical technique can be found in the "Methods" section of the article (Chapter III).

CHAPTER THREE: ARTICLE

Authors' contributions

Under Dr Tareck Ayad's supervision, Liyue Xie has completed the following tasks: obtained approbation from the ethics committees from HMR and CRCHUM, organized the dissection sessions, collected the data, performed statistical analysis, contributed to some illustrations of the article (figures 1, 2A, 5 and 6) and wrote the article.

Dr Tareck Ayad, the research director, has guided Liyue Xie through all the tasks mentioned above and has significantly contributed in the article editing.

All the other coauthors, Dr François Lavigne, Dr Akram Rahal, and Dr Sami Moubayed, have participated in dissection sessions and in the editing of the article.

Original Article

Facial Artery Musculomucosal Flap for Reconstruction of Skull Base Defects: A Cadaveric Study

Running title: FAMM flap for skull base reconstruction

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Abstract

Objective: Failure in skull base defects reconstruction following tumour resection can have serious consequences such as ascending meningitis and pneumocephaly. The nasoseptal flap showed a very low incidence of cerebrospinal fluid leak but is not always available. The superiorly pedicled facial artery musculomucosal (FAMM) flap has been successfully used for reconstruction of head and neck defects. Our objective is to show that the FAMM flap can be used as a new alternative in skull base reconstruction.

Study Design: Cadaveric study. Feasibility.

Methods: Thirteen specimens underwent bilateral FAMM flap dissection. Two new modifications of the traditional FAMM flap have been developed. Feasibility in FAMM flap transfer to the skull base was investigated through endoscopic skull base dissection and maxillectomy in four specimens. Measurements were recorded for each harvested flap.

Results: The mean surface area of the modified FAMM flap efficient for reconstruction was 15.90 cm^2. The flaps easily covered the simulated defects of the frontal sinus and the fovea ethmoidalis areas. Modifications of the traditional FAMM flap were necessary for a tension-free coverage of the planum sphenoidale and sella turcica.

Conclusion: The FAMM flap holds high potential as a new alternative vascular flap in skull base reconstruction. However, it has not been used in patients yet and should be considered only when other options are not available. New modifications developed in this paper can elongate the traditional FAMM flap, potentially contributing to a tighter seal of the skull base defect than FAMM flap alone.

Key words: Skull base reconstruction, FAMM flap, musculomucosal flap, facial artery, cerebrospinal fluid leak

Level of Evidence: 4

Introduction

Skull base reconstruction remains one of the most challenging tasks in endoscopic skull base surgery. Locoregional flaps with a reliable vasculature are usually prioritized over the other reconstructive options when the vascularization of the recipient site is compromised by previous surgeries or radiation therapy. A vascularized flap contributes to faster healing, prevents infections at the operative site and is robust enough to withstand post-operative radiotherapy.

The facial artery musculomucosal (FAMM) flap was first described by Pribaz in 1992[39]. It includes mucosa and submucosa of the cheek and a portion of the buccinator muscle[45]. It can be pedicled inferiorly on the facial artery and superiorly on the angular artery. The superiorly based FAMM flap can reach the nasal fossa through an incision at the level of the superior gingivobuccal junction. When based on the angular artery, the FAMM flap has been used in the reconstruction of the palate, upper vestibule, nasal cavity and orbit[38,39,42,45,46]. This flap has many advantages including reliability, absence of an externally visible scar and negligible morbidity of the donor site. Some of the disadvantages include possible scar contracture at the donor site, its limited size, and the need for a second-stage procedure to section the pedicle in some patients.

Our main objective is to demonstrate that the FAMM flap is a feasible option in the reconstruction of skull base defects. Our secondary objectives are to describe the maximal defect size that can be reconstructed with this flap and assess potential extensions of the FAMM flap to adjacent anatomic structures such as the fascia of the masseter muscle or the periosteum of the mandible.

Materials and Methods

This study has been approved by the Research Ethics Committee of Hôpital Maisonneuve-Rosemont. We used 13 cadaveric specimens dissected bilaterally for a total of

26 FAMM flaps. Ten specimens were fresh cadavers and 3 were preserved with the Thiel embalming technique.

Harvesting technique

The anatomy and the harvesting technique of the traditional FAMM flap have been detailed in previous articles[39,42,45-48]. We will therefore only describe the modifications brought to the traditional FAMM flap in this article. Figure 1 is our schematic drawing of the superiorly-based FAMM flap design.

A. FAMM flap with extension to the periosteum of the mandible (Fig. 2)

1. At the inferior border of the traditionally drawn superiorly based FAMM flap, the distal (inferior) incision is prolonged anteriorly and posteriorly along the alveolar crest sparing 3 to 5 mm of gingival mucosa for donor site primary closure.

2. The mucosa and the periosteum are incised at the inferior border according to the drawing and care is taken to avoid sectioning the mental nerve. Note that in edentulous patients, the mental nerve is located closer to the alveolar border and the incision should therefore be made along the alveolar crest to minimize the risk of nerve injury.

3. The periosteum is stripped off using a periosteal elevator to reach the lower mandibular border. Dissection should not proceed beyond the second premolar tooth, where the mental neurovascular bundle exits.

4. The periosteum and part of the submucosa are incised at the most distal edge.

5. The anterior and the posterior limits of the exposed periosteum are then incised to release the distal end of the extension flap, which usually exposes the masseter muscle. The facial artery is usually located just anterior to the masseter and can therefore be ligated and cut. The flap is then elevated from the inferior pole towards the pedicle.

B. FAMM flap with extension to the fascia of the masseter muscle (Fig. 3)

The submandibular approach is performed for this dissection.

1. An incision is made through the skin, subcutaneous tissues and the platysma 4 cm below and parallel to the inferior border of the mandible to spare the marginal mandibular branch.

2. By incising the fascia of the submandibular gland, the facial vessels and the marginal mandibular branch are exposed. The facial artery is ligated and cut, as well as the facial vein if identified.

3. The marginal mandibular branch and the buccal branch of the facial nerve are identified and protected as the dissection is progressed superiorly to release the parotidomasseteric fascia covering the masseter muscle. The fascia must be continuous with the facial artery as this is the extension to the FAMM flap.

4. The usual technique of harvest of the FAMM flap is then performed intraorally without sectioning the facial artery at the inferior border. The parotidomasseteric fascia released in step 3 is then transferred into the oral cavity through a blunt dissection anterior to the masseter muscle.

Transfer of the flaps to the skull base (Fig. 4 and 5)

1. The incisions of the pedicle of the FAMM flap are prolonged to the midline and deepened to reach the maxillary bone.

2. The anterior wall of the maxillary sinus is exposed using a periosteal elevator and should not be carried out too high in order to avoid the neurovascular bundle exiting the infraorbital foramen.

3. An opening large enough for the FAMM flap is made in the anterior wall of the maxillary sinus. The bony edges are smoothed out to avoid flap injury during the transfer.

4. Through an endoscopic approach, the middle turbinate is medialized and a maxillary antrostomy is completed. The bony edges of the antrostomy are removed and smoothed out to create an opening wide enough for the passage of the flap pedicle so it is not compressed or injured.

5. Figure 5 illustrates the course of the FAMM flap to the skull base after it exits the maxillary os. In the figure, the middle turbinate has been resected for illustration purposes. If not resected, it can simply be medialized to allow the flap to exit the maxillary os without any compression. If the patient's disease directs to the removal of the middle turbinates, for example in case of tumour invasion, the flap transfer technique is identical regardless of presence or absence of turbinates.

6. The flap is transferred to the nasal cavity untwisted following the passage created by these 2 openings. The flap is apposed in an onlay fashion to the skull base defect. Inset of the flap requires to direct the mucosal lining towards the nasal cavity and insertion of the muscular component into the defect. Extensions of the FAMM flaps can be folded and used as an inlay layer if deemed necessary.

Measurements

Length and width were taken for all the FAMM flaps and their respective extension flaps (Fig. 6). All measures were taken with a millimetric scaled ruler by the same observer.

Results

The data for all the flaps are presented in Table 1 and the average measures are presented in Table 2. There are 3 FAMM flaps alone, 3 FAMM flaps with extension to the masseteric fascia and 20 FAMM flaps with extension to the mandibular periosteum.

We performed endoscopic maxillary antrostomies in 4 specimens (8 sides). We found that the distal 4.80 to 5.50 cm of each of the FAMM flaps reached the skull base in addition to their extensions. The flaps were able to cover the simulated defects of the planum sphenoidale (Fig. 7A and 7B), and the sella turcica (Fig. 7C and 7D) when brought to its most posterior territory. They easily covered defects in the frontal sinus and the fovea ethmoidalis areas (Fig. 7E to 7H). From our observations, the coverage of the anterior skull base was tension-free even without the use of the extensions. For the posterior defects, inclusion of an extension to the FAMM flap was required for a tension-free coverage.

The mean surface area of the extensions is 5.72 cm^2 overall, 5.06 cm^2 for the mandibular periosteum and 10.10 cm^2 for the fascia of the masseter. The mean total surface area available for reconstruction was 15.90 cm^2 (Table 3).

We were able to identify the facial vein and include it in 3 flaps. However, the facial vein limited the reach of the flap and were therefore cut before inset.

Discussion

The principle in skull base reconstruction is to build a "water-tight" seal separating the cranial cavity and the sinonasal tract in order to prevent potentially fatal complications such as CSF leak and meningitis[23]. For small defects, a success rate greater than 95% can be achieved using a variety of avascular reconstruction options[12]. For larger defects, free grafts gave rise to an unacceptable high rate of CSF leaking, and encouraged skull base surgeons to search for better reconstruction options. Vascular flaps are now the most reliable and preferred options in skull base reconstruction, especially in a previously irradiated territory or when postoperative radiation therapy is planned.

The nasoseptal flap developed by Hadad-Bassagasteguy in 2006 has become the workhorse[12] in endoscopic skull base reconstruction since it was described. It can lower CSF leak rate close to 5%, a rate similar to that of the transcranial approaches[12], and lower the rate of perioperative insertion of external lumbar drains[49]. This flap can cover the entire anterior skull base from the frontal sinus to the sella turcica. One of the disadvantages of the nasoseptal flap is that it needs to be harvested before resection of the skull base tumor. Previous skull base surgery involving posterior septectomy or sphenoidotomy can injure the vascular pedicle and precludes the use of this flap. Other contraindications include the presence of a septal perforation and tumoral involvement of the septum. In these specific cases, alternative flaps should be sought. The inferior turbinate flap[29,31], the middle turbinate flap[30], the endoscopic assisted pericranial flap[28], and the palatal flap[7,50] are all exemples of alternative locoregional vascular flaps used in endoscopic skull base reconstruction. Each of these flaps has specific indications with their own advantages and disadvantages. Other potential flaps such as the bipedicled anterior septal[51] and the occipital galeopericranial[52] flaps have been described in cadaveric studies.

The FAMM flap is a very versatile flap commonly used in oncologic head and neck reconstruction[42,47]. Its arterial supply is based on the facial artery and the venous return is dependant on the venous buccal plexus[38]. Inclusion of the facial vein is therefore not mandatory for flap survival.

The facial artery has variable branching patterns and terminal branches reported in many studies[32-36]. For this reason, preoperative imaging such as angiography of the facial vessels might be indicated for patients selected for skull base reconstruction with the FAMM flap.

This flap has shown many advantages over the last two decades[42]:

- Reliability with low necrosis rate
- Many possible reconstruction sites due to the length and big axis of rotation
- Primary closure of the donor site with negligible morbidity
- Absence of an externally visible scar
- Ease of harvest

The use of a modified FAMM flap in the reconstruction of skull base was previously reported in a cadaveric study by Rivera-Serrano (referred in their study as the facial artery buccinator or FAB flap)[53]. They found that the superiorly based FAB flap reliably reached the anterior skull base and the planum sphenoidale. In their study, some of the flaps were raised without the mucosal part. In our study, we decided to include the mucosa in the flap as we felt that a muscle flap alone could be more easily torn when handled in comparison to a musculomucosal flap and that inclusion of the mucosa would offer a tighter seal against CSF leaks. This is also the first paper to report modifications of the traditional FAMM flap with extensions. Such modifications yield an average lengthening of 2.67 cm and an average increase in surface area of 5.16 cm^2. These findings are convincing in extending the use of FAMM flap for reconstruction of larger defects and possibly new sites that the FAMM flap alone cannot reach.

As opposed to the nasoseptal flap, the FAMM flap can be harvested after complete resection of skull base lesions and be tailored to the resulting defect. Another advantage of this flap in skull base reconstruction is its distant location from the tumour site and therefore, devoid of harmful effects from preoperative radiation therapy or previous local surgeries. The vasculature of the facial artery is strong enough for flap survival if postoperative radiation therapy is anticipated. The FAMM flap is also much bulkier than the nasoseptal flap, an obvious advantage against CSF leaks.

We used the mandibular periosteum and masseteric fascia as extensions to the traditional FAMM flap, allowing an average lengthening of 2.67 cm (2.39 cm for the periosteum and 4.50 cm for the fascia of masseter). This lengthening is critical for the reconstruction of the more posterior regions of the skull base because the FAMM flap alone gives rise to some tension when apposed to these areas. On the other hand, the FAMM flap did not show any tension when brought to the fovea ethmoidalis and the frontal sinuses. Note that the coverage of these areas by the nasoseptal flap can be incomplete[54]. Extensions are probably not required for a full coverage of defects in these areas but they could be used as an inlay layer or an additional onlay layer. Our initial plan was to use the fascia of the masseter as the extension to the FAMM flap. This modification was feasible and relatively easy in terms of harvest. We obtained very impressive results with the full coverage of skull base defects because of the important surface area of the extension but also because the extension could be used as an independent island flap with increased mobility. However, we decided to abandon this modification after 3 flaps because the buccal and marginal branches of the facial nerve course superficially on the masseteric fascia and the risk of injury was considered too high. We then developed the modification with the extension to the mandibular periosteum, which is harvested intra-orally and has less potential morbidity. This modification was applied to the remaining specimens with satisfactory results.

Our findings in 3 specimens make us believe that the facial vein limited full reach of the FAMM flap to the skull base. When the veins were cut, the flaps had increased mobility and were able to reach every important skull base landmarks. There are two potential explanations for this phenomenon. First, according to Lohn's study, the facial vein is a very predictable vessel passing from the inner canthus in a straight line crossing the mandible[36], therefore it is not as tortuous as the facial artery to accommodate the “stretching” of the FAMM flap. Another anatomic explanation could be due to the more posterior position of the facial vein [36-38].

For calculation purposes, we assumed that the distal FAMM flap and the extension flaps are of rectangular shape and their surface areas are approximations only. In the four specimens that underwent endoscopic dissection, the mean surface area made up of the combination of the distal FAMM flap and its extension was 15.90 cm^2. When compared to the other available vascular flaps in skull base reconstruction, the modified FAMM flap has slightly smaller surface area than that of the nasoseptal flap (25 cm^2)[30,51], but larger than that of the inferior (2.40-4.97 cm^2)[29,31,55], middle turbinate (5.60 cm^2)[30] and palatal (10 cm^2)[53] flaps. The entire flap actually has a much greater surface area but the proximal portion was excluded in the calculations as it serves as a bridge from the donor site to the defect. We chose the transmaxillary route for flap transfer as described by Rivera-Serrano[13].

Although all flaps were dissected by respecting anatomic landmarks, some variations in size still exist. Aside from anatomic variations in the specimens, in edentulous specimens with receded mandible height, the length of the mandibular periosteum is necessarily shorter than that of a dentate specimen. The second reason for flap variability is surgeon-dependent because two surgeons participated in the dissection of all the flaps and their technique may differ slightly.

Since this is a cadaveric dissection study, many questions remain unanswered. Flap extensions viability is questionable and hard to assess unless practiced in a living patient. Potential drawbacks of the FAMM flap in the reconstruction of skull base include difficulty in positioning the flap and holding it in place considering the potential gravitational tension of the vertical positioning of the FAMM flap when apposed to the skull base. There is also a risk of retraction on the long term although previous studies have shown low retraction rate when used in head and neck reconstruction[42].

Conclusion

The superiorly pedicled FAMM flap is a feasible option in skull base reconstruction. The FAMM flap can reach the frontal sinuses, the fovea ethmoidalis, the sella turcica and the planum sphenoidale. Modification of the design with inclusion of mandibular periosteum or masseteric fascia can elongate the traditional FAMM flap and allow a better reach for more posterior skull base areas. The FAMM flap holds high potential as a new alternative vascular flap in skull base defects reconstruction but has not been used in patients yet. It should be used only when other options are not available. Further studies are needed to assess its safety and efficacy in skull base reconstruction.

Acknowledgments

We would like to thank Roula Drossis for her expertise in medical drawings. We would also like to thank Gilles Bronchti and his team for providing the Thiel embalming technique preserved specimens (Anatomy laboratory at Université du Québec à Trois-Rivières).

List of tables

Table 1: Measurements for all the flaps

Flap	Type	FAMM		FAMM + Extension	Extension flaps	
		Length (cm) *	Width (cm)	Length (cm) *	Length (cm)	Width (cm)
1	F	9.0	2.0	NA	NA	NA
2	F	8.7	2.3	NA	NA	NA
3	F	9.5	2.4	NA	NA	NA
4	FF	8.5	2.4	16.0▪	5.0▪	2.5
5	FF	8.5	2.4	15.0	4.5	2.0
6	FF	8.2	3.1▪	13.2	4.0	2.2
7	FP	7.8	2.2	9.5	1.7	2.0
8	FP	7.0◆	2.2	8.5◆	1.5	1.8
9	FP	8.8	1.9	12.3	3.5	2.1
10	FP	8.5	1.8	12.5	4.0	2.3
11	FP	9.4	1.9	11.4	2.0	1.0◆
12	FP	8.6	2.5	10.8	2.2	2.6
13	FP	8.5	2.2	10.5	2.0	2.5
14	FP	9.5	3.0	12.7	3.2	1.8
15	FP	8.5	2.1	10.0	1.5	2.2
16	FP	9.0	2.5	12.0	3.0	1.9
17	FP	8.7	2.9	10.9	2.2	1.5
18	FP	8.4	1.3◆	11.5	3.1	2.6
19	FP	8.5	3.0	10.8	2.3	1.7
20	FP	8.3	3.0	10.8	2.5	1.7
21	FP	9.8	2.7	11.5	1.7	2.4
22	FP	9.9	2.3	11.3	1.4◆	3.0
23	FP	11.5▪	2.5	14.4	2.9	2.5
24	FP	9.8	2.8	12.8	3.0	3.5▪
25	FP	8.3	2.2	9.9	1.6	1.7
26	FP	8.1	2.2	10.6	2.5	1.1

F = FAMM; FF = FAMM + fascia of masseter; FP = FAMM + periosteum; NA = not available

* Length is measured from the pivot point

◆ Minimum value

▪ Maximum value

Table 2: Average measurements for all the flaps

Type	FAMM		FAMM + Extension	Extension flaps	
	Mean Length (cm)	Mean Width (cm)	Mean Length (cm)	Mean Length (cm)	Mean Width (cm)
F	9.07	2.23	NA	NA	NA
FF	8.40	2.63	14.73	4.50	2.23
FP	8.85	2.36	11.24	2.39	2.10
All	8.82	2.38	11.69	2.67	2.11

F = FAMM; FF = FAMM + fascia of masseter; FP = FAMM + periosteum; NA = not available

Table 3: Measurements of the surface areas efficient for reconstruction in the specimens which undergone endoscopic dissection

Flap	Type	Area of the extension (cm^2)	Area of the distal FAMM (cm^2)	Total area (cm^2)
3	F	NA	12.00	12.00
7	FP	3.40	10.78	14.18
8	FP	2.70	11.77	14.47
9	FP	7.35	10.07	17.42
10	FP	9.20▪	9.90	19.10
11	FP	2.00◆	9.31◆	11.31◆
12	FP	5.72	12.25	17.97
14	FP	5.76	15.00▪	20.76▪
Mean		5.16	11.39	15.90

F = FAMM; FP = FAMM + periosteum; NA = not available

◆ Minimum value

▪ Maximum value

Area of the extension = extension length * extension width

Area of the distal FAMM = median length of the distal FAMM that touches the skull base * distal width of the FAMM

Total area = area of the extension + area of the distal FAMM

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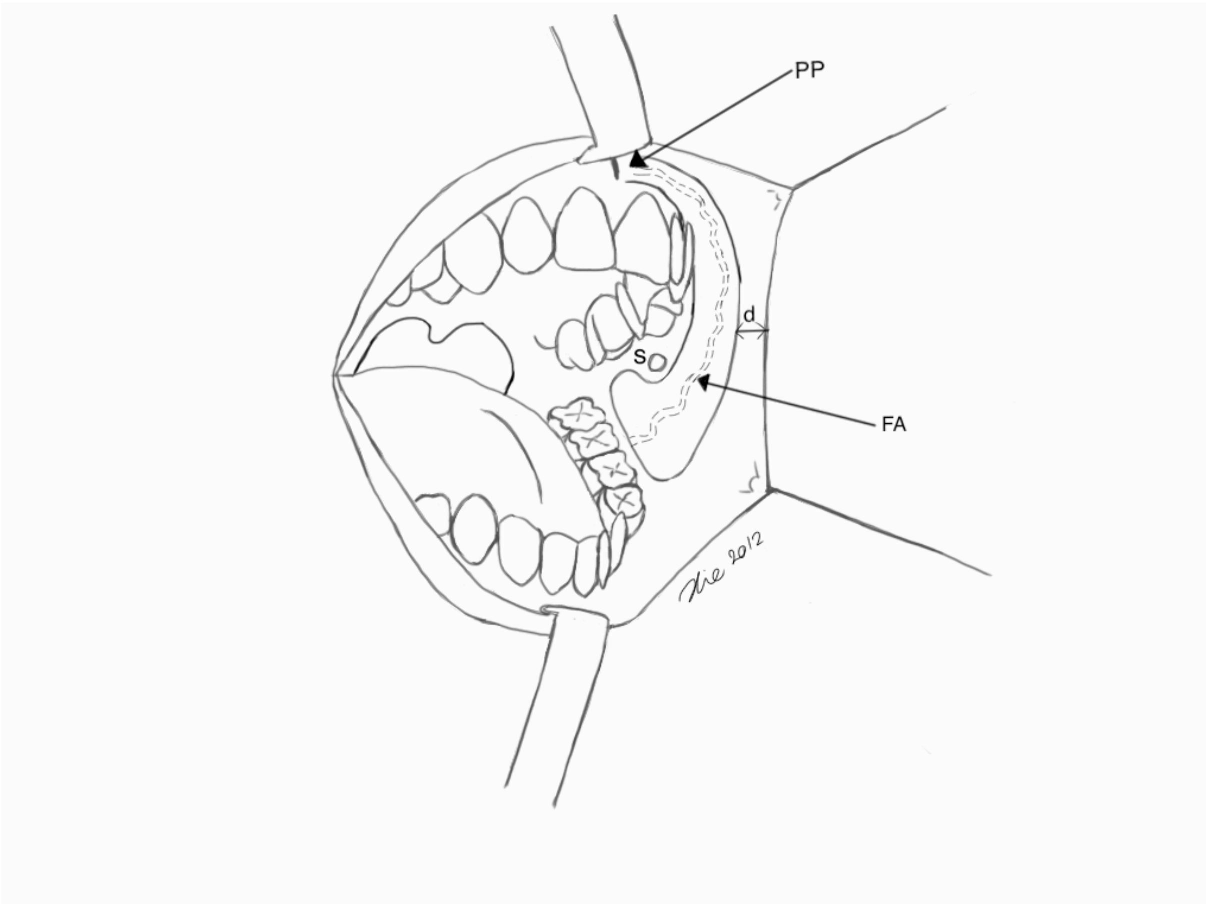

Fig. 1. The superiorly pedicled FAMM flap has an oblique orientation over the facial artery (FA) with its pivot point (PP) at the superior gingivobuccal sulcus. The distance between the anterior border of the flap and the labial commissure (d) should measure 1 cm to avoid commissure retraction. The flap is located anterior to the Stensen's duct (S).

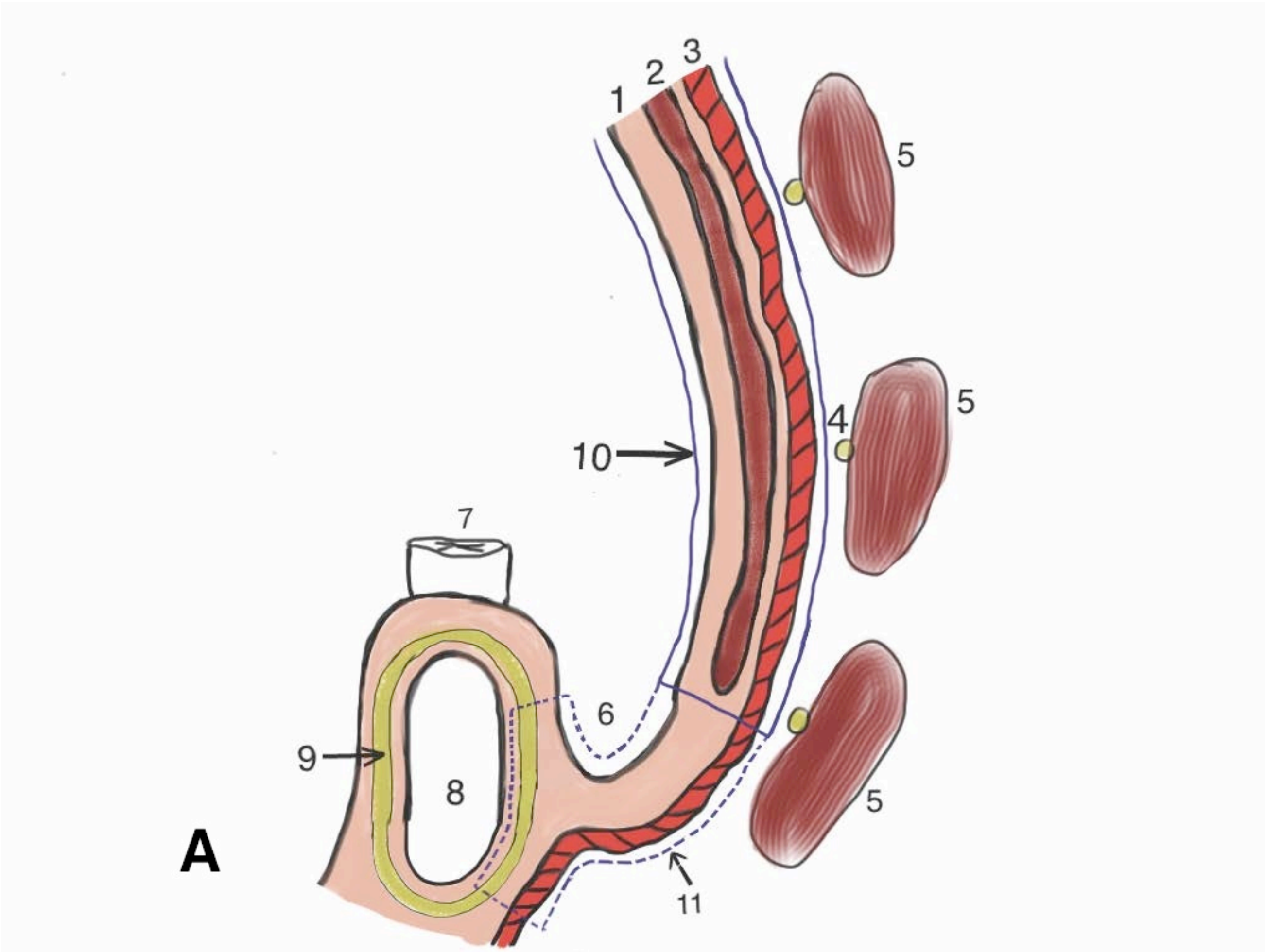
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Fig. 2. (A) Schematic representation of the FAMM flap with extension to the periosteum of the mandible in a coronal cut through the cheek. 1: mucosa and submucosa; 2: buccinator muscle; 3: facial artery; 4: motor branches of the facial nerve; 5: mimic facial muscles; 6: inferior gingivobuccal sulcus; 7: molar; 8: mandible; 9: periosteum; 10: limit of the traditional FAMM flap (full line); 11: modification with extension to the mandibular periosteum (interrupted line). (B) FAMM flap (1) and its periosteum extension (2) in a cadaveric specimen.

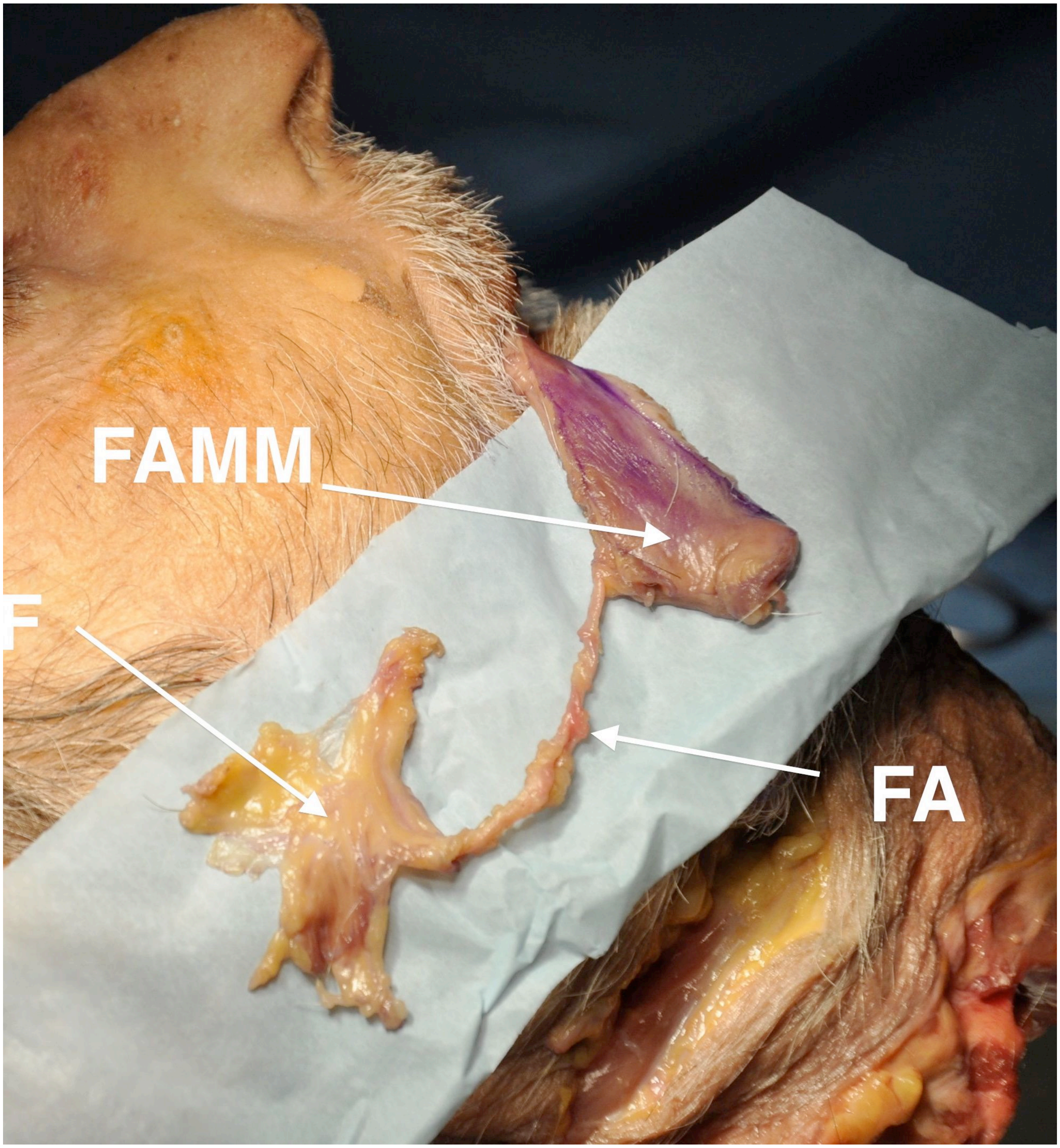
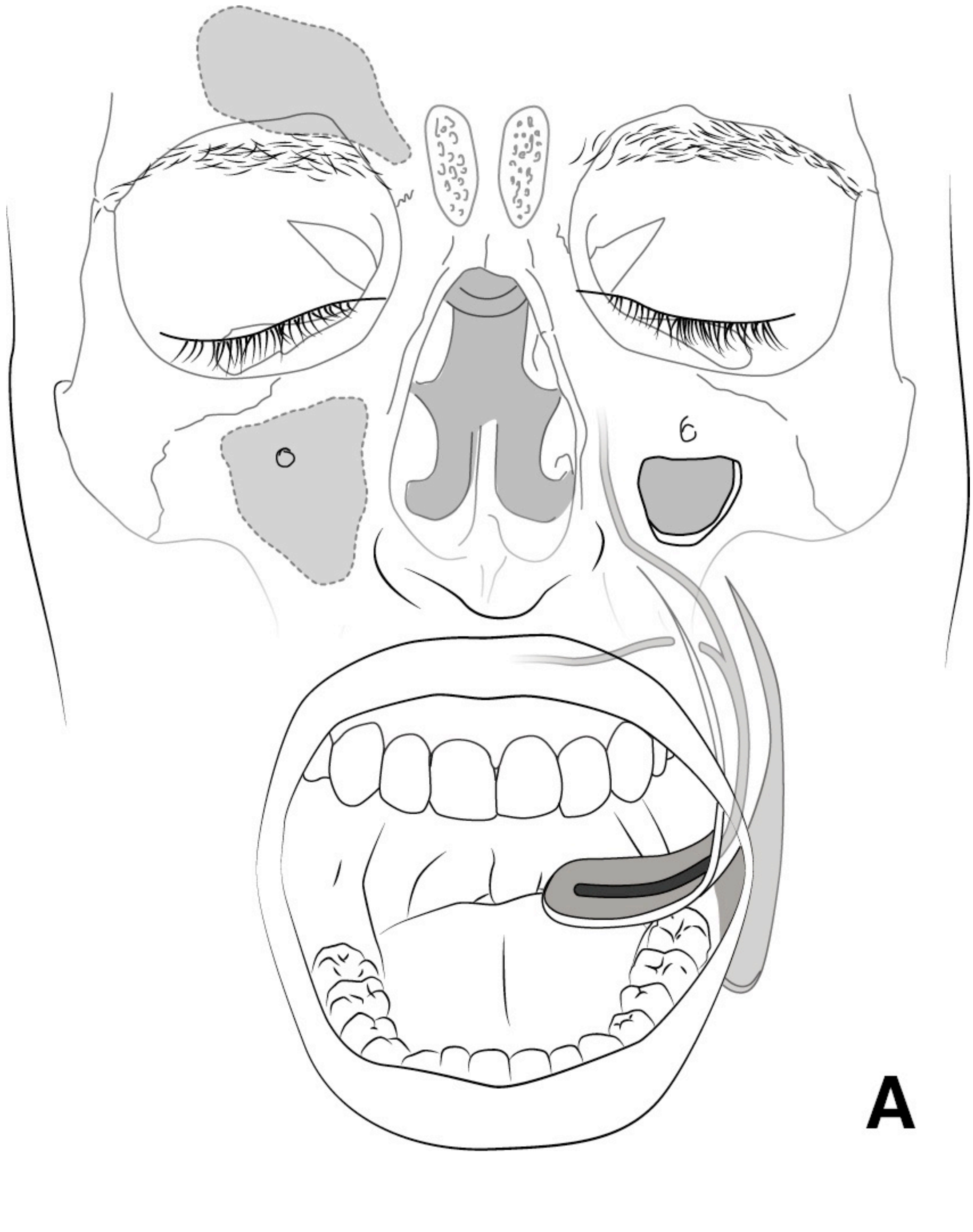


Fig. 3. FAMM flap and its masseteric fascia extension (F) connected by the facial artery (FA) in a cadaveric specimen.



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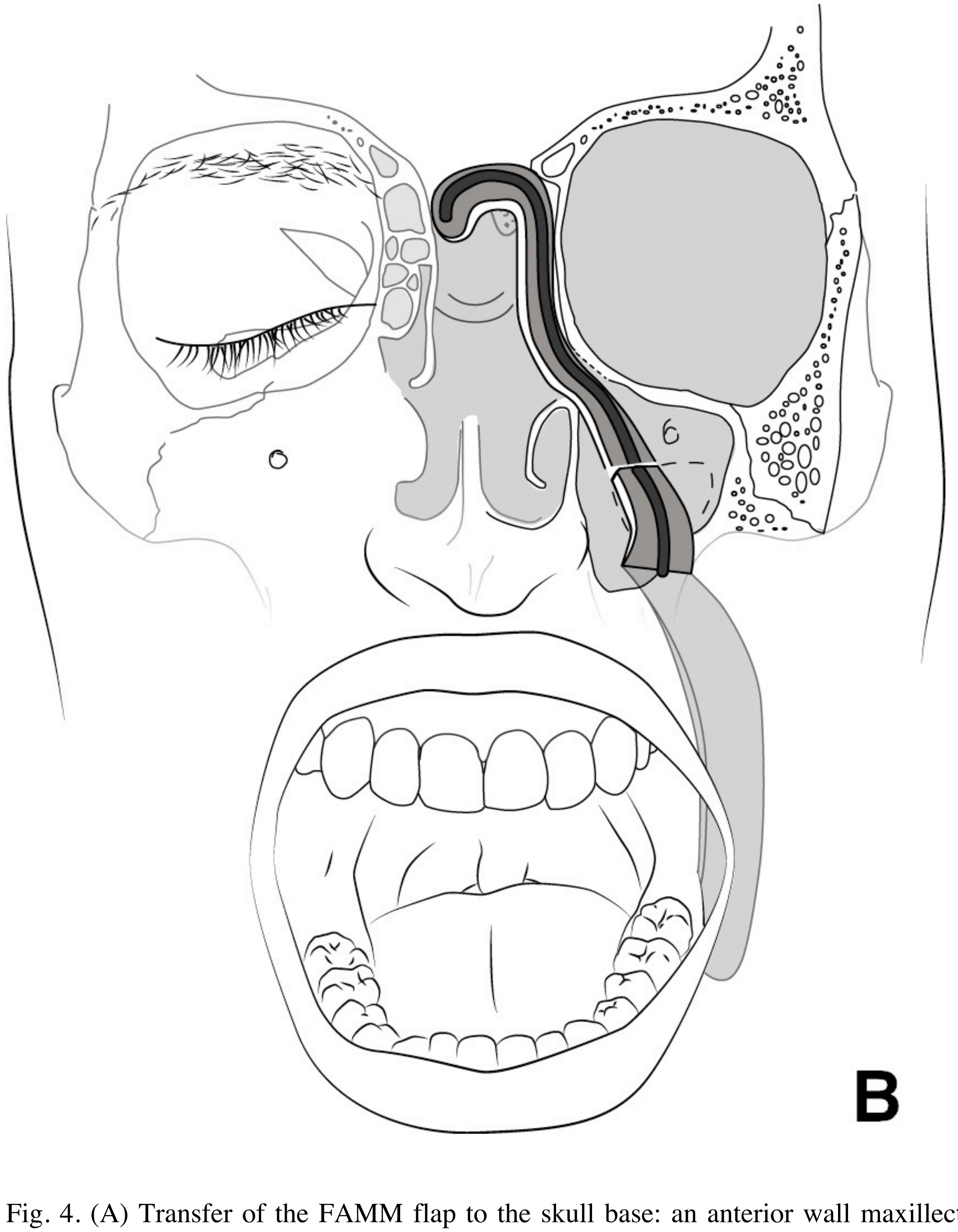


Fig. 4. (A) Transfer of the FAMM flap to the skull base: an anterior wall maxillectomy has been made for the passage of the harvested FAMM flap. (B) Transfer of the FAMM flap to the skull base: the FAMM flap is delivered untwisted to the ethmoid areas through the maxillary sinus and the nasal cavity. Note that the mucosal part is directed towards the nasal cavity.

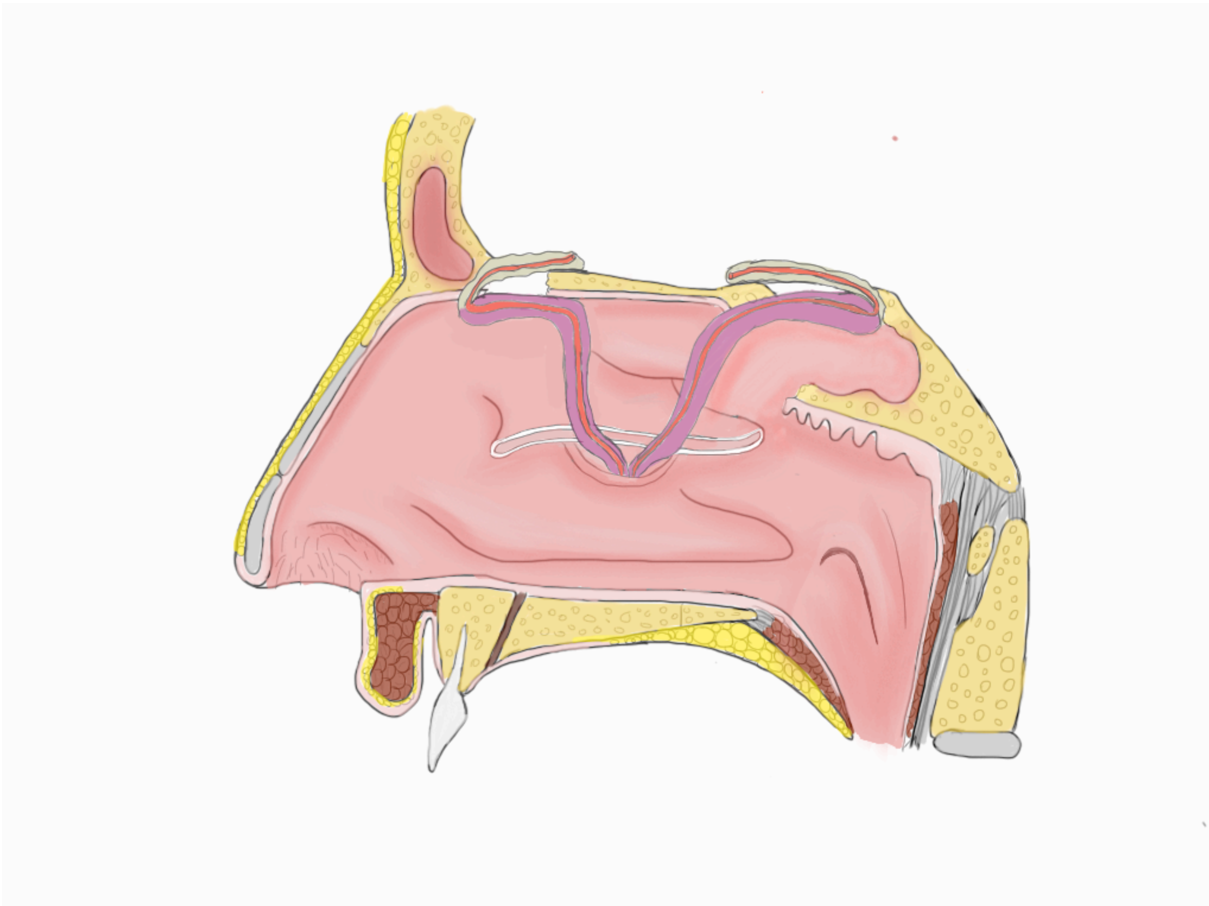


Fig. 5. Sagittal view of the FAMM flap with its periosteum extension used as an inlay layer in the reconstruction of the fovea ethmoidalis and the sella turcica regions. The flap passes from the maxillary sinus to the nasal cavity through a widened antrostomy. In this figure, the middle turbinate has been resected for illustration purposes.

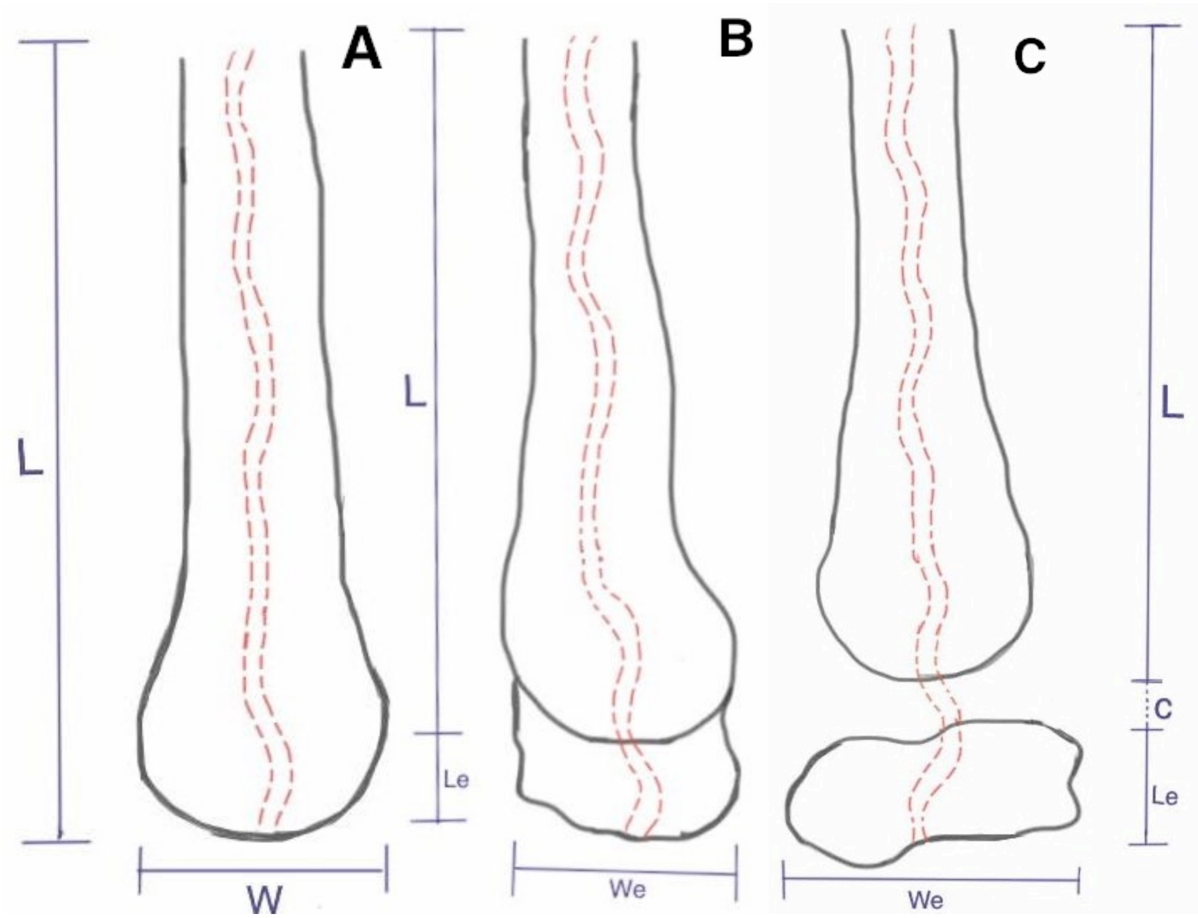
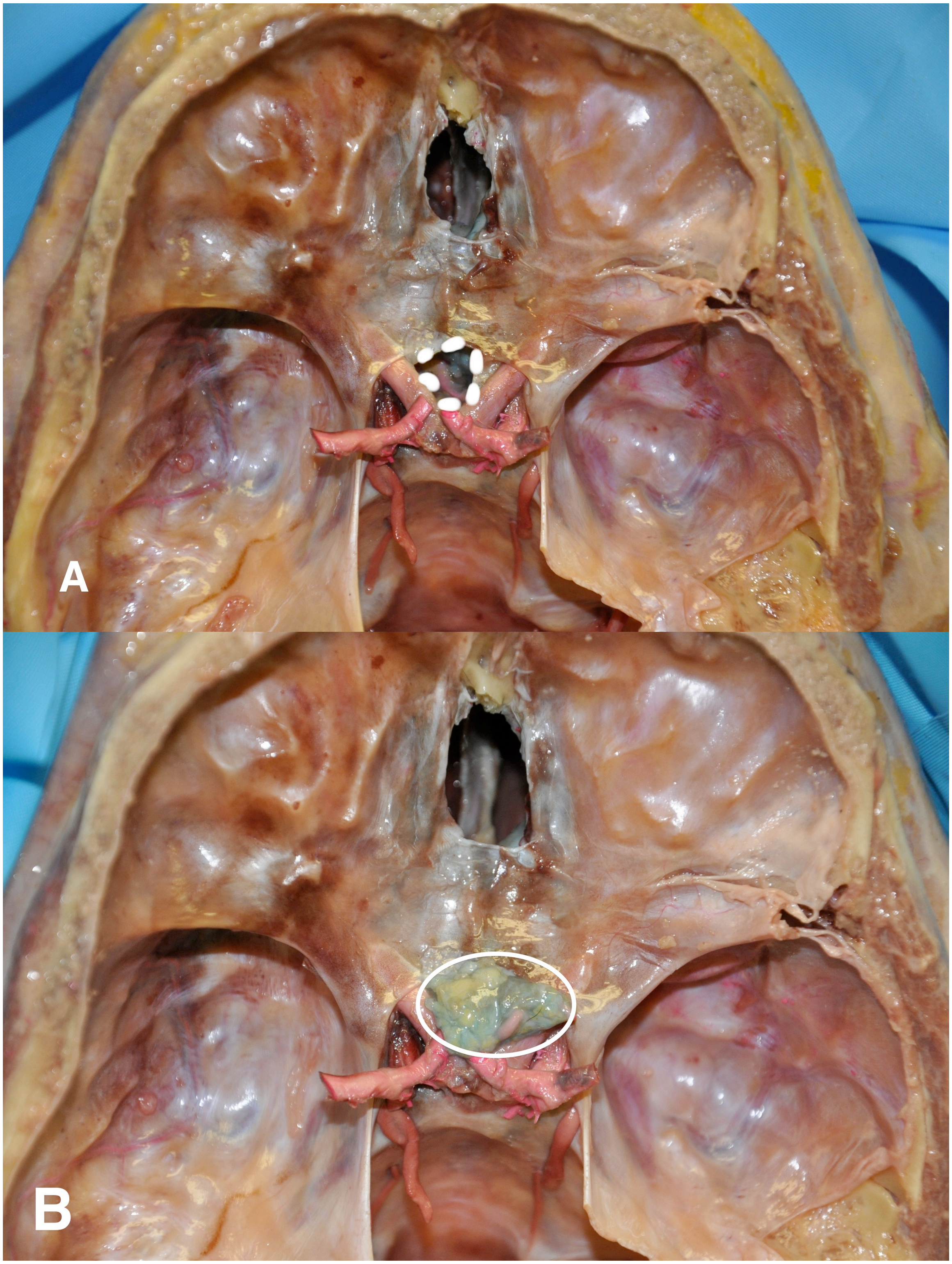


Fig. 6. (A) Measurements of the FAMM flap alone. L: length; W: width (B) Measurements of the FAMM flap with extension to the mandibular periosteum. L: length; Le: extension length; We: extension width (C) Measurements of the FAMM flap with extension to the masseteric fascia; L: length; Le: extension length; We: extension width; C: connecting facial artery.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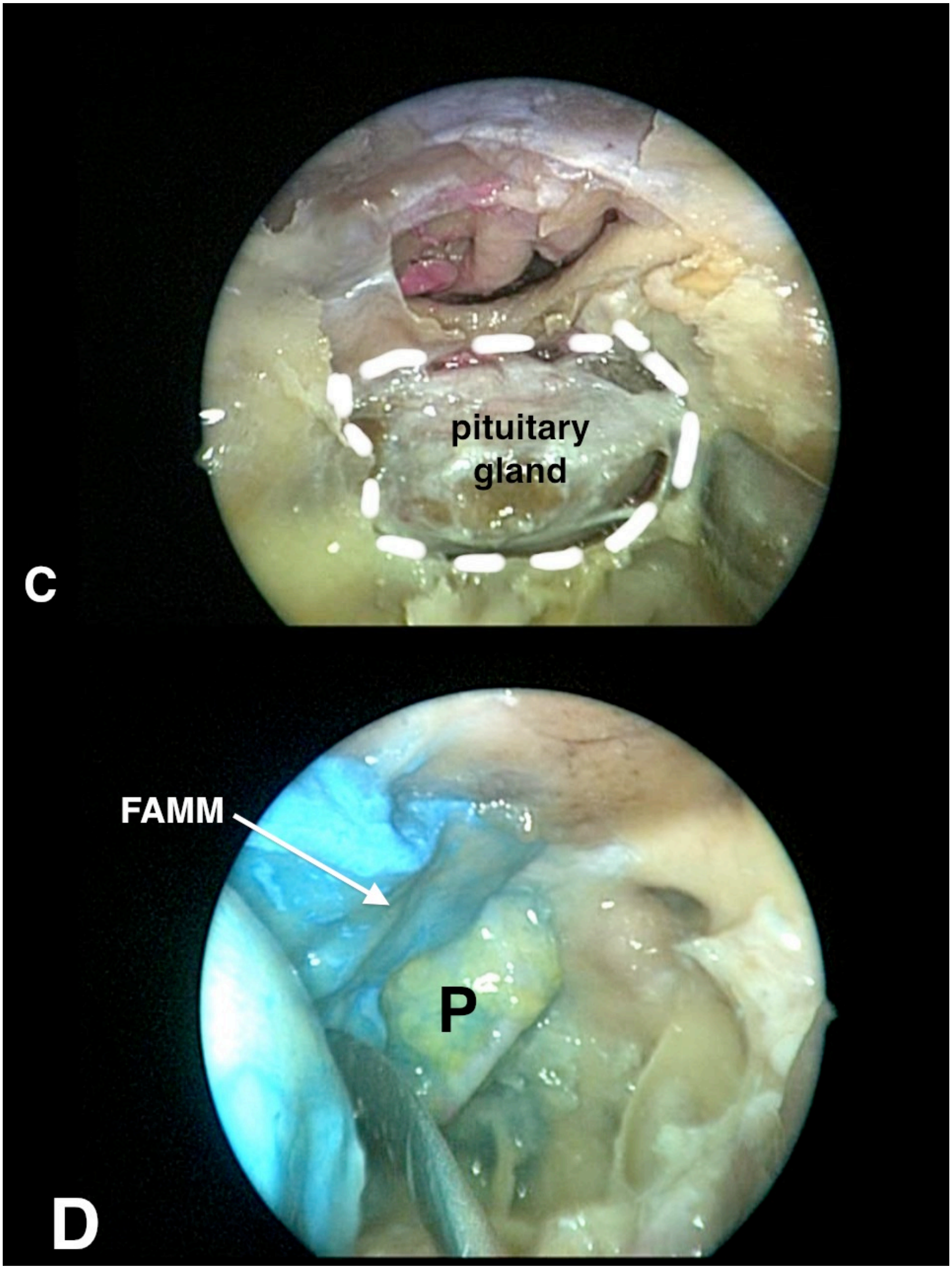
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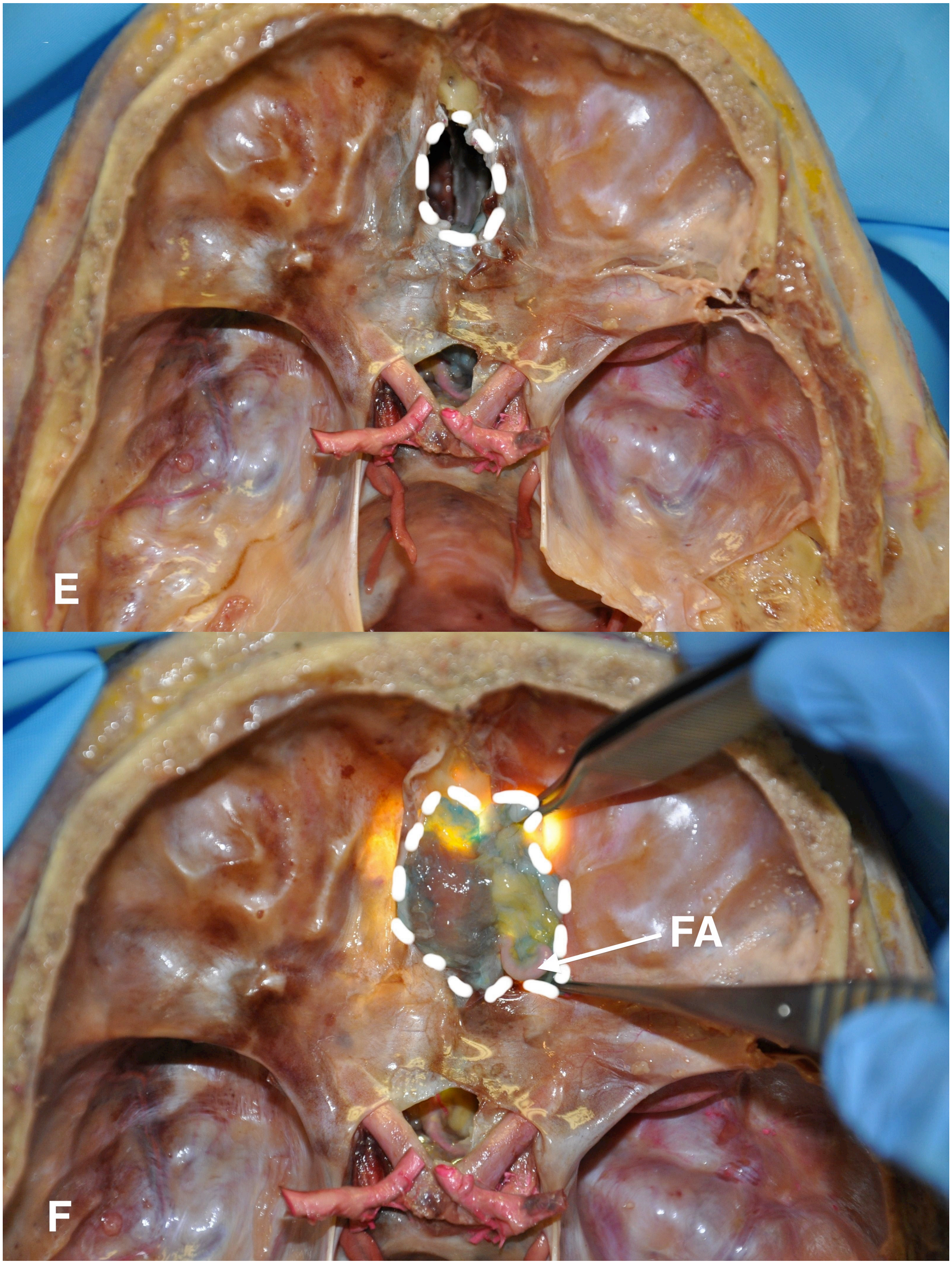
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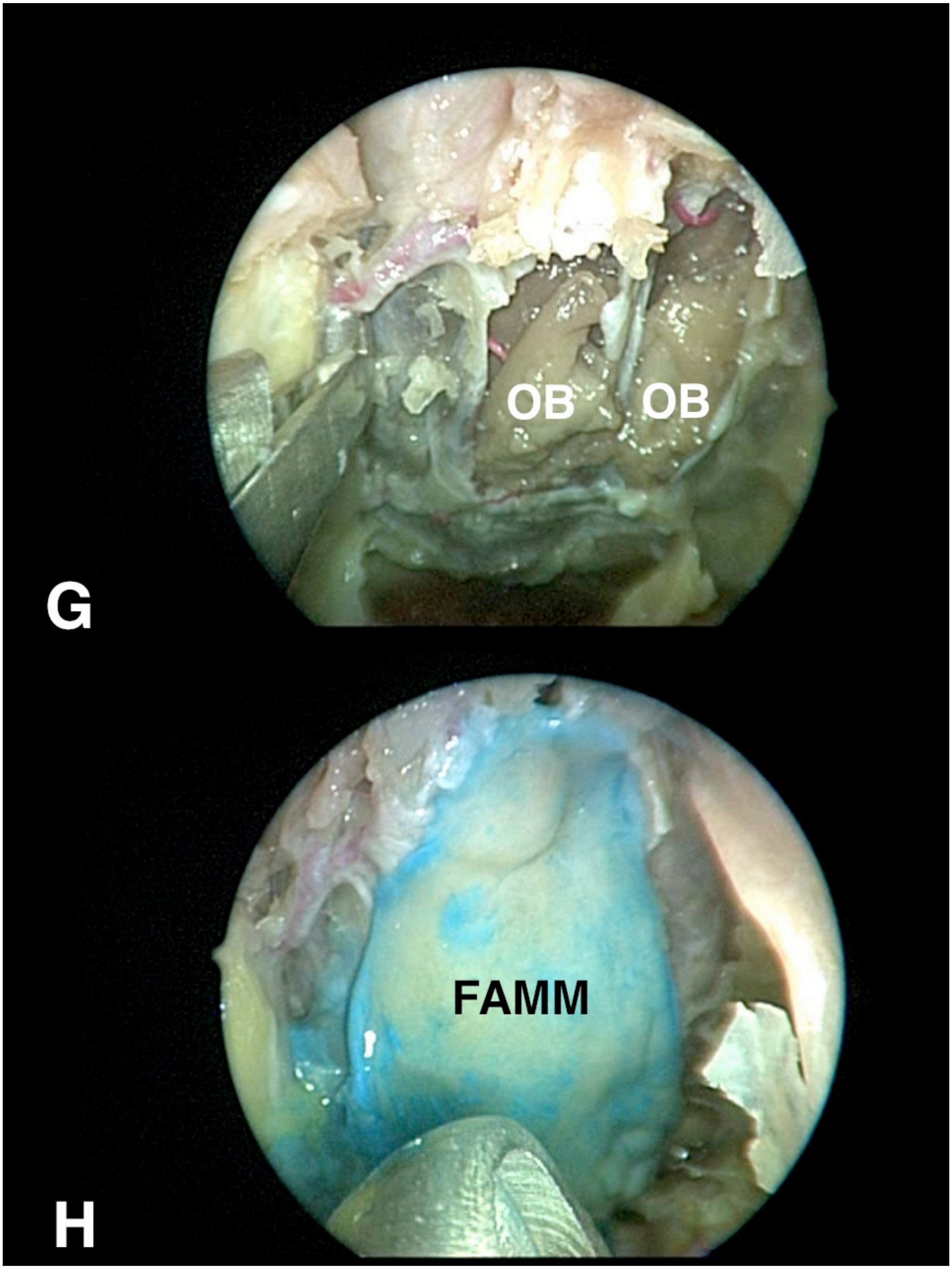
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Fig. 7. (A) Endocranial view of the simulated planum sphenoidale defect. (B) Endocranial view of the complete coverage of the planum sphenoidale defect by mandibular periosteum. (C) Endoscopic view of the simulated sella turcica defect exposing the pituitary gland. (D) Endoscopic view of the complete coverage of the sella turcica defect by the FAMM flap and its periosteum extension (p) in a multilayer fashion. (E) Endocranial view of the simulated fovea ethmoidalis defect. (F) Endocranial view of the complete coverage of the fovea ethmoidalis defect by mandibular periosteum. A small portion of the facial artery (FA) is visible. (G) Endoscopic view of the ethmoid areas exposing the olfactory bulbs (OB) after cribriform plates removal. (H) Endoscopic view of the complete coverage of the ethmoid areas by the FAMM flap with the periosteum underneath (not shown).

CHAPTER FOUR: DISCUSSION AND CONCLUSION

Discussion

Feasibility of the research

The primary objective of this research project was to evaluate the feasibility of bringing the superiorly-based FAMM flap all the way to the SB. Literature review of the FAMM flaps showed that the most common site of reconstruction in the head and neck region was the oral cavity.[42,56,57] The orbits are the furthest sites reconstructed by the FAMM flaps but details on the surgical techniques were not provided.[42] The study with the most similar goal to our own is a cadaveric study conducted by Rivera-Serrano et al., which showed that the FAMM flap (referred in their article as the "facial artery buccinator flap") reliably reached the anterior SB and the planum sphenoidale.[13] Their specimens were non homogeneous (3 fresh and 6 formalin preserved cadaveric specimens) and data were not recorded for each flap. As mentioned previously, the tissues from the formalin preserved specimens do not have the same pliability as the ones taken from living tissues and these specimens were not the ideal specimens to be used for our study and would not help us meet the goal we had set out for this research.

We have only used fresh or Thiel embalmed cadavers in the attempt to make our specimens more homogeneous. Moreover, we have recorded all measures for each harvested flap, and consequently, our statistical analysis turned out to be more indicative than those of our predecessors. Notwithstanding the foregoing, our results did confirm Rivera-Serrano et al.'s findings; the FAMM flap can reliably reach key areas of the SB comprised of the fovea ethmoidalis, the frontal sinus, the sella turcica and the planum sphenoidale.

The downside to using cadaveric studies is that it becomes impossible for researchers to evaluate flap survival. This significant aspect can only be evaluated when performing this kind of reconstruction on a living patient under very strict indications, such as the unavailability of the nasoseptal flap. Following the completion and publication of this study, we came upon a clinical case at our institution (Hôpital Notre-Dame) where a patient had a chordoma invading the clivus. After tumor removal, there was a defect of the clivus and an exposure of the internal carotid artery in the nasopharyngeal portion. A superiorly-based FAMM flap with extension to the MF measuring up to 10 cm in length and 2.5 cm in width was successfully harvested and was able to completely cover the defect. The flap survived during clinical follow up, even after undergoing radiation therapy at the operating site. This is our first case report of a successful reconstruction of the nasopharynx using the FAMM flap. The article detailing this specific case is currently being written and will be published at a later date.

At the same time as we conducted our own research, another team was investigating the same reconstructive option on a living patient. After our article was published in May 2013 (Chapter III), Patel et al. reported the first case of an anterior SBR using the FAMM flap on a living patient.[44] In their article, they referred to the FAMM flap as "facial artery buccinator flap." The case involves a female patient with sinonasal mucosal melanoma who had undergone surgery, pericranial flap reconstruction and adjuvant radiation therapy. She had developed osteoradionecrosis three years later, which presented itself as an anterior cranial fossa CSF leak. The CSF leak was completely resolved after the reconstruction. This is the first live case found in the literature where a patient underwent a successful skull base reconstruction using the FAMM flap. These findings support and complement the results of our own research.

Vascular reconstruction

It is well known in the field of SBR that a vascularized flap promotes faster healing and is less susceptible to migration, thus decreasing the rate of CSF leak.[12] In comparison to the NSF, the FAMM flap also has a reliable vasculature based on the FA or the angular artery. When employed in head and neck reconstruction, the rate of total necrosis ranged from 0.9% to 12.5%.[39-43,46,56-63] The most commonly reported complication was venous congestion and they usually resolved spontaneously within 48 to 72 hours. Total flap loss and flap complications requiring revision surgery are rare.[46,62]

Modifications of the FAMM flap

Before deciding to undertake this study, we had performed a "pre-evaluation" session on the feasibility of our main objective by harvesting a FAMM flap and performing an endoscopic endonasal dissection on one cadaveric specimen. Our preliminary findings showed that the traditional FAMM flap was able to reach the SB with a certain degree of tension, especially when brought to the posterior regions of the ventral SB. This presented itself as a potential problem should we wish to carry out our project, so we started working on the idea of developing new modifications to elongate the traditional FAMM flap. After extensive review of the literature on the anatomy of the cheek mucosa, the FA and the FAMM flap, we decided to harvest the FAMM flaps with the new modifications developed in our study. The modification using the MP is technically easier to harvest than the one with the MF, and carries a smaller risk of damaging the buccal and mandibular branches of the facial nerve. Considering that the former modification gave rise to satisfactory coverage of the key areas of the SB, this was our preferred modification method for most of our flaps. Several authors have recommended using alternative flaps such as the posterior pedicled inferior turbinate flap to reconstruct defects of the planum sphenoidale because of its very posterior location.[31,44]

However, with our newly developed modifications, the FAMM flaps can reach the planum sphenoidale without any tension and could potentially eliminate the problem of posterior SBR.

Several other modifications of the FAMM flap have been reported in the literature. Among them, some modifications have the purpose of harvesting an island FAMM flap in order to mobilize the flap even further. Massarelli et al. developed the arterialized FAMM island flap (a-FAMMIF), which is solely based on the FA, with the soft tissues around the pedicle being fully dissected and divided (figure 4). The authors mentioned that the venous return was based on the venae comitantes which are present in the colar of fat located around the FA. This modification extended the reach of the FAMM flap.[41] The a-FAMMIF was described as early as 1995 by Uglesic et al.[64] Although they did not name it the a-FAMMIF, the principle remains the same.

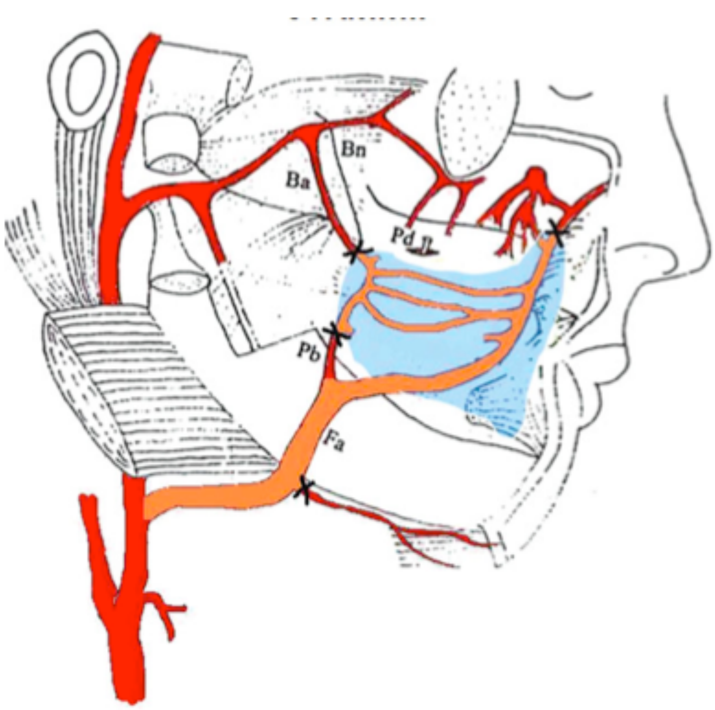

Figure 4. Facial artery musculomucosal island flap (FAMMIF). Fa: facial artery; Ba: buccal artery; Bn: buccal nerve; Pd: parotid duct; Pb: perforator branch

Source: Massarelli et al. *Cheek mucosa: a versatile donor site of myomucosal flaps. Technical and functional considerations*. Head & neck 2013.[41]

Massarelli et al. have also designed the bilobed or trilobed island FAMM flap (figure 5).[65-67] Both FA and FV are dissected bluntly from the surrounding cheek tissues to release the flap, which is then tunnelized to the neck through a paramandibular tunnel. The drawback of this modification is a possible higher risk of marginal mandibular branch palsy because a wide dissection of the facial pedicle is required through a narrow tunnel of the cheek. Massarrelli at al. have first published this modification under the term of buccinator myomucosal island flap[65] and then under the name of tunnelized-facial artery myomucosal island flap (t-FAMMIF).[68]

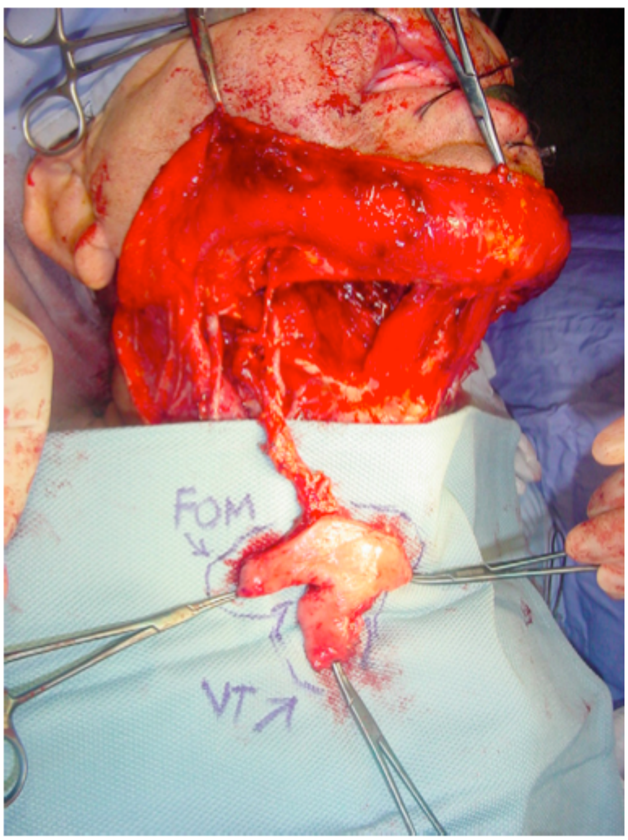

Figure 5. Trilobed myomucosal FAMM island flap showing reconstruction of 2 adjacent sites. FOM: floor of mouth; VT: ventral tongue

Source: Massarelli et al. *Three-dimensional primary reconstruction of anterior mouth floor and ventral tongue using the 'trilobed' buccinator myomucosal island flap*. Int J Oral Maxillofac Surg 2008. [65]

In our study, it is the MF that is islanded in order to increase the mobility and the reach of the entire flap. The island of fascia is connected to the distal FAMM flap by an interposition of free FA. If the islanded FAMM flaps developed by Massarelli et al. survived, we can therefore assume that the MF being islanded in our modification should be viable as well. All the above modifications mobilize the FAMM or the extension flap as island flaps and greatly increase the reach of the flap toward further head and neck sites or even the skull base.

Practical implications

The results from this research now provide the SB surgeons with a new flap in the reconstruction armamentarium. When the SBD, after tumor removal, is large and the NSF is unavailable, the superiorly-based FAMM flap can be considered to be an alternative choice. There are of course other alternative pedicled flaps which are available but the choice should be made based on several factors such as the size and location of the defect.[69] As we have previously demonstrated, the FAMM flap is a good choice for anterior SBD providing a tension-free coverage. As for the more posteriorly located planum sphenoidale, we would recommend including the newly developed modifications as additional length or as multilayer reconstruction. The modification with the fascia of the masseter has been successfully used in a living patient, as previously mentioned, but special care should be taken when considering the modification with the periosteum since this has never been used in a clinical case.

The size of the defect should be evaluated before opting for the modified FAMM flap with MP because it has a mean surface area of 15.90 cm^2 (range 11.31 cm^2 to 20.76 cm^2). If the defect is larger, one can consider using the FAMM flap with the extension to the MF. We harvested 3 flaps with the fascia of the masseter and the mean extension surface area was 10.10 cm^2 (range 8.8 cm^2 to 12.5 cm^2), which was two times larger than the periosteum extension (5.06 cm^2). Let us assume that our measurements of the distal portion of the FAMM flap touching the SB were consistently the same, this would give rise to a mean efficient surface area for reconstruction totalizing 21.49 cm^2 (10.10 cm^2 + 11.39 cm^2), which is almost as large as the NSF.

Limitations of the study

One of the limitations of this study was the difficulty in taking precise measurements of the distal portion of the FAMM flap which touches the SB endoscopically, giving rise to potential instrumental biases. Also, given the tissue's characteristics, the flaps could have been overstretched depending on the pulling tension we exerted when we transferred it into the nasal cavity and brought it to the SB. In such a case, a greater distal portion would have touched the SB and the measure could then have been falsely increased. The measurements were then taken by placing the scaled ruler on the flap. Although the ruler was pliable, it was sometimes very difficult to place it perfectly on the flap in the small endoscopic corridor. This is the main reason why the measurements were reported as a range of measures (4.8 cm to 5.5 cm).

Theoretically, we had planned to perform endoscopic dissection and bilateral maxillectomy on all 13 specimens. Finally, we only ended up dissecting 4 specimens, which allowed us to take endoscopic measures for 8 flaps. We have decided not to proceed with further dissections because the findings were consistent and conclusive, and we considered them to be sufficient to reach our main objective.

Directions for future research

It has been stated in several studies that free flaps offer significant advantages over local and pedicled flaps.[69-72] A few of the advantages include flap flexibility, better aesthetic outcome, and the ability to introduce large of well-vascularized tissue directly where it is needed. When the pedicled flaps are used in reconstructing SBD, is it usually the crucial distal portion which is involved in covering the defect. Unfortunately, it is also the most distal portion which is at risk of necrosis.[69,73] A small area of marginal necrosis can lead to CSF leak.[72] We have reviewed the literature on FAMM flap complication rates and the average partial necrosis rate was 8.2%. Most of the time, it is the distal portion which necroses.[43,63] In light of these findings, the incorporation of the extension flaps of periosteum and fascia to achieve a multilayer reconstruction is highly recommended.

Massarelli et al. have recently reported a case report of free FAMM flap in contralateral cheek mucosa reconstruction.[74] The flap is harvested with the FA and FV and the mucosa of the pedicle is cut in order to allow the use of the FAMM flap as a free flap. In this case report, the patient underwent postoperative radiation therapy with a maintained flap bulk and excellent aesthetic results ensued. One of the main drawbacks of musculocutaneous free flap is that it is often too bulky for skull base reconstruction. The FAMM flap is not too voluminous and has the advantage of being a musculomucosal flap which can allow the replacement of the SB linings with similar tissues. If the FAMM flap is used as a free flap in SBR, the total surface area which can be efficiently used for the reconstruction will now cover the total length of the flap, and not only the distal portion. When it was used as a pedicled flap, the proximal portion was "lost" because it solely served as a bridge from the donor site to the defect.[75]

Conclusion

We have successfully achieved our main objective by showing the possibility and feasibility of using the FAMM flap as a new alternative in SBR. This flap is best suited for reconstruction of the anterior SB. Reconstruction of the posterior SB, such as the planum sphenoidale, might generate some tension which can be relieved with the inclusion of the newly developed extension flaps. We hope that our study and the study conducted by Rivera-Serrano et al. will encourage further research in evaluating the reliability of the FAMM flap in SBR in living humans. Our first clinical case and the case reported by Patel et al. [44] in living human beings are additional examples of the versatility of the FAMM flap. This flap deserves a place in the armamentarium of any reconstructive surgeons.

CHAPTER FIVE: REFERENCES

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APPENDICES

Appendix I. Ethic certificate from Hôpital Maisonneuve-Rosemont

HMR Hôpital Maisonneuve-Rosemont
Centre affilié à l'Université de Montréal

Pour vous, pour la vie

Certificat éthique

Le Comité d'éthique de la recherche de l'Hôpital Maisonneuve-Rosemont a approuvé et assurera le suivi du projet de recherche intitulé:

> ***Évaluation du lambeau myomuqueux de la joue (FAMM flap) dans les reconstructions des déficits de la base du crâne antérieur. (Réf. CÉR : 11045)***

présenté par ***Dr Akram Rahal.*** Cette étude est conforme aux normes éthiques actuelles.

Ce certificat est valide pour la période du ***7 juillet 2011*** au ***7 juillet 2012.***

[redacted]

Paule Savignac, Conseillère à l'éthique
Vice-présidente
Comité d'éthique de la recherche
Hôpital Maisonneuve-Rosemont

PS/fh

Appendix II. Ethic certificate from Centre de Recherche du Centre hospitalier de l'Université de Montréal

CHUM

COMITÉ D'ÉTHIQUE DE LA RECHERCHE DU CHUM

Édifice Cooper
3981, boulevard St-Laurent, Mezz 2
Montréal (Québec) H2W 1Y5

Le 30 juin 2011

Dr Tareck Ayad
Hôpital Notre-Dame du CHUM
[redacted]

Dre Liyue Xie
[redacted]

Objet : ***11.093 – Approbation accélérée initiale et finale CÉR***

Évaluation du lambeau myomuqueux de la joue (FAMM flap) dans les reconstructions des déficits de la base du crâne antérieur

Docteur Ayad,

J'ai pris connaissance des documents suivants reçus au CÉR du CHUM en date du 21 juin 2011 en vue de l'approbation du projet en rubrique :

- *Formulaire de demande d'évaluation éthique d'un projet de recherche*
- *Résumé du protocole*
- *Lettre du chef de division ORL et chirurgie cervico-facial – UdeM – 01 juin 2010*

En vertu des pouvoirs qui me sont délégués par le Comité d'éthique de la recherche du CHUM pour procéder à une évaluation accélérée, il me fait plaisir de vous informer que j'approuve votre projet puisqu'il s'agit d'un projet se situant sous le seuil de risque minimal.

La présente constitue l'approbation finale du comité suite à une procédure d'évaluation accélérée. Elle est ***valide pour un an à compter du 30 juin 2011*** *date de l'approbation de votre projet. Je vous rappelle que toute modification au protocole et/ou au formulaire de consentement en cours d'étude, doit être soumise pour approbation du comité d'éthique.*

Cette approbation suppose que vous vous engagiez :

1. *à respecter la présente décision;*
2. *à respecter les moyens de suivi continu (cf Statuts et Règlements)*
3. *à conserver les dossiers de recherche pour une période d'au moins deux ans suivant la fin du projet afin permettre leur éventuelle vérification par une instance déléguée par le comité;*
4. *à respecter les modalités arrêtées au regard du mécanisme d'identification des sujets de recherche dans l'établissement.*

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Le comité suit les règles de constitution et de fonctionnement de l'Énoncé de Politique des trois Conseils et des Bonnes pratiques cliniques de la CIH.

***Pour toute question relative à cette correspondance**, veuillez communiquer avec la soussignée à l'adresse courriel suivante :* [redacted] *ou avec sa collaboratrice par courriel ou téléphone :* [redacted]

Vous souhaitant la meilleure des chances dans la poursuite de vos travaux, je vous prie d'accepter, Docteur Ayad, mes salutations distinguées.

[redacted]

Brigitte St-Pierre, conseillère en éthique
Présidente
Comité d'éthique de la recherche du CHUM

BSTP/go

C.c. *Bureau des contrats*
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