INTRODUCTION

Nowadays, nasal reconstruction is one of the most complex procedures performed in the face; all 3 layers of mucosa lining, skeletal-cartilaginous framework, and skin envelope must be restored for a successful reconstruction. The causes that lead to nasal defects are categorized as follows: traumatic, postablative due to malignancies, infection, cocaine abuse, Wegener granulomatosis, and congenital arhinia.¹

Microvascular Reconstruction of Complex Nasal Defects: Case Reports and Review of the Literature

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Background: The area of nasal reconstruction can be challenging for the microsurgeon, as the nose is a complex structure. A 3-dimensional understanding of the organ is a prerequisite for a successful outcome. A combination of procedures is usually necessary to completely repair subtotal or total nasal defects. Contouring and secondary revisions may ensue to enhance the postoperative functional and aesthetic outcome of the reconstruction. This study aimed to present a review of the various methods of microvascular reconstruction for complex nasal defects based on the radial forearm flap (RFF).

Methods: Two independent reviewers screened the literature on PubMed according to the inclusion criteria. The keywords for the search were "microvascular," "nasal reconstruction," and "free flaps in nasal reconstruction." Articles on locoregional flap reconstruction, experimental animal studies, letters to the editors, non-English literature, and articles without full text were excluded from the study. The protocol is registered at the International Prospective Register of Systematic Reviews (CRD42019146447) under the umbrella of the National Institute for Health Research, and it is reported in line with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses statement.

Results: Eighteen eligible studies were included in our articles. The infolding RFF, multiple skin paddles RFF, and prelaminated RFF were described. The results have been more than encouraging so far. Also, 3 clinical cases where the RFF provided intranasal lining and a forehead flap resurfaced the nose were presented.

Conclusion: The RFF is a reliable technique for nasal reconstruction in expert hands. (Plast Reconstr Surg Glob Open 2020;8:e3003; doi: 10.1097/GOX.0000000000003003; Published online 23 July 2020.)

The reconstruction aims to restore the anatomy and function of the nose. A 3-dimensional understanding of the organ, its intrinsic anatomical structure, architectural support, and facial subunits is a prerequisite for a successful outcome. A combination of procedures is usually necessary to completely repair subtotal or total nasal defects. Contouring and secondary revisions may ensue to enhance the postoperative functional and aesthetic outcome of the reconstruction. Often, in oncologic resections, a combination of ablative procedures is warranted to completely excise the tumor. Thus, subtotal or total nasectomy, maxillectomy, parotidectomy, cheek, upper lip, and eyelid excisions may be required.

The surrounding local tissues may have undergone radiation therapy or may be insufficient to cover a large nasal defect. Thus, a free flap reconstruction becomes a necessity in these cases because local tissue is unavailable. A customized approach is required because the defect may be complex, mandating multiple operations to completely reconstruct it and restore the function.

The acquired nasal defects are classified by Zhang et al² into 5 types. Each type affects different nasal subunits,
thus requiring special consideration to appropriately match the size, shape, and depth of the defect.

The understanding of the aesthetic nasal polygons is fundamental to achieve a cosmetic reconstruction of the nasal subunits. These subunits resemble geometric polygons, shapes, curves, lines, and shadows, which can be analyzed before any reconstructive work on the nose. By reshaping and realigning the nasal cartilaginous framework, symmetric polygons are created. Namely, there are 12 aesthetic nasal polygons: glabellar, dorsal bone, dorsal cartilage, lateral bone, upper lateral cartilage, dome triangles, lateral crus, interdomal, facet polygons, infralobular, columellar, and footplate polygon.3

This study aimed to present a review of the literature along with our cases of radial forearm flap (RFF) to reconstruct total nasectomy defects.

MATERIALS AND METHODS

A literature review was performed in the PubMed database on nasal reconstruction with the free RFF technique. The keywords for the search were “microvascular,” “nasal reconstruction,” “nasectomy,” “rhinectomy,” “free radial forearm flap,” “prelaminated,” and “nasal lining.” The inclusion criteria were cohort studies and case reports with no time limit. Articles on either locoregional flap nasal reconstruction or free flaps other than the RFF, experimental animal studies, letters to the editors, non-English literature, and articles without full text were excluded from the study. An online screening process was performed by 2 independent reviewers (K.G., G.-A. S.) using the Covidence tool based on the above-mentioned criteria. The initial screening involved the elimination of irrelevant articles based on titles and abstracts. The remaining results were read in their entirety for eligibility for inclusion. Once the screening was complete, the data were extracted manually into a predetermined spreadsheet. The protocol was registered at the International Prospective Register of Systematic Reviews (CRD42019146447) under the umbrella of the National Institute for Health Research, and it is reported in line with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses statement.

RESULTS

Our database search identified a total of 202 articles. Of these articles, 24 full texts were reviewed for eligibility and 18 met the inclusion criteria. The Preferred Reporting Items for Systematic Reviews and Meta-Analyses flow diagram is shown in Figure 1.

The main characteristics of the key eligible articles on the use of the RFF (total number 68) for nasal reconstruction are summarized in Table 1. Details of the particular technique, complications, and postoperative outcomes are shown in this table.

More specifically, partial flap necrosis and infection were the prevalent complications reported by Salibian et al4 and Burget and Walton.5 Their technique is discussed later in the article.

Haack et al6 raised an RFF for nasal reconstruction; they used a 3-dimensional template to help them design and mark the flap on the forearm. The skin was turned over to provide lining, and the raw surface was covered with a skin graft. As in most cases, the forehead flap resurfaced the dorsal nasal raw area after the skin graft removal and insertion of the L-strut cartilaginous framework that was carved from the fifth rib.6

Kobayashi et al7 described 4 different types of RFF that they used to reconstruct nasal defects: cutaneous, osteocutaneous, osteofascial, and osseous flap. They encountered 2 radial fractures, postoperatively.

Between September 2011 and October 2019, 10 RFFs for the reconstruction of hemi-rhinectomy and total rhinectomy defects were performed by the senior author (K.C.). All 10 cases are presented in Table 2.

Case Presentations

Case 1

A 71-year-old woman presented to our outpatient department with a disfigured right nostril and columella due to squamous cell carcinoma recurrence (Fig. 2). The tumor was excised with a 1-cm margin resulting in a 2 × 2 full-thickness defect of the columella and right nostril (Fig. 3). Simultaneously, sentinel node biopsy and RFF elevation were performed, and a forehead flap was used to cover the defect using ear cartilage for nare support (Fig. 4). Finally, 2 months postoperatively, we performed flap debulking and division of the pedicle. Twelve months postoperatively, adequate symmetry of the nostrils, tip projection, and functional restoration of the nasal breathing have been achieved with preservation and with respect to the facial subunits (Fig. 5).
Case 2

A 68-year-old woman underwent total nasectomy for basal cell carcinoma excision elsewhere (Fig. 6). Six months after total rhinectomy and radiation therapy, she was referred to us and she had RFF for nasal lining (Fig. 7), and full-thickness skin graft for temporary skin cover (Fig. 8). Finally, 2 months after the secondary procedure, she underwent raising and inset of a forehead flap for permanent external coverage (Fig. 9) with the use of rib cartilage grafts for support (Fig. 10). A cosmetically pleasant postoperative result was achieved, and no complications encountered after 12 months (Fig. 11).

Case 3

A 59-year-old man presented with an extensive ulcerative squamous cell carcinoma on the dorsum of the nose. Initially, amputation of the nose was performed with adjuvant radiotherapy (Fig. 12). At the second stage, an expander (50 mL) was inserted in the forehead that was gradually injected with saline at 15-day intervals. Two months postexpander insertion, an RFF was raised. The flap was used for internal lining, the skeleton of the nose was crafted from rib cartilage graft, and it was secured in place with a titanium mesh. External coverage was achieved with the expanded forehead flap, and the donor site was closed directly (Fig. 13). Finally, 8 weeks postoperatively, the forehead flap pedicle was divided. An excellent reconstruction was achieved postoperatively with an uneventful full recovery after 12 months (Fig. 14).

Postoperatively, the patients were instructed to wear silicone nasal retainer size 8–10 depending on the reconstructed nostril size for 12 months. The retainer may be removed during shower or social interaction. The retainer is used to prevent scar contracture after surgery and radiation.

Table 1. List of Major Studies, with Characteristics Such as the Type of Flap, Complications, and Outcomes

| Study            | n  | Type of Flap for Nasal Reconstruction | Complications | n  | Functional and Aesthetic Postoperative Outcomes |
|------------------|----|--------------------------------------|---------------|----|-----------------------------------------------|
| Salibian et al²  | 47 | Infolded RFF                         | Flap failure  | 3  | Excellent                                      |
|                  |    |                                      | Minor RFF necrosis | 11 |                        |
| Burget and Walton³ | 10 | Multiple skin paddles RFF            | Infection     | 1  | Satisfactory                                  |
| Haack et al⁴     | 1  | RFF                                  | Partial necrosis | 1  |                        |
| Kobayashi et al⁵ | 10 | Osteocutaneous RFF                   | Flap drooping  | 0  | Excellent                                      |
|                  |    |                                      | Unstable grafted bone | 2  | Satisfactory                                  |
| Pribaz et al⁶    | 4  | Prelaminated RFF                     | Partial flap necrosis cartilage graft exposure | 2  | Good                                           |

Table 2. Characteristics of the Rhinectomy Cases Reconstructed with a Free Radial Forearm Flap and a Forehead Flap

| Case # | Age | Indication | Details of Radiation Treatment | Defect Size (cm) | Operative Approach | Complications | Postoperative Outcomes |
|--------|-----|------------|--------------------------------|------------------|-------------------|---------------|------------------------|
| 1      | 71  | SCC        | None                           | Full-thickness   | 2-stage           | None          | Excellent              |
| 2      | 68  | BCC        | Adjuvant postoperative         | Total nasal defect | 2-stage           | None          | Excellent              |
| 3      | 59  | SCC        | Adjuvant RTx                   | Total nasal defect | 3-stage           | None          | Excellent              |
| 4      | 78  | SCC        | Adjuvant postoperative         | Full-thickness   | 3-stage           | Poor healing of skin graft | Good                  |
| 5      | 66  | SCC        | Adjuvant postoperative         | Hemi-rhinectomy  | 3-stage           | None          | Excellent              |
| 6      | 71  | BCC        | None                           | Hemi-rhinectomy  | 3-stage           | None          | Excellent              |
| 7      | 19  | GSW        | None                           | Total nasal defect | 3-stage           | None          | Excellent              |
| 8      | 16  | GSW        | None                           | Total nasal defect | 3-stage           | None          | Excellent              |
| 9      | 17  | GSW        | None                           | Total nasal defect | 3-stage           | Skin graft infection, good | Good                  |
| 10     | 69  | SCC        | Adjuvant RTx                   | Hemi-rhinectomy  | 3-stage           | Infection, reoperative forehead flap | Good                  |

BCC, basal cell carcinoma; GSW, gunshot wound; RTx, radiation therapy; SCC, squamous cell carcinoma.
All 3 patients were satisfied with the final aesthetic result. No complications and no cancer relapse are reported.

**DISCUSSION**

There are 3 major distinct variations of the RFF for nasal reconstruction described in the literature.

**Folded RFF**

In the latest largest study on microvascular nasal reconstruction by Salibian et al.1, the authors refined their technique to achieve a high standard of nasal reconstruction through several stages over 8 months.

Stage 1 consisted of a folded free RFF to provide the lining of the vault and columella. A fasciocutaneous lateral extension was incorporated in the RFF to cover the lining of the nasal floor. In the second stage (2 months later), the excess skin of the RFF was used to provide nostril and alar adjustments with cartilage grafts or to offer a salvage option in cases of complications. Dorsal support was provided by an osseocartilaginous rib graft screwed either in the frontal bone or remnants of the nasal bones with a T-shaped miniplate. A full-thickness expanded forehead flap was raised to provide resurfacing of the underlying structure of the new nose. In the third operation (1 month later), the forehead flap was thinned and detailed sculpting of the underlying cartilage occurred. In the fourth operation (1 month later), contouring, thinning of the RFF to improve the airway, and additional
cartilage support for the nostrils and nasal tip were performed before pedicle division. Finally (4 months later), secondary revision procedures, such as cheek lipofilling, 3-dimensional sculpting of the framework, and defatting and recreating of the alar creases, were undertaken to augment the aesthetic outcome.

Special attention was paid to the sculpting of the nostrils to avoid the complications of scar contracture with subsequent airway narrowing. They also avoided the use of stents. Initially, this technique was applied in a cohort of 13 patients with results ranging from good to excellent. The patient-reported outcome measures include high patient satisfaction with very good nares opening. Despite this, they did encounter 11 minor RFF necroses and 3 complete flap failures.

Multiple Skin Paddles RFF

Burget and Walton used a different approach to the RFF configuration. In stage 1, depending on the extent of defect, they designed 2 or 3 skin paddles of the RFF for the reconstruction of the nasal vestibule and columella lining. The paddles were designed in such a way that the skin served as the future nasal mucosa, while the subcutaneous fat as a vascularized bed for skin grafts. The skin paddles were placed onto the defect in a counterclockwise fashion. This configuration avoids the problem of scar contracture of circumferential or tubed scars. Also, to allow for potential further contracture, the paddles were oversized up to 150% so that it would eventually fit in the right position. In addition, the vestibular lining flaps were invested with cadaveric alloplastic cartilage graft for support. This translates to the avoidance of nasal vestibule stenosis in the future. Special care was paid not to obstruct the space anterior to the nasal vestibule by the flap.

In stage 2 (13 months later), the skin grafts are replaced with an unexpanded forehead flap. The rationale for using an unexpanded forehead flap is to avoid thinning the dense subcutaneous tissue of the flap, which is important for achieving an aesthetic result. A solid cartilaginous
Fig. 9. Case 2. A, During the second stage of the reconstruction 2 months later, the contracted skin graft is removed. B, A paramedian forehead flap is marked.

Fig. 10. Case 2. Upon elevation of the forehead flap, dorsal and columellar support is provided by meticulously contoured rib cartilage grafts. Reconstructing this framework is an essential step for achieving a satisfactory cosmetic and functional outcome. A, Front view. B, Lateral view. C, A paramedian forehead flap provides skin cover of the nasal framework.

Fig. 11. Case 2. Postoperative views 12 months postoperatively. A, Front. B, Lateral.
nasal framework was recreated from harvested costal cartilages. External dorsal support was performed with diced cartilage grafts wrapped in oxidized regenerated cellulose (Surgicel). The partially closed donor area on the forehead was left to heal by secondary intention to avoid lagophthalmos and corneal exposure. The third stage of the operation consisted of thinning of the forehead flap, contouring with quilting sutures, and expansion of the nostrils by removal of excess fibrofatty tissues. The quilting sutures are removed in 2 days to avoid skin marks, and the columella is shaped into an hourglass configuration as a separate procedure 3 weeks later. Finally, the pedicle was divided and the upper part of the defect contoured.³

Three major complications were encountered: osseous grafts infection, late contracture, and flap necrosis. Specifically, in one patient, a severe infection of the non-vascularized cranial bone grafts occurred; thus, removal of the grafts and hardware warranted salvage reconstruction with a free composite osteomyocutaneous flap based on the thoracodorsal artery. In another patient, late contracture of the nasal floor necessitated the recruitment of a new RFF. The third patient developed partial necrosis of

Fig. 12. Case 3. A, The patient underwent a total rhinectomy due to an ulcerative SCC on the dorsum of the nose followed by radiation therapy. B, Lateral view. SCC indicates squamous cell carcinoma.

Fig. 13. Case 3. A, The free RFF was inserted with the raw surface at the exterior. A meticulous framework was reconstructed with an ultrathin titanium mesh. B, Rib cartilage grafts contoured to provide dorsal support. The expanded forehead flap was raised to cover the RFF.
the nasal lining flaps and the columella part of the forehead flap. A dorsal metacarpal free flap was used as a lifeboat option.5

**Prelaminated RFF for Nasal Reconstruction**

Prelamination allows for a remote insertion of a composite 3-dimensional nasal construct to be recreated in a distant body area (eg, the forearm), which is transposed in the recipient site at a later stage.9

Pribaz et al10 reported 4 cases where the prelaminated free RFF served for the reconstruction of complex central facial defects, including the entire nose, cheeks, and upper lip. At the first stage, the flap was prelaminated for 2–4 weeks. At the second stage, the 3-dimensional construct was harvested along with the pedicle of the radial artery and its venae comitantes. Finally, separation of facial subunits took place, and often, multiple revision procedures were required. The purpose of these refinements was to resurface the flap after its inset with a forehead flap, to provide further delicate cartilage support and definition, and to accommodate additional nasal lining with local flaps.10

The free ulnar RFF11–13 free auricular helical flap,2 free fibula osteocutaneous flap,14 prelaminated temporoparietal fascial flap,15 first dorsal metacarpal, and dorsalis pedis9 are all alternative options for selected patients.

Patient-reported aesthetic outcomes should be integrated into the patient care pathway. A standardized reliable questionnaire was developed by Moolenburgh et al16,17 for patients undergoing nasal reconstruction, known as the Nasal Appearance and Function Evaluation Questionnaire. This tool evaluates both aesthetic and functional outcomes reported by the patients themselves. The functions of nasal respiration, olfaction, phonation, snoring, epistaxis, and dry mucosa were assessed. The general satisfaction with the total nasal appearance but also with the various nasal subunits are part of the Nasal Appearance and Function Evaluation Questionnaire.18

**CONCLUSIONS**

Total nose reconstruction with microvascular techniques is a work in progress, and it gains more popularity as the field of microsurgery evolves. It is an exciting endeavor for the reconstructive microsurgeon. The RFF is considered to be the workhorse flap in nasal reconstruction. It is a reliable and safe option in experienced hands. The results have been more than encouraging so far. However, larger case series and a customized approach should be used before embarking on such a demanding task.

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**PATIENT CONSENT**

Patients provided written consent for the use of their images.

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All procedures performed in the study were in accordance with the ethical standards/Institutional Review Board approval and conformed with the 1964 Helsinki Declaration and its later amendments.

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