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REVIEW ARTICLE

Gracilis free flap in head and neck reconstruction beyond facial palsy reanimation

Carlos Miguel Chiesa-Estomba[a,i,*], José Ángel González-García[a], Cesare Piazza[b], Miguel Mayo-Yanez[c,i], Alberto Grammatica[d], Jerome R. Lechien[e,i], Taseer F. Din[f], Petros Karkos[g], Leire García-Iza[a], Tareck Ayad[h,i]

[a] *Otorhinolaryngology – Head & Neck Surgery Department, Hospital Universitario Donostia, San Sebastian, Guipuzkoa – Basque Country, Spain*
[b] *Department of Otorhinolaryngology, Maxillofacial and Thyroid Surgery, Fondazione IRCCS, National Cancer Institute of Milan, University of Milan, Milan, Italy*
[c] *Otorhinolaryngology – Head and Neck Surgery Department, Complexo Hospitalario Universitario A Coruña (CHUAC), 15006 A Coruña, Galicia, Spain*
[d] *Department of Otorhinolaryngology – Head and Neck Surgery, University of Brescia, Brescia, Italy*
[e] *Department of Human Anatomy & Experimental Oncology, University of Mons, Mons, Belgium*
[f] *Division of Otolaryngology, University of Cape Town, Groote Schuur Hospital, Cape Town, South Africa*
[g] *Department of Otolaryngology – Head Neck Surgery, Ahepa University Hospital, Thessaloniki, Greece*
[h] *Division of Otolaryngology – Head & Neck Surgery, Centre Hospitalier de l'Université de Montréal, Montreal, Canada*
[i] *Head & Neck Study Group of Young-Otolaryngologists of the International Federations of Oto-rhino-laryngological Societies (YO-IFOS), France*

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KEYWORDS
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Free flap;
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Abstract
Introduction: The gracilis muscle free flap has gained popularity in head and neck reconstruction due to minimal donor-site morbidity, reliable vascular pedicle, strong muscular component, and possibility to perform nerve coaptation. However, almost all the existing evidence in the literature is related to its use for facial palsy reanimation. The aim of this study was therefore to review and provide a comprehensive summary of all the possible indications and outcomes of this versatile free flap in head neck reconstructive surgery.
Materials and methods: A systematic review of the literature was conducted including articles from 1970 to 2019. All articles were examined and described.
Results: Twenty-seven papers published between 1994 and 2019 were identified for analysis. The evidence highlights the use of the gracilis muscle free flap for parotid, forehead and midface defects, oral tongue, oral sphincter, lower and upper lip, cheek, and oral commissure defects, among others, as the most common defects reconstructed.

* Corresponding author.
E-mail address: chiesaestomba86@gmail.com (C.M. Chiesa-Estomba).

Conclusion: This flap represents an easy to harvest and versatile free flap with low donor-site morbidity and multiple proven uses in head & neck reconstruction. We therefore encourage reconstructive surgeons to include this flap in their armoury, either as a first or as a second-line option.

PALABRAS CLAVE
Gracilis;
Colgajo libre;
Reconstrucción de cabeza y cuello

Colgajo libre de gracilis en cirugía reconstructiva de cabeza y cuello, más allá de la reanimación de parálisis facial

Resumen
Introducción: El colgajo libre de músculo gracilis ha ganado popularidad en la reconstrucción de cabeza y cuello debido a una mínima morbilidad en el sitio donante, un pedículo vascular confiable, un componente muscular fuerte y la posibilidad de realizar una coaptación nerviosa. Sin embargo, casi toda la evidencia existente en la literatura está relacionada con su uso para la reanimación de la parálisis facial. El objetivo de este estudio fue, por tanto, revisar y proporcionar un resumen completo de todas las posibles indicaciones y resultados de este versátil colgajo libre en cirugía reconstructiva de cabeza y cuello.
Materiales y métodos: Se realizó una revisión sistemática de la literatura incluyendo artículos de 1970 a 2019. Todos fueron examinados y descritos.
Resultados: Se identificaron 27 artículos publicados entre 1994 y 2019 para su análisis. La evidencia destaca el uso del colgajo libre de músculo gracilis para defectos de parótida, frente y región medio facial, lengua oral, esfínter oral, labio inferior y superior, defectos de mejilla y comisura oral, como los defectos reconstruidos más comunes.
Conclusión: Este colgajo representa un colgajo libre versátil y fácil de elevar con baja morbilidad a nivel del sitio donante y múltiples posibilidades en la reconstrucción de cabeza y cuello. Por lo tanto, representa una herramienta útil en el arsenal reconstructivo de cualquier cirujano, ya sea como una opción de primera o de segunda línea.

Introduction

Since its first description by Harii et al. in 1976,[1] the *gracilis* muscle free flap (GMFF) has gained popularity in the head and neck (HN) reconstruction due to a minimal donor-site morbidity, reliable vascular pedicle, strong muscular component, and possibility to perform nerve coaptation. Anatomically, the *gracilis* is part of the adductor muscles of the hip, it is located in the superficial-medial aspect of the thigh and measures approximately 25 cm in length. It originates from the ischiopubic ramus and inserts onto the medial tibia, below the condyle, via the *pes anserinus*. Innervation is provided by the obturator nerve, measuring approximately 12 cm in length. Its vascular supply usually arises from the *profunda femoris* artery and, occasionally, from the medial circumflex artery, accompanied by 2 *venae comitantes* draining into the deep venous systems of the thigh. The entry point of the pedicle is generally located 8−10 cm caudally to the pubic tubercle and its average length is up to 6 cm with an artery caliber ranging from 1 to 2 mm (Figs. 1 and 2).

Nearly all the existing evidence in the literature about GMFF is related to its use for facial palsy reanimation. This was recently summarized by Roy et al. in a systematic review on the effectiveness and safety of GMFF for dynamic smile restoration in facial paralysis.[2] However, there is a multitude of other uses described in HN surgery such as resurfacing or reconstruction of parotid defects,[3,4] forehead defects and midface reconstruction,[5,6] oral tongue,[7–12] oral sphincter,[13] and lower and upper lip reconstruction,[14–19] cheek and oral commissure defects,[20,21] after orbital exenteration covering,[22,23] temporalis region defects,[24] after salvage laryngectomy,[25] post-cranioplasty defects reconstruction,[26] after sarcoma resection,[27] H&N soft tissue reconstruction[28] and after frontotemporal defects.[29,30] The aim of this study was therefore to review and provide a comprehensive summary of all the possible indications and outcomes of this versatile free flap in HN reconstructive surgery.

Methods

The systematic approach for the search strategy in peer-reviewed journals regarding the use of the GMFF in HN reconstruction, was based on the recommendations of the Preferred Reporting Items for Systematic reviews and Meta-Analyses (PRISMA) statement (Fig. 3). The inclusion

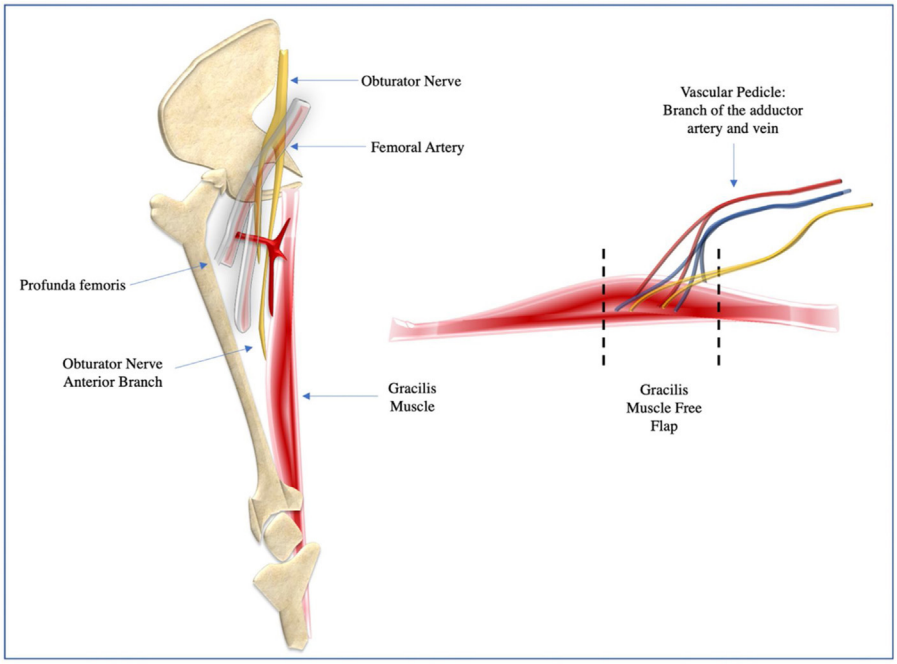

Figure 1 Anatomical representation of the Gracilis Muscle Free Flap.

criteria were based on the population, intervention, comparison, outcome, timing and setting (PICOTS) framework. The heterogeneity among studies, mainly due to the type of reconstruction performed and the absence of randomization, limited our ability to statistically combine data into a formal meta-analysis.

Eligibility criteria

Authors considered prospective, retrospective, case series, controlled or uncontrolled studies published in peer-reviewed journals in the English and Spanish languages, investigating the role of GMFF.

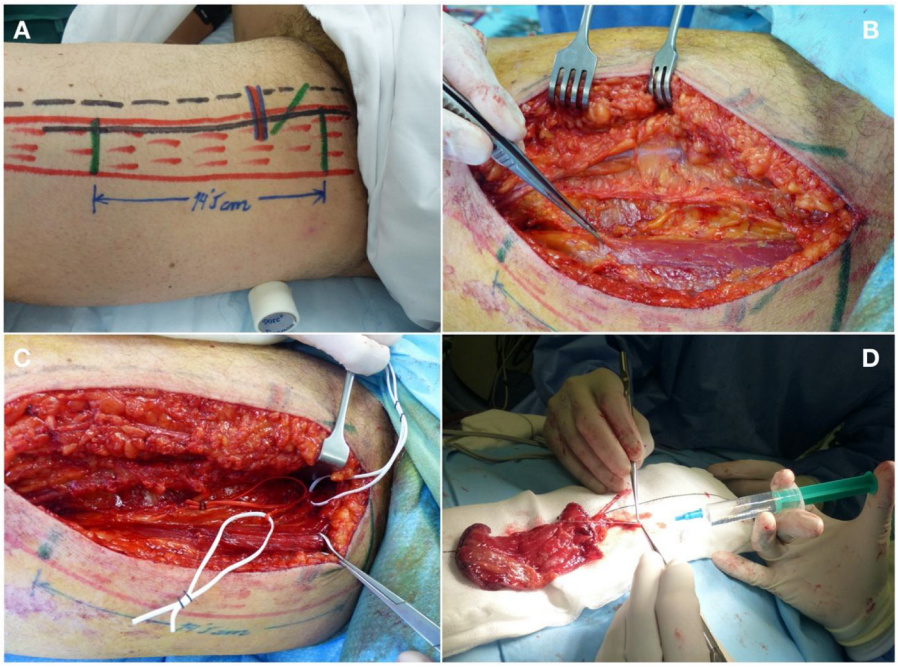

Figure 2 (A) Surgical delineation. (B) Flap harvesting. (C) Nerve & vessel isolation; red vessel-loop = vascular pedicle; white vessel-loop: obturator nerve. (D) Flap preparation.

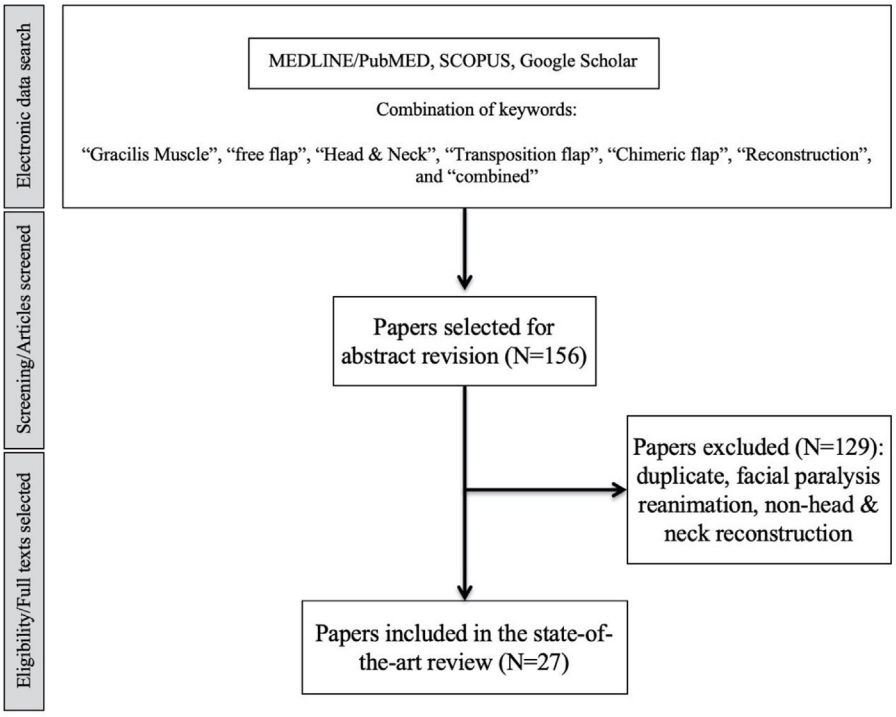

Figure 3 PRISMA flowchart.

Participants inclusion/exclusion criteria
Studies were considered for analysis if they reported results of patients >18-year-old who required HN reconstruction using the GMFF. Studies related to facial palsy reanimation, those with patients <18-year-old and those not related to GMFF reconstruction were excluded.

Intervention and comparison
This study investigated the role of GMFF in HN reconstruction without comparison with other types of flap.

Outcomes
The primary outcome evaluated was the success of reconstruction by GMFF in every variant described, either as a muscle or a muscle-cutaneous flap. Secondary outcomes were flap failure and complications rates.

Timing
The minimum median follow-up time considered to evaluate complications and functional outcomes was 12 months after surgery.

Setting
Tertiary academic and non-academic hospitals.

Search strategy
PubMed, Google Scholar, Scielo and Scopus search was conducted by two independent authors (C.M.C.E. and M.M.) to identify articles published from 1976 to 2019 that fit the inclusion criteria. Studies were screened for availability of full texts. The following keywords were used: ''gracilis muscle'', ''free flap'', ''head and neck'', ''transposition flap'', ''chimeric flap'', ''reconstruction'', and ''combined''. Where applicable, a manual review of relevant articles referenced was carried out to identify studies missed using the search strategy (Fig. 3). Finally, a critical analysis of the selected studies was performed (Supplementary table). Ethics committee approval was not required for this review.

Assessment of quality
The risk of bias was assessed by assigning a score using the Methodological Index for NOn-Randomized Studies (MINORS), an already extensively validated instrument of literature assessment. Non-comparative studies are assessed in 8 domains, where the items are scored 0 (not reported), 1 (reported but inadequate) or 2 (reported and adequate). The optimal score for non-comparative studies is therefore 16. For the purposes of this review, a value of 10 or below was considered to represent a high risk of bias.

For case reports, the risk of bias was assessed using a specially adapted methodological index based on CARE guidelines. This 13-item checklist provides a framework to satisfy the need for completeness and transparency for published case reports. Instead of using the different items as a dichotomous variable (Yes/No), the same criterion was applied as in MINORS, scoring each domain from 0 to 2. The optimal score for non-comparative studies is therefore 26. For the purposes of this review, a value of 16 or below was considered to represent a high risk of bias.

Results

A total of 156 manuscripts were revised. From those, 129 were excluded for the following reasons: facial palsy reanimation ($N = 89$), Non-Head & Neck Reconstruction ($N = 28$),

Table 1 Studies investigating the role of gracilis muscle free flap in head & neck reconstruction.

References	Country	Design	Number of patients	Flaps *n*	Sex	Mean age	Indications of reconstruction	Reconstruction target	Outcome	Complications	Characteristics	Follow-up (months)	MINORS[a] / CARE[b]
Bramm M. et al., 1994[3]	USA	CS	4	4	Male: 2 Female: 2	63.5	Post-oncological ablation (resurfacing of parotid defects)	Cosmetic	100%	1 post-op hematoma	Post-total parotidectomy defect.	8–18	8[a]
Sasaki et al. 1998[4]	Japan	CR	1	1	Female: 1	1	Forehead functional reconstruction	Functional	100%	No	Reconstruction after vascular tumor resection	NE	15[b]
Yousif et al., 1999[5]	USA	CS	8	8	Male: 4 Female: 4	56.5	Oral tongue reconstruction	Functional	100%	1 neck flap necrosis	GMFF flap with an obturator to hypoglossal anastomosis for the creation of a neotongue	5–47	11[a]
Burt et al. 2000[13]	USA	CR	1	1	Male: 1	2	Oral sphincter reconstruction	Functional	100%	No	GMFF for oral sphincter restoration after avulsion.	5	17[b]
Wechselberger et al. 2001[a,29]	Germany	CS	5	5	Male: 3 Female: 2	67	Three case of acoustic meatus after SCC resection. One case of fronto-orbital reconstruction after BCC and one case after oral floor SCC resection.	Functional	100%	One case of donor-site dehiscence and one case of flap-wound-edge separation	Clinical application of the transverse GMFF	17	10 [a]
Lengelé et al., 2004[14]	France	CR	1	1	Male: 1	1	Total lower lip After dog bite	Functional	100%	Scar contraction	GMFF for oral sphincter restoration after avulsion.	48	16[b]
Huemer et al. 2004[28]	Germany	CS	7	7	Male: 1 Female: 6	60	Soft-tissue reconstruction of H&N defect.	Aesthetic	100%	Skin graft lost in one patient. Minimal donor-site morbidity	Two patients after trauma and five after oncological resection	21 (4–37)	10[a]

Table 1 (*Continued*)

References	Country	Design	Number of patients	Flaps *n*	Sex	Mean age	Indications of reconstruction	Reconstruction target	Outcome	Complications	Characteristics	Follow-up (months)	MINORS[a] / CARE[b]
Ueda et al. 2006[15]	Japan	CR	1	1	Male: 1	63	Total lower lip After hemangioma resection	Functional	100%	No	Functional lower lip reconstruction with a forearm flap combined with a free gracilis muscle transfer	6	16[b]
Cordova et al., 2008[16]	Italy	CR	2	2	Male: 2	74	70% lower lip reconstruction	Functional	100%	No	GMFF for morpho-functional reconstruction of the lower lip	9	17[b]
Kropf N. et al., 2008[4]	USA	R	10	10	Male: 7 Female: 3	57 (33–84)	Seven patients had a malignant skin tumor; 3 patients had a parotid gland tumor (resurfacing parotid defects)	Cosmetic	100%	No	Gracilis myocutaneous flap with a vertically oriented skin paddle	8 (2–20)	10[a]
Del Frari et al., 2009[30]	Austria	CS	11	12	Male: 6 Female: 5	63.4 (17–82)	6 SCC, 2 adeno carcinomas, 1 basal cell carcinoma, 1 Merkel cell carcinoma, 1 porocarcinoma and haemangioma resection.	Tissue bulk after ablative surgery and external skin coverage.	100%	1 hematoma in the recipient site.	Gracilis free flap and the myocutaneous gracilis free flap	20.7 (1–67)	12[a]
Ueda et al. 2009[17]	Japan	CR	1	1	Male: 1	19	Large left peri-commissure upper and lower lip	Functional	100%	No	Reconstruction after arteriovenous malformation resection using a GMFF combined with a RFFF	22	15[b]

Table 1 (*Continued*)

References	Country	Design	Number of patients	Flaps *n*	Sex	Mean age	Indications of reconstruction	Reconstruction target	Outcome	Complications	Characteristics	Follow-up (months)	MINORS[a] / CARE[b]
Sharma et al. 2009[8]	India	CR	2	2	Male: 1 Female: 1	35 63	Near total glossectomy reconstruction	Functional	100%	No	Functional reconstruc-tion after near total glossectomy	9	18[b]
Ninkovic et al., 2010[18]	Germany	CR	2	2	Male: 1 Female: 1	21 43	Lower lip reconstruction	Functional	100%	No	GMFF was combined with FAMM flap to provides inner mucosa coverage.	12	15[b]
Lin et al. 2010[20]	Taiwan	RR	24	24	Male: 24	43	Cheek region +/− oral commissure reconstruction	Functional	100%	One case of skin paddle partial loss	GMFF functioning muscle transfer to reconstruct and reanimate the face immediately following tumor excision in the cheek region	24	12[a]
Weizmann et al. 2010[a,22]	Israel	RR	3	3	Male: 1 Female: 2	17	Free flap reconstruction in Children with malignant Head and neck tumors	Functional	100%	NE	Three cases of orbital exanteration	15	16[b]
Calabrese et al., 2011[9]	Italy	CS	10	10	Male: 8 Female: 2	50.9	Tongue reconstruction	Functional	100%	Two patients develop a cervical fistula. One patient develop a neck infection.	Seven underwent total glossectomy and three partial glossectomy	15 (6–28)	13[a]

Table 1 (*Continued*)

References	Country	Design	Number of patients	Flaps *n*	Sex	Mean age	Indications of reconstruction	Reconstruction target	Outcome	Complications	Characteristics	Follow-up (months)	MINORS[a] / CARE[b]
Oh et al., 2011[21]	South Korea	CR	1	1	Male	21	Craniofacial venous malformations,	Extensive venous Malformation of the face	100%	No	Extensive venous malformation of the right cheek that underwent combined gracilis muscle and jejunal free-flap reconstruction after a wide excision of the deep tumor and the buccal mucosa	60	14[b]
Balasubramanian et al. 2011[a,10]	India	CS	2	2	NE	NE	Dynamic tongue reconstruction	Functional	100%	No	Simultaneous doble free flap combining GMFF with a Gastro-Omental flap	NE	15[b]
Del Frari et al., 2012[24]	Austria	CR	1	1	Male	75	Merkel cell carcinoma	Left tem-poroparietal region defect	100%	No	Aesthetic reconstruction of large head defects	43	17[b]
Gurunluoglu et al., 2012[11]	USA	CS	3	3	Male: 3	37.3	Neat total/total lower lip reconstruction	Functional	100%	Scar revision, vermilion reconstruc-tion, vermilion tattoo, intraoral flap debulking, dental rehabilitation after 2-3 months	Combined reconstruction using FFF and GMFF after Gunshot wounds	14	16[b]
Jing et al., 2013[25]	UK	R	22	22	Male: 19 Female: 3	64.8	Reconstruction following total laryngectomy	Salvage	95%	1 patient suffer a GMFF fail complicated with a chronic fistula	Use of GMFF vs PMF in salvage laryngectomy	24	14[a]

Table 1 (*Continued*)

References	Country	Design	Number of patients	Flaps *n*	Sex	Mean age	Indications of reconstruction	Reconstruction target	Outcome	Complications	Characteristics	Follow-up (months)	MINORS[a] / CARE[b]
Nicoli et al. 2014[23]	China	CS	9	9	Male: 8 Female: 1	44.7	Reconstruction after orbital exenteration	Functional and aesthetic	100%	No	In six cases reconstruction was secondary to oncological resection and in three cases secondary to trauma ablation.	20 (12–36)	13[a]
Koray et al. 2015[19]	Turkey	CS	7	7	Male: 7	60.4	Lower lip reconstruction after oncological resection.	Functional	100%	1 patient develop wound dehiscence	Lower lip functional reconstruction	15	10[a]
Ehrl et al. 2016[6]	Germany	CS	6	7	Male: 4 Female: 2	58.6	One case after Cutaneous breast cancer metastasis, two cases after SCC resection, one case after trauma, one case after Microcystic adnexal carcinoma and one case after astrocytoma surgery.	Functional	100%	One patient had recurrence of a squamous cell carcinoma next to the free flap and thus needed additional resection and a second forehead free flap recon-struction.	Forehead reconstruction	51.8	12[a]
Chou et al., 2017[a,26]	China	CS	1	1	Male	39	Brain Abscess	Temporoparietal Reconstruction (back-up flap)	100%	Partial necrosis	Salvage of post-cranioplasty implant exposure using free tissue transfer	ND	16[b]
Righini et al. 2018[12]	Italy	CS	15	15	Male: 11 Female: 4	60	Tongue reconstruction after total glossectomy	Functional	86%	2 flap loss	Dynamic tongue reconstruction after total glossectomy with laryngeal preservation	ND	13[a]
Pedreira et al. 2019[a,27]	USA	CS	1	1	1	NE	Head & Neck Reconstruction	NE	NE	NE	Case series about GMFF after sarcoma ablative surgery	NE	N/A

H&N: Head & Neck; GMFF: Gracilis Muscle Free Flap; RFF: Radial Forearm Flap; FFF: Fibula free flap; PMF: Pectoralis major flap; FAMM: Facial Artery Muscle-Mucosal flap; CS: Case series; CR: Case Report; RR: retrospective report; NE: Not specified; ND: Not described.

[a] Case series with multiple flap or defects reconstructed with different type of flaps. Only cases of GMFF were included in this chart.

and duplicate studies ($N = 12$) (Fig. 1). Twenty-seven papers published between 1994 and 2019 were identified for analysis.[3–30] All of them were examined and described, and inherent information are summarized in Table 1.

Summarizing the evidence from this review, the overall success rate of GMFF described ranges between 86% and 100%. The GMFF has been described as a reliable option for orbicularis oris muscle sphincter,[14–19] forehead defect,[5,6,24,29,30] midface,[3] parotidectomy,[3,4] near-total or total glossectomy,[7–12] palate defect,[13] laryngectomy defect,[25] salivary fistula,[20,21] cerebrospinal fluid leaks.[26]

Different recipient nerve was described according to the target reconstruction. For lip reconstruction the marginal mandibular branch of the facial nerve is the most frequently used,[16] followed by the buccal, zygomatic and, in some cases, the main trunk of the facial nerve.[42] For oral tongue dynamic reconstruction, re-innervation is usually dependent on the hypoglossal nerve.[7,9,12]

Some authors describe the use of this flap in combination with local flaps like the facial-artery muscle mucosal flap or a mucosal graft for vermilion and/or intraoral cavity reconstruction. Its use is also described together with visceral free flaps like gastro-omental for pharyngeal reconstruction, and jejunal after resection of an extensive venous malformation.[21] In combination with a fibula free flap for total lower lip and mandible reconstruction after ballistic trauma.[11] Or in combination with a radial forearm and a vertical rectus abdominis myocutaneous free flap for extensive mid- and lower-face reconstruction is also described.[13]

Quality of evidence according to MINORS guidelines and risk of bias of studies included according to CARE guidelines are summarized and described in the Table 1.

Discussion

Since the original description by Pickrell et al.[31] for anal sphincter reconstruction, the *gracilis* muscle has been used in reconstructive surgery both as pedicled and free flap. Considering its use for sphincter reconstruction, this flap gained popularity for its potential restoration of physiologic function in different areas after oncological or trauma surgery. In 1976, the use of *gracilis* muscle as a free flap for facial reconstruction was first reported.[1] Later, O'Brien et al.[32] were the first to report the use of GMFF for single-stage facial reanimation to restore functionality after facial paralysis. Owing to its reliable anatomy, ability to use nerve coaptation for functional reconstruction, ease of harvest and low donor-site morbidity, the p for smile restoration after facial palsy.[33] Besides facial reanimation, however, GMFF presents an abundance of other indications in HN reconstruction.[33]

Indications for use of GMFF

There is an increasing number of reports on reconstructive experiences using the GMFF. This flap has been used following either oncologic and benign disease ablative surgery (i.e. vascular tumors, arteriovenous malformations), trauma or in a salvage surgery setting following failure of previous flaps. The sites possibly reconstructed by such a technique are detailed in Table 2.

Table 2 Head & neck sites reconstructed with a Gracilis Muscle Free Flap (GMFF).

Sites of reconstructed with the GMMF
1) *Orbicularis oris* muscle sphincter[14–19]
2) Forehead defect[0,5,6,24,29,30]
3) Midface[3]
4) Parotidectomy[3,4]
5) Near-total or total glossectomy.[7–12]
6) Palate defect.[13]
7) Cranioplasty defects
8) Laryngectomy defect[25]
9) Cheek defects
10) Salivary fistula[20,21]
11) Cerebrospinal fluid leaks[26]
12) Temporal defects

Reconstruction targets

The most common reconstructive targets described are functional or cosmetic/aesthetic ones. The use of this flap has been however described also after oncologic salvage surgery (after failure of previous radiation) and as a salvage (second) free flap.

The GMFF has been described as a reliable option in extended forehead reconstruction (defect > 50 cm^2), in combination with a split thickness skin graft, in cases of previous radiation, osteoradionecrosis, osteomyelitis, trauma, and prior local flap failure.[6] To achieve better results, some authors suggest following the dissection enlargement technique proposed by Huemer et al. through a microscopically aided intramuscular dissection to remove the fascia or perimysium to expand the flap, dissecting all connective tissue to get optimal spread of the muscle, increasing the size of the flap approximately by 3–4 times over the regular width.[34]

Jing et al. highlight the advantages of using GMFF after salvage total laryngectomy in comparison with the pectoralis major muscle flap (PMMF). They quote the reliability of this flap, its good volume, lower donor site morbidity and better aesthetic outcomes than the PMMF. The GMFF can also be raised simultaneously to the laryngectomy procedure and gives the surgeon the possibility to preserve the PMMF as a back-up flap.[25] However, patients' comorbidities, need for microsurgical expertise, special free flap postoperative care and increased costs related to the use of microsurgical instrumentation need to be addressed and put into the right perspective when considering its cost-effectiveness ratio.

Ozdemir et al. reported good sensory recovery after coaptation of the lateral cutaneous nerve of the forearm to the mental nerve. However, the use of a sensate radial forearm flap does not truly address the drooling issues.[35] Different strategies to reconstruct the lower lip after an extended resection have been described, being the major drawback, the use of a non-sensitive and non-contractile soft tissue. By contrast, Sacak et al. highlights the advantages of the GMFF in the functional reconstruction of the lip, alone or in combination with another flap, to possibly re-establish mobility of the lip, intraoral lining, vermilion and external resurfacing, by using an innervated mucosal flap to offer improved

sensation.[36] Nonetheless, it is clear that lip reconstruction has multiple goals. After critical analysis to achieve the best possible outcome, the GMFF can be a good option to improve oral closure, but other flaps or other strategies may be warranted to attain the best functional results.

An important goal in HN reconstruction is the need for dynamic oral tongue reconstruction after total or subtotal tongue resection. In the past, the only method proposed to avoid potential problems was combining total glossectomy and total laryngectomy. However, there is a more recent tendency, parallel to the evolution of dynamic reconstruction, to only consider this option when the tumor extends to the supraglottic larynx. Instead, a conservative approach can be sometimes offered to selected young and motivated patients, allowed by functional reconstructive techniques based on musculocutaneous free flaps. As highlighted by Righini et al., if motor innervation is achieved, creating a mobile neotongue increases the chances of adequate swallowing and speaking.[12] To this end, multiple reports have described the advantages of dynamic reconstruction after total or subtotal glossectomy using the GMFF.[7–12]

Neural innervation for functional purposes

In facial palsy reanimation, the masseter nerve is usually selected to ensure reinnervation. However, when using the GMFF for functional reconstruction, nerve selection is made according to the structure to be restored. For example, in lip reconstruction the marginal mandibular branch of the facial nerve is the most frequently used,[16] followed by the buccal, zygomatic and, in some cases, the main trunk of the facial nerve.[36] When the flap is used for oral tongue dynamic reconstruction after partial or total glossectomy, re-innervation is usually dependent on the hypoglossal nerve.[7,9,12] Proponents for dynamic reconstruction highlight also the ensuing preservation of muscle bulk with net reduction of muscular atrophy, something per se improving functional outcomes of swallowing and speech articulation.[37]

Integrity of neural coaptation has been questioned in patients undergoing postoperative RT.[37] However, an increasing number of reports suggest that adjuvant treatments could play no detrimental effects on results of reinnervation.[38]

Combined flap

The GMFF is commonly used as a muscular rather than a myo-cutaneous flap because of the inconsistency of related perforators. There is a trend to use this flap in combination with others to obtain better functional results: for example, with secretory flaps (Jejunal or Omental flaps), or skin grafts providing external surface covering, fascio-cutaneous flaps or others potentially offering mucosal resurfacing. The GMFF was described also in combination with local flaps like the facial-artery muscle mucosal flap or a mucosal graft for vermilion and/or intraoral cavity reconstruction. Its use is also described together with visceral free flaps like gastro-omental for pharyngeal reconstruction, and jejunal after resection of an extensive venous malformation.[21] Moreover, it was applied in combination with a fibula free flap for total lower lip and mandible reconstruction after ballistic trauma.[11] Its use in combination with a radial forearm and a vertical rectus abdominis myocutaneous free flap for extensive mid- and lower-face reconstruction is also described.[13] Furthermore, its use as a split GMFF divided into 2 mini-flaps based on separate pedicles for reconstruction of smaller defects such as cerebrospinal fluid leaks, palate defects, stomal defects, salivary fistulae, and mastoid defects has been also proposed.[39]

Outcome and complications

Summarizing the evidence from this review, the overall success rate of GMFF described ranges between 86% and 100%. The most commonly described complication is the entire flap loss or partial/complete necrosis of its skin paddle. Generally, all the authors describe good functional outcomes when oral competence and/or deglutition were the main targets of the reconstructive procedure. On the other hand, regarding donor site morbidity, Calabrese et al. described the GMFF advantages compared with the antero-lateral thigh flap.[9] Moreover, functional outcomes in dynamic oral tongue reconstruction seem superior due to the possibility to perform neural suture with ensuing flap reinnervation. In this light, Yousif et al. hypothesized that active contraction of the GMFF can support the elevation of the posterior pharynx, recreating a pharyngeal phase of swallowing due to the isometric contraction of the flap itself, usually suspended to the mandible at one end and hyoid bone/thyroid cartilage at the opposite one.[7] Sharma et al. suggests that the GMFF muscular properties may be able to accomplish a functional laryngeal elevation.[8] Righini et al.,[12] in a series of 15 patients, reports a fully intelligible speech in 76.9% and a moderately intelligible speech in the remaining 23.1%. For what concerns swallowing, Yousif et al. described oral deglutition in 7 out of 8 patients; however, placement of a feeding gastrostomy was necessary to supplement the daily caloric intake in all these patients.[7] Sharma et al. reported the use of multiple flaps (GMFF and gastro-omental flap) in two patients undergoing tongue reconstruction. In both cases, electromyography showed effective innervation of the GMFF.[15] Finally, Calabrese et al. described how 9 out of 10 patients of their series regained complete oral intake without the need for a gastrostomy and that all regained intelligible speech after GMFF reconstruction.[9]

For what regards lip reconstruction, selecting the right flap is essential due to the peculiar functional (speech, mastication, provision for oral competence, expression of emotions) and aesthetic characteristics of such an anatomical subunit. The flap most often used for total lip reconstruction is the radial forearm flap.[40] However, the popularity of GMFF is increasing due to its shape, reduced donor-site morbidity, and possibility for functional reinnervation.[19] Udea et al. reported a variant of this technique using an innervated GMFF placed between the folded skin islands of a radial forearm, thus achieving a dynamic lower lip reconstruction with an acceptable functional outcome and the ability to voluntarily move the flap.[17]

Limitations

Some limitations from our review needs to be addressed, as the low number of patients include in each series,

limited information about outcome, heterogeneity about reconstruction target and the risk of bias related to the surgeon's experience. Therefore, functional outcomes after GMFF reconstruction is not really clear. While many papers report ''excellent function'' or ''improved swallowing'' after reconstruction, it should be highlighted that demonstration of muscular contraction, whether EMG or video swallowing, etc. indicates re-innervation and not necessarily an improved function or a better quality of life (QOL) from the patient's perspective, and the same is true for sensate flaps. As we can see in this review, the majority of the literature comes from small, single institution, often single surgeon case series, with no objective measures of function, no validated patient reported outcomes, and without a comparison or control group. For this reason, the functional claims of these reports should be viewed with caution, especially in the post radiation setting. In future reports, we encourage authors to include before and after objective video analysis, and pre and post patient reported outcomes to objectively evaluate functional recovery.

Conclusion

Due to its extreme versatility, ease of harvest and low donor site morbidity, the GMFF offers a multitude of possible applications, and a future increase in its use for HN reconstruction can be reasonably expected. A deeper insight on its functional and aesthetic outcomes, especially in comparison with other more traditional options, is needed to establish the role of this flap as a primary option or as a second line/salvage flap in HN reconstruction beyond its common use in facial palsy reanimation. We therefore encourage reconstructive surgeons to include this flap in their armamentarium, either as a first or as a second-line option.

Conflict of interest

The authors declare that they have no conflict of interest.

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