32 Principles and New Approaches in Surgical Reconstruction

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Abstract

The reconstruction of oncological defects remains a critical element in the surgical treatment of head and neck cancer. Goals of reconstruction are wound healing, vital structure protection, function, and cosmoses. In this chapter, we discuss the reconstructive ladder as it applies to defects of the oral cavity, or pharynx, nose, orbit, misfile, hypopharynx, larynx, and cervical esophagus. Patient cases are shown to illustrate outlined principles. New approaches in surgical reconstruction are discussed, including salvage surgery after failed chemoradiotherapy, the use of perforator flaps, and the frontier of transoral laser microsurgery defects that require flap reconstruction.

Keywords

Transoral laser microsurgery • Tongue reconstruction • Facial reconstruction • Radial forearm free flap • Laryngeal organ preservation • Hypopharynx reconstruction • Oral cavity defect

32.1 Reconstruction of Surgical Defects: Principles and Goals

The scientific community that is concerned with head and neck cancer had to face that alternative multimodality treatment of squamous cell carcinomas of the head and neck (HNSCC) also has handicaps like early and late toxicities, reduced functional outcome, and treatment failure leading to high-risk salvage surgery with several complications in many cases. To address this problem, Lefebvre and Ang [1] worked out a list of guidelines for better outcome specification after organ preservation therapy, which should be used (not only) in further clinical trials. These guidelines describe a new endpoint: "laryngoesophageal dysfunction-free survival," implicating the highly important issue of late functional outcome. Today's main guidelines for treatment in HNSCC are still based on phase III trials and comprehensive meta-analyses (MACH; [2]), with excess of radiation or chemoradiation studies at the expense of surgical trials. As stated by Higgins and Wang [3], clinical recommendations for HNSCC treatment based on evidences are difficult due to a disproportion of surgical and nonsurgical trials. This conflict is triggered by the fact that instruments for evaluating best surgical practice are different from methodological standards in nonsurgical phase II or III trials. But, going back to clinical routine, well-established and proven standards in surgery of HNSCC are defined as state-of-the-art tumor resection procedures and reconstruction, following consented resection criteria like clear margins (R0 resection) [4]. In general, as recently proposed by Wittekind et al. (2009), the inclusion of the minimal distance between tumor

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Fig. 32.1 The principle of subunits in facial reconstruction. A right upper lip defect is shown following the excision of a skin cancer. A local tissue advancement flap was designed along relaxed skin tension lines and used to reconstruct the upper lateral lip subunit. The medial suture line was placed along the philtral ridge. The resulting scars are camouflaged

tissue and resection margins into the current R classification would be useful [5]. In HNSCC a distance of 5 mm in minimum (except tumors of the glottis fold) is highly recommended. Also standardized neck dissection [6] should be included into the tumor stage-related surgical concept. Altogether, primary surgery and additional adjuvant treatment of HNSCC is ever recommended if R0 resection is possible (also consequently ignoring biomolecular tumor configurations in today's clinical routine). Therefore, the choice of either surgery or multimodality treatment is mainly based on clinical experience and medical culture since there is still a high degree of haziness in view of the best biology-based treatment. To conclude, the treatment decision should be based on an interdisciplinary view (tumor board) on best tumor-specific and overall survival, best late functional outcome, and best consideration of individual patient's needs.

In case of decision for primary surgery, the reconstruction of a surgical defect follows a generalized set of principles applied to the patient's anatomic and functional deficit(s). These principles allow the surgeon to reconstruct a wide variety of defects to achieve optimal functional and aesthetic outcomes for patients, implication of high-level surgical skills, and competence as indispensable part of the interdisciplinary treatment team. Before a patient is ever taken to the operating room, the potential defect and postoperative functional and cosmetic results should be known and accepted by both the patient and the surgeon. In addition, a consequent oncologically sound resection must be performed, meaning the surgeon must not compromise the complete excision of neoplastic disease, even if a larger or more challenging reconstructive defect may result.

The first and most basic principle in reconstructive surgery applies to the creation of a defect. When planning to make incisions, these should be made in areas of low tension to facilitate optimal wound healing. If incisions are made in a cosmetic area, such as the face, this is especially important. The facial relaxed skin tension lines, such as the melolabial crease, are often diagrammed in textbooks to convey this point. Further, the creation of surgical defects should be mindful of aesthetic and functional subunits (Fig. 32.1).

Incisions should not cross subunits if this can be prevented, and in surgeries involving facial or neck tissue, the excision of an entire subunit often allows for better reconstructive results. In the creation of a surgical defect, the surgeon should be mindful of its functional, aesthetic, and psychological impact upon the patient. A reconstructive plan should be made before a resection ever takes place.

The second principle in reconstructive surgery applies to the repair of a defect and follows a sequence often referred to as the "reconstructive ladder." As this analogy suggests, wound management should begin with the most simple technique first and then progress to more complex rearrangement and transfers as needed. The strategy ultimately chosen should provide the best functional and cosmetic outcome for patients, yet pose the least surgical risk. The dense anatomical structures in the head and neck, coupled with limited soft tissue redundancy, must be allowed for in surgical planning.

The lowest rung of the ladder, and therefore the simplest option for defect closure, is to allow a wound to heal on its own with no intervention, so-called secondary intention. In the head and neck, some limited mucosal and superficial cutaneous or scalp defects will heal well by secondary intention. The next option is to reapproximate wound edges in a primary closure, although when tissue is missing, this method effectively becomes repair by local advancement flaps. When tension or tissue loss negates this type of repair, skin grafting or tissue expansion techniques may be used. Alternately, local or regional tissue can be inset into a wound bed by creating transposition, advancement, or rotation flaps. If wounds involve multiple tissue layers, such as the skin, subcutaneous fat, muscle, and mucosa, the use of a skin graft or local flap may lack adequate volume, strength, or function;

in these cases, the use of composite grafts, composite local flaps (e.g., the Gilles fan flap), pedicled flaps, or microvascular free flaps must be considered.

A "flap" refers to tissue that is moved from a donor to recipient site and carries its own blood supply. Although there are multiple classification schemes for flaps, the two main types that will be discussed here are pedicled flaps and microvascular free flaps. These two flaps differ from each other in that pedicled free flaps remain connected to their native blood supply, either random or axial, while microvascular free flaps are tissue units with axial vessels, completely separated from their donor site and then connected to a recipient vein and artery at the defect.

A pedicled flap offers some advantages in head and neck reconstruction. As exemplified by the pectoralis major myocutaneous flap popularized in 1979, pedicled flaps can be inset into a wound in a single stage and bring with them a robust and reliable blood supply [7]. Pedicled flaps are best suited for defects requiring tissue bulk for a multilayer tissue closure in which minimal tissue folding is required. They are also potentially a good choice for reconstruction when a patient has vascular disease or donor site morbidity that would preclude the use of a microvascular free flap. However, the arc of rotation for a pedicled flap is limited, and the pedicled nature of the blood supply limits tissue molding, sculpting, and tubing. The bulk of pedicled flaps also limits their functional use when used in the oral cavity or alimentary tract. Other pedicled flaps used in head and neck reconstruction include the latissimus dorsi flap, trapezius flap, deltopectoral flap, temporoparietal flap, and scapular flap [8–12].

Microvascular free tissue transfers offer distinct advantages in head and neck reconstruction for use in scalp, facial, oral cavity, osteocutaneous defects, and pharyngeal defects. The ability to mold and sculpt microvascular free flaps to three-dimensional forms allows them to be used in a multitude of settings. Although first described in case reports, such as the use of a free jejunal segment for cervical esophageal reconstruction in 1959 [13], subsequent angiosome mapping has inspired many different free flaps for reconstructive use [14]. By understanding angiosomes as discrete subunits of vascularized tissue with identifiable and reasonably predictable zones of blood supply, free flaps with both bone and soft tissue from all over the body can be designed and tailored to suit a specific defect. High-utility flaps in head and neck reconstruction have been the radial forearm and anterolateral thigh free flaps, which afford low donor site morbidity, and vascular pedicles with good length and vessel caliber (recommended artery caliber 2–2.5 mm) [15, 16]. For defects requiring bony and soft tissue reconstruction, a fibular osteocutaneous free flap can be used to bridge large or mandibular defects and provide a skin paddle for intra-, extraoral, or combined use [17, 18]. For shallow defects requiring tissue coverage without excess bulk, the thinned anterolateral thigh flap is ideal [19].

Although free flap success has been the rule due to advances in microsurgical techniques and technologies, flap "salvage" is necessary if arterial or venous flow is compromised [20–22]. Impairment of the flap macrocirculation can be addressed by exploring and revising vascular anastomoses, with the removal of any occluding thrombi. To minimize mainly venous problems, end-to-side anastomosis of the flap vein to the internal jugular vein proved to be highly sufficient. Moreover, new coupler systems offered smooth adaption of the veins and could reduce the operation time (Bild). Damage to the microcirculation or interstitial areas of the flap can be more difficult to remedy, with techniques ranging from thrombolytic agents, hyperbaric oxygen, to leeching of the flap [23–25]. In principle, operation time (cut to suture) and intraoperative blood loss turned out to be independent risk factors for postoperative morbidity, and therefore, two teams should work in parallel (tumor and flap team) to save time and to keep the ischemic period as short as possible.

As transferred tissue heals and inosculates, revising the flap may be necessary to improve function and contour. Bulky flaps may need to be thinned in order to improve functional results, and tethered tissues may need to be released. Flap revision is especially important for reconstructions of the tongue for speech or to afford swallowing if tissue transfer has caused dysphagia and obstruction from excess bulk in the pharynx [26].

Ultimately, the choice of reconstructive technique must afford patients with the best functional outcome that poses the least surgical risk, and these factors must be carefully weighed for each individual. By applying basic principles and carefully negotiating the reconstructive ladder, patients can have restored aesthetics and function after the resection of disease.

32.2 Goals of Reconstruction: Wound Healing, Vital Structure Protection, Function, and Cosmesis

The overarching goal of reconstructive surgery is to create new tissue arrangements that serve in place of native structures, allowing for form to follow function. Because of the enormous complexity and interrelatedness of the deep tissue function, surgery of the head and neck poses unique challenges in achieving reconstructive results that go beyond simple wound healing. The reconstructive surgeon must devise strategies that preserve a patient's ability to eat, speak, swallow, and breathe, in addition to yielding an acceptable aesthetic outcome and quality of life. A site of defect-based approach to reconstruction will be discussed here and will incorporate general principles and techniques in treating defects of the oral cavity, oropharynx, hypopharynx, esophagus, larynx, midface, and orbit.

32.2.1 Oral Cavity

The mouth or oral cavity encompasses the lips, alveolar ridges, floor of the mouth, retromolar trigone, buccal regions/cheeks, and hard palate. These structures rest on the foundation of the mandible. The primary functions of the oral cavity include mastication, speech, facial expression, and early deglutition. The oral preparatory stage and oral phase of swallowing take place in the mouth. Oral cavity malignancy can leave a patient with a postsurgical defect that impairs any one of these essential functions. Reconstructive efforts should focus on maintaining oral competence, tongue bulk and mobility, and the ability to initiate a swallow.

Beginning with defects of the lip or oral soft tissue, the surgeon needs to consider the wound in terms of location, size, and thickness. Due to the highly cosmetic impact of lip reconstruction, few areas should be left to heal by secondary intention, but include superficial vermillion and cutaneous and inner mucosa lip defects, especially those that are in close proximity to the alar–cheek junction. A local advancement design with linear repair may be considered when the defect occupies less than 30–35 % of the lip. Limitations to primary closure include potential for microstomia as well as cosmesis. Full-thickness skin grafts can be used for superficial cutaneous defects, but often do not provide a cosmetically favorable result compared to local flap options. A wide variety of local flap options exists for lip reconstruction and are designed based on the involvement of the mucosal, vermillion, or cutaneous lip, in addition to involved lip subunits (see Fig. 32.1). These include the Abbe or Estlander flaps for redistributing full-thickness tissue from the unaffected lip to the operated lip [27, 28], cheek rotation or advancement flaps (e.g., Gilles flap, Johansen flap) [29], and the Karapandzic flap which acts as a circumferential rotation/advancement flap with partially preserved muscle function and sensation for large full-thickness defects [30]. If a cancer resection results in a loss of >40 % of the total lip area, or >80 % of either lip, any local reconstructive technique will result in undesirable microstoma, which is especially problematic for those with dentures. In these cases, total or subtotal lip reconstruction must be undertaken and is best accomplished with a microvascular tissue transfer, such as the radial forearm free flap [31].

In addition to lip reconstruction, tongue reconstruction must be carefully planned in order to preserve a patient's ability to eat, speak, and swallow. Defects of the oral tongue often include a lateral or anterior floor of the mouth wound, a hemiglossectomy defect, or a total/subtotal oral glossectomy defect (very rare, selected situations) in which complete reconstruction is necessary to restore optimal function (which is limited due to the complex motility pattern of the tongue and the limitations of complete reconstruction). For small superficial mucosal defects, healing by secondary intention is often possible. Occasionally, a skin graft may be used. In partial tongue resections which create a small anterior or a longitudinal defect, primary closure can provide excellent results. However, in considering primary closure, or advancement of limited local tissue, the surgeon needs to be cautious about creating a lateral or anterior tethering effect on the tongue that would impair speech or swallowing. Pedicled myocutaneous flaps may play little or no role in tongue reconstruction. However, for patients who have undergone a total or hemiglossectomy, or will have an unacceptable functional deficit from remaining tissue, a microvascular tissue transfer usually affords the best results (see Fig. 32.2a). The reconstruction of the oral tongue is a

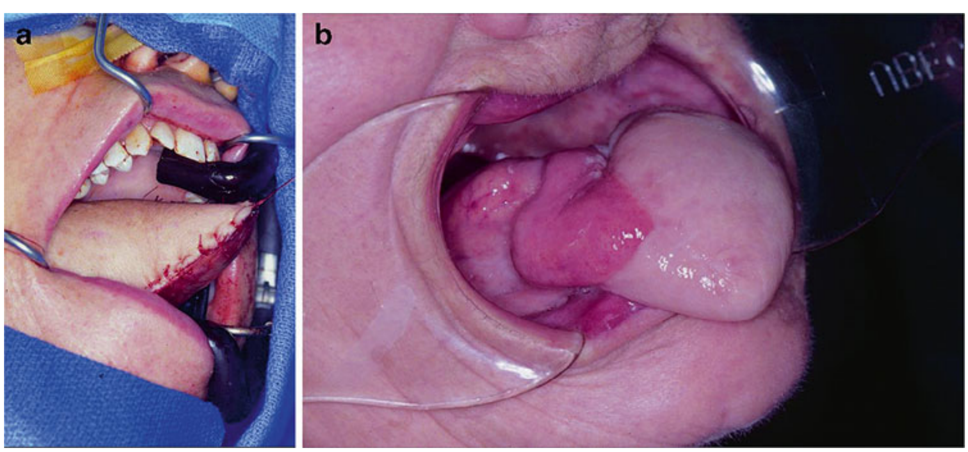

Fig. 32.2 (**a**) Functional tongue reconstruction. Fifty-three-year-old patient with a T2N0M0 squamous cell carcinoma of the right lateral tongue. He underwent a two-thirds anterior glossectomy and floor of the mouth resection, followed by a radial forearm free flap reconstruction with a neurorrhaphy between the lingual nerve and the lateral antebrachial cutaneous nerve. (**b**) "Fold-and-roll" tongue reconstruction. Final healed result of the fold-and-roll technique at 8 months postoperatively (preoperative radiation therapy only). The native tongue remnant is atrophied from a previous anastomosis of cranial nerves XII to VII

prime example of where a free flap bestows a distinct functional advantage compared to other choices on the reconstructive ladder. In using a free flap, the surgeon is able to mold the tissue to form a tubed or rolled structure that can ultimately approximate with the palate, lips, or teeth to allow speech and facilitate a functional swallow [32–36] (Fig. 32.2b). Reconstructive options include fasciocutaneous flaps, such as the radial forearm free flap, and the fasciocutaneous version of the anterolateral thigh flap [37]. If a concomitant mandibular defect is being reconstructed, a fibular free flap can also be employed in the reconstructive effort [38] (Fig. 32.3). For defects of bone reconstruction, the readers are referred elsewhere [39]. In case of defects after subtotal glossectomy including parts of the floor of the mouth, reconstruction can be improved by combination of free and pedicled flaps. Remmert described a highly suitable technique by using pedicled infrahyoidal flaps of both sides which can be pulled through the defect of the floor of the mouth and fixed to the remnant parts of the base of the tongue. Additionally radial forearm flap can be applied to create an epithelialized lining of the dorsum and suitable coverage of the floor of the mouth. The infrahyoidal flaps provide sufficiently the lacking volume of the tongue which cannot be substituted by the free flap alone [40]. In case of bilateral use of the infrahyoidal flap, the surgeon has to keep in mind the supplying pedicle from the superior thyroid artery which may not be used for the arterial anastomosis of the free flap.

32.2.2 Oropharynx

The oropharynx, similar to the oral cavity, plays an essential role in swallowing and also maintains velopharyngeal competence. The oropharynx extends from the plane of the posterior hard palate to the horizontal plane of the pharyngo-epiglottic folds and contains the soft palate, base of the tongue, and the lateral oropharyngeal walls, including the tonsils and their arches. Contact of the soft palate to the posterior pharyngeal wall effectively separates the oropharynx from the nasopharynx superiorly and allows food and air propulsion to occur without nasal regurgitation. The palate also aids in controlling airflow during speech and respiration. A surgical defect of the soft palate or pharyngeal walls can cause a patient to reflux food into the nasal cavity during swallowing efforts and can also make speech unintelligible. Reconstructive goals in this zone are designed around maintaining the separation of the nasopharynx from the oropharynx and preserving velopharyngeal competence with speech and deglutination. Base of the tongue reconstruction is designed to protect the airway against aspiration, promote swallowing, and avoid oral tongue tethering. As such, a well-tailored fasciocutaneous flap is the best option if more than 2/3 of the tongue base is missing [32].

Due to the rising relevance of HPV16-related disease and consecutive dramatically increase of incidence in North America and Western Europe, current trials suggest that surgery could be substituted by radio- or chemoradiation

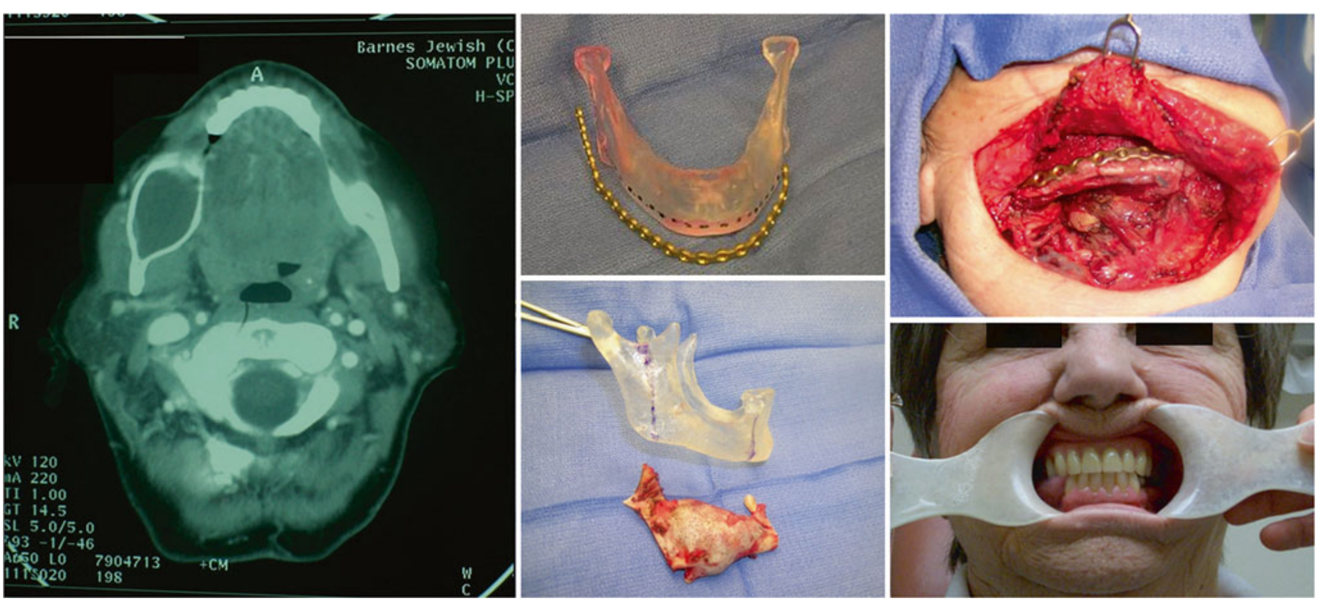

Fig. 32.3 Medical models for reconstruction. Advances in three-dimensional imaging and technologies allow precise models to be created for preoperative reconstruction planning. An axial CT image reveals an expansile cystic lesion (*left image*). Surgical planning to remove this dentigerous cyst includes a generated mandibular model for precise reconstruction bar fitting (*upper middle image*) and planning of segmental mandibulectomy (*lower middle image*, tumor specimen shown). Fibular free flap reconstruction is then performed followed by successful postoperative placement of dental implants (*right-sided images*)

treatment since response to nonsurgical treatment raised significantly. Moreover, treatment de-escalation trials including nonsurgical and surgical treatment are on the way implicating minimal invasive surgical techniques (TLM, transoral robotic surgery (TORS)) as acceptable choices to minimize functional deficits in HPV16-positive disease. Today, there are no data showing in direct comparison superiority of surgical or nonsurgical treatment. Nevertheless, current data (based mainly on p16 testing) show that HPV16-positive oropharyngeal cancer patients do much better than HPV16 negative regardless of both treatment directions, primary surgery and chemoradiation. Therefore, current evidence is not adequate to abolish primary surgery in HPV16-positive patients and to change routine treatment options beyond clinical trials.

Recently, TORS (transoral robotic surgery) has been approved for small (T1, 2) oropharyngeal lesions and is used in routine treatment for lesions of the tonsillar region and base of the tongue in many North American centers with good results. In Europe, TORS is in strong competition to TLM which is limited especially in base of the tongue lesions but highly sufficient in well-trained hands in most regions of the upper aerodigestive tract. Since TORS is still new and neither evidence for superiority toward TLM does not exist nor reimbursement in Europe does cover the terrific costs, this technique is not recommended for first-choice routine treatment.

The small volume of the oropharynx and limited tissue redundancy restrict reconstructive options. Healing by secondary intention may cause unwanted scarring, contracture, and stenosis if a very large or circumferential raw surface area is exposed. An open wound may pose risk to surrounding structures if a communication exists between the oropharynx and deep neck. Primary closure may be possible if there is limited tension and narrowing from reapproximated wound edges. Skin grafts can be used to restore superficial tissue loss. More involved defects of the oropharynx or soft palate are best treated with a regional flap, free flap, or prosthesis. There are some limited local flaps for soft palate reconstruction, such as the superior constrictor advancement rotation flap (SCARF) [41]. The SCARF reconstruction is a myomucosal advancement flap that aims to restore the sphincter function of the nasopharynx. Another local flap option is the palatal island flap, in which hard palate mucoperiosteum pedicled on the greater palatine artery is rotated posteromedially into the defect [42]. For larger defects, a thin free tissue transfer of fasciocutaneous tissue can be performed, and the donor tissue should be carefully designed and inset. To avoid velo- or nasopharyngeal stenosis with resultant nasal obstruction, sleep apnea, and rhinolalia clausa, the surgeon should aim to imbricate the flap tissue for soft palate reconstruction such that both dorsal and central linings of the neo-soft palate are provided, but without obstructive bulk. Free flap options for the soft palate and base of the tongue include the radial forearm free flap (working horse) [43], other fasciocutaneous flaps, and a thinned rectus abdominis flap [44] (Fig. 32.4). The use of free flaps can also be combined with local flaps as necessary [45–47].

32.2.3 Hypopharynx

The hypopharynx represents a functional junction between the passage of air from the pharynx to the larynx anteriorly and the routing of food into the cervical esophagus posteriorly. The final pharyngeal phase of swallowing occurs in the

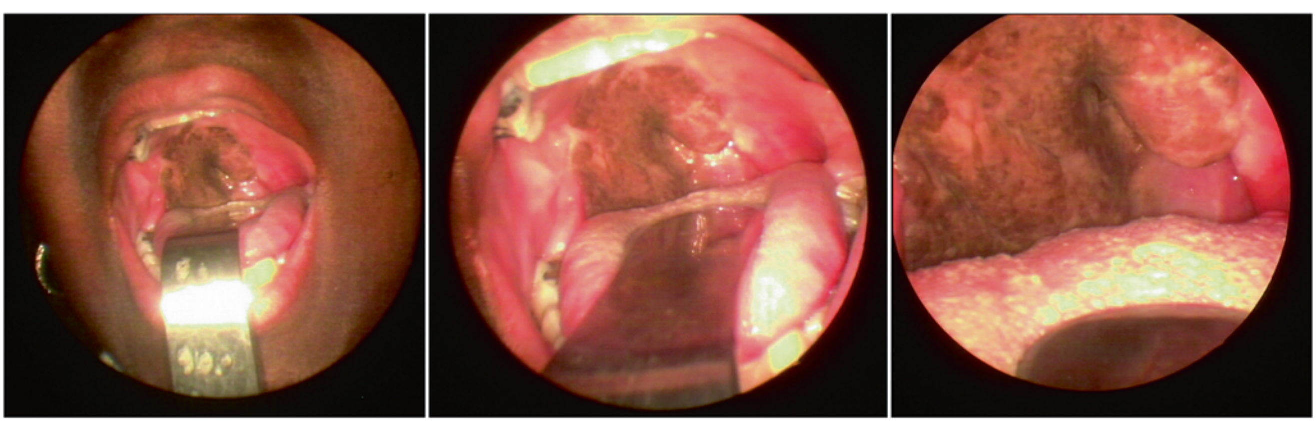

Fig. 32.4 Transoral *inset* of a free flap. Sixty-five-year-old woman s/p radial forearm free flap for reconstruction following resection of a T3N1M0 squamous cell carcinoma of the right tonsil and soft palate. The patient's resection included a transoral CO_2 laser partial pharyngectomy, parapharyngeal space resection, base of tongue glossectomy, and wide soft palate resection. A widefield view of her skin paddle inset is shown on the *left*, with *middle* and *right images* demonstrating the neo–uvula junction with the soft palate, in addition to volume recreation in her right tonsillar fossa and excellent pharyngeal wall coverage

hypopharynx, as the tongue propels food posteriorly, and local peristalsis combined with distal muscle relaxation allows food to pass inferiorly into the alimentary tract. The regions of the hypopharynx include its posterior wall, continuous above with the posterior oropharyngeal wall, the floor of the vallecula superiorly, the postcricoid area anteriorly, and the pyriform sinuses laterally.

The function of the hypopharynx relies on the circumferential movement of muscles in order to facilitate a swallow, and any reconstructive efforts must maintain this form. Creating a functional funnel or U-shaped reconstruction can pose a significant challenge in patients who have failed organ preservation therapy for hypopharyngeal cancer or who have undergone a combined pharyngolaryngectomy for advanced-stage disease. If the larynx is present, the prognosis for swallowing must remain cautious [48]. Most defects of the hypopharynx should not be left to heal by secondary intention due to risk of fistulization or contamination of deep tissue spaces with saliva. In defects that have sacrificed minimal hypopharyngeal mucosa, a primary repair may be possible. The superior hypopharynx is often more amenable to a primary repair than defects that approach the cervical esophagus, and the surgeon must be especially careful to eschew an area of dysfunctional stenosis. Historically, repairs of hypopharyngeal defects have relied on a multitude of different grafting techniques in attempts to avoid narrowing or stricture. These have included shaping skin grafts around mesh [49] or a tube [50], but were unfortunately related to high rates of fistulization and stricture. Currently, skin grafts are best used for partial, noncircumferential defects, and larger reconstructions are best repaired with pedicled or free flaps.

For circumferential defects, e.g., from a total laryngopharyngectomy, the use of a local, broadly based cervical flap was introduced by Wookey in 1942 and resulted in the first series of patients with reliable functional results following extensive pharyngeal repair [51]. Subsequently, the robust pectoralis major flap was used in pharyngeal reconstruction and excelled in importing well-vascularized muscle to aid in wound closure, even in contaminated or previously radiated fields [7]. However, the functional result and inset of the pectoralis flap is limited by its bulk, which makes tubing and circumferential shaping of the flap difficult [52].

The thin, reliable fasciocutaneous free flap has largely replaced pedicled flap reconstruction of pharyngoesophageal defects. The anatomy of the fasciocutaneous tissue lends itself to three-dimensional molding and inset, characteristics that can be used to restore function and create a circumferential repair [53–55]. These features are shared by the anterolateral thigh (ATLF) and the radial forearm flaps, which can provide a larger skin paddle, in addition to muscle tissue [55–58]. However, the ALTF is often limited by the course of its perforators (intramuscular versus intermuscular and fascial) and its degree of thickness, dependent on a patient's body habitus. However, the ALTF can be thinned peripherally. Considering the goal of laryngoesophageal dysfunction, free survival fasciocutaneous flaps seem to result in less pharyngeal stricture following surgery and adjuvant (chemo) radiation.

Occasionally, defects of the hypopharynx require a long segment of circumferential tissue for reconstruction that cannot be accomplished with a fasciocutaneous flap. Historically, this has been accomplished with the use of either a jejunal free flap or a tubed gastric pull-up. Both of these options have the increased morbidity of intrathoracic or intra-abdominal surgery for flap harvest and inset. The jejunal flap is harvested via a laparotomy, and the defect is reanastomosed end to end. The use of this flap was first described in the early 1900s [59] and later became the first free tissue transfer described in humans [13]. Functionally, the jejunal flap provides a tube of mucosal peristaltic tissue and has been used in large numbers of patients [60–65]; however, in addition to functional problems and risks associated with the pharyngeal reconstruction such as fistula and stricture [66], patients are at risk for small bowel obstruction, peritonitis, and intra-abdominal adhesions from the donor site [67]. Similarly, the transposition of proximal stomach tissue to reach the edge of a pharyngeal defect in a gastric pull-up requires exposure in the abdomen, thorax, and neck, posing increased donor site morbidity to patients. The use of a gastric transposition was described in the 1960s [68, 69] and has evolved to incorporate laparoscopic techniques to reduce complications from open abdominal or thoracic surgery. Functionally and technically, the advantages of a gastric pull-up for hypopharyngeal or esophageal reconstruction include a decreased rate of stricture, a single anastomosis, fairly although not totally reliable bloody supply, and incontinuity of mucosal surface in the alimentary tract. The main disadvantage is the failure to reach the pharynx without tension and the high rate of perioperative morbidity [70]. New techniques for better ischemic conditioning of the flap provide a two-step procedure. First step is a pure laparoscopic mobilization of the stomach including the cardia and preparation of the gastric conduit. Second step would be the pull-up procedure to connect the distal pharyngeal end with the stomach tube after tumor resection and esophagectomy. Major postoperative complications were observed in 13.3 % of the patients, and the 90-day mortality was 0 % in a series of 83 % of patients with primary esophageal cancer [71].

32.2.4 Cervical Esophagus

The cervical esophagus extends from the cricopharyngeal inlet and is a tubular striated muscle and tubed segment of mucosal, stratified squamous epithelium. Functionally, the cervical esophagus transmits food and secretions from the hypopharynx to the distal esophagus via peristalsis coordinated with cricopharyngeal muscle relaxation. Any surgical defect of the cervical esophagus will impair a patient's ability to swallow and also puts the patient at risk for fistula and mediastinitis. Reconstructive goals include restoration of swallowing coupled with maintenance of laryngeal airway and voice production. Tissue for reconstruction should be thin and cylindrical to afford swallowing and should be with sufficient diameter to avoid stricture or dysphagia. For incomplete or partial defects (less than 50 % of circumference), reconstructive options include the use of a "patch on" flap, such as the pliable radial forearm free flap [72, 73]. For longer segment defects above the thoracic inlet, tubed fasciocutaneous flap options or the jejunal free flap may be used as discussed above [74, 75]. For defects extending below the brachiocephalic vessels, a gastric transposition flap may be used [76].

32.2.5 Larynx

Surgery of pharyngoesophageal tumors often necessitates surgery of the larynx, as disease may be isolated or confluent in these closely related structures. The larynx has a range of critical functions, including the generation of speech, regulation of airflow into the trachea and lungs, and airway protection during eating and swallowing. Defects and malfunction of the larynx can impair a patient's ability to breathe, eat, and phonate. Anatomically, the larynx has three main subunits that extend from the tip of the epiglottis to the inferior border of the cricoid cartilage. The supraglottic larynx encompasses the epiglottis, the false vocal cords, ventricles, aryepiglottic folds, and arytenoids. The glottic larynx encompasses the true vocal cords and anterior commissure and extends inferiorly by 5 mm below the free margin of the cords. The subglottic larynx is the airway segment between the vocal cords and the trachea and extends inferiorly to the distal cricoid cartilage. After surgery involving any one of these structures, goals of laryngeal reconstruction are to maintain a protected airway, to preserve airway patency with avoidance of long-term tracheostomy, and to allow for speech generation.

There has been a tremendous effort in the treatment of head and neck cancer to preserve the larynx and its functionality. Historically, and in chronological order, laryngeal organ preservation techniques have included modified surgical techniques that remove only part of the laryngeal framework involved by disease, radiation therapy, and chemoradiotherapy (CRT) [77–79]. Partial laryngectomies are accomplished by transoral endoscopic laser microsurgery (TLM), resulting in a vertical hemilaryngectomy or a supraglottic laryngectomy [80–82]. Historically, these procedures have been performed by the open techniques and more frequently committed a patient to a tracheostomy due to aspiration or upper airway obstruction. However, the TLM approach, the only minimally invasive technique available on a routine basis for larynx cancer, results in a low (<5 %) tracheostomy rate and rapid functional recovery, even for advanced disease [82]. TORS is feasible for supraglottic carcinomas but has well-known limitations and disadvantages in comparison to TLM. Therefore, TORS is not the first-choice transoral approach for the larynx [83]. In the context of well-trained modern surgical personnel and services, a total laryngectomy, by contrast, is an infrequent event [84].

Following treatment for laryngeal cancer, reconstruction is largely confined to two populations of patients: (1) patients who are undergoing surgery as a primary treatment modality and (2) patients who require a partial laryngectomy after failing CRT. The first subset of patients may require advancement of distal laryngeal structures to approximate the edges of the defect or recruitment and transposition of extralaryngeal musculature [85–91]. These types of local reconstructive options are more limited for the second subset of patients, whose local tissues are more likely to have radiation damage, including fibrosis and impaired vasculature. In these patients, pedicled myocutaneous flaps can be used to aid in wound healing, but are limited by their bulk and pedicle reach in functional reconstruction. In a radiated field, free tissue transfer may offer the best functional results in reconstructive efforts [92].

The radial forearm free flap may be used to aid in reconstruction following primary laryngeal surgery as well as in salvage efforts. The tissue can be inset into hemilaryngectomy defects, including those with concomitant pharyngeal involvement [93–95]. In addition to the radial forearm free flap, the temporoparietal flap may be utilized as a "vascular carrier" in various reconstructive efforts, meaning that it provides a blood supply to otherwise avascular graft materials, such as cartilage [92, 96–99]. A reconstructive method for patients who have undergone a standard hemilaryngectomy after radiation failure includes using the temporoparietal flap as a vascular supply in a technique described by Ralph Gilbert [92]. In this technique, a layered reconstruction is created with a buccal mucosa graft on the deep laryngeal surface, followed by the temporoparietal tissue enveloping an avascular cartilage graft superficially, effectively mimicking the native laryngeal tissue structure of mucosa, perichondrium, and cartilage [92]. A study of functional outcomes in 21 patients included 90 % resuming a normal diet within 6 weeks after surgery and 85 % of patients being discharged without a tracheotomy. No patients were reported as being tracheotomy dependent at 3 months after surgery [92].

In summary, there are multiple surgical options for laryngeal organ preservation, many of which offer patients an oncologically sound and functionally restorative outcome, without progressive inexorable long-term tissue degeneration, which results in high late "toxicity" (i.e., swallowing failure) rates [100].

32.2.6 Orbit, Nose, and Midface

Tumors of the head and neck may involve the orbit, nose, or midface and create significant reconstructive defects that greatly impact a patient's appearance and functional capacity. The orbits are bony compartments that include the globe, periorbital fat, and extraocular muscles, bordered by 16 named maxillofacial bones. The zygomatic, frontal, sphenoid, maxillary, palatine, ethmoid, and lacrimal bones comprise the bony orbit, which is situated lateral to the ethmoid sinuses, superior to the maxillary sinus, inferior to the frontal sinus, and anterior and inferior to the cranial vault. The shape of the orbital space approximates a quadrangular pyramid with an apex at the deep surface, near the optic nerve in its bony foramen. Functionally, the orbit houses the visual organ system and provides bony support and protection of the eye. Reconstruction may follow an orbital exenteration, in which a significant volume deficit may be present along with exposed bone. An empty orbital space can be reconstructed with a split-thickness skin graft to line the orbital cavity and permits the use of an ocular prosthetic. Alternately, a local (e.g., forehead, temporalis) or free flap can be used to restore volume. The rectus abdominis muscle or other myocutaneous flaps can be used to restore contour to the orbit and obliterate dead space after extensive surgical resection, although the volume requirement is surprisingly small [101–103] (Fig. 32.5). Sometimes a thick fasciocutaneous flap will suffice.

In any reconstruction of the orbit or midface, the separation of anatomical compartments, especially the subarachnoid space, must be recreated. The skull base, bony orbit, sinuses, and oral cavity need reliable tissue or bony barriers to permit function and also restore facial form. Anatomically, the midface can be conceptualized as consisting of three subunits: lower, upper, and central [104]. The lower subunit supports the maxillary dentition and effects a separation between the midface and oral cavity, allowing for functional speech and eating. The upper subunit provides facial contour, separates the midface and maxillary sinus from the cranial vault, and supports the orbital contents. The central subunit provides structural support to counteract forces of mastication and dictates the proportions of vertical facial height. The central subunit additionally provides the scaffolding for midface soft tissue and projection. Priority in reconstruction should begin with establishing the most important barrier or functional subunit first, with meticulous care given to defects involving the skull base.

The evolution of midface reconstruction has progressed slowly due to a multitude of factors, including interval use of prosthetics, poor prognosis in advanced disease, and a wide variety of surgical paradigms. Wound healing, facial contour, and palatal competence are the basic requirements of any midfacial reconstruction. Options for reconstruction must offer appropriate bulk for facial symmetry and orbital support. Similar to other defects of the head and neck, this was initially attempted using locoregional pedicled flaps [105–108]. As techniques have progressed, midfacial reconstruction may now utilize multiple components of the reconstructive ladder to offer a comprehensive result (Fig. 32.6). A single reconstruction may employ a free tissue transfer from the radial forearm, scapula, rectus, or fibula depending on tissue bulk and bony defects [109, 110]. These may be combined with local or pedicled flaps, free bone grafts, or

Fig. 32.5 Orbital reconstruction with a rectus abdominis free flap. Sixty-six-year-old gentleman initially presented with a history of major skin cancer, including a massive basal cell carcinoma invading the orbit and the frontal bone. This necessitated a wide excision of the frontal bone, orbital exenteration, partial excision of the maxilla, and repair with a rectus abdominis free flap. This lesion had arisen from the left lower lid

Fig. 32.6 Subtotal nasal reconstruction with radial forearm free flap and second stage debulking. Patient is an elderly woman with a history of invasive basal cell carcinoma of the right lateral nasal sidewall and ala (*top left*) who underwent Mohs excision resulting in a subtotal nasal defect, right cheek defect, and right upper lip defect (*top right*). A reconstruction for soft tissue coverage and bulk was performed using a radial forearm free flap, followed by a second stage revision of the flap, including adjacent tissue transfer, debulking, and insetting (*lower left* and *right images*). A conchal cartilage graft for alar reconstruction was also performed

prosthetics to ultimately restore function. Details of skull base reconstruction are specifically excluded in this chapter, the reader being directed to other sources [111].

32.3 New Approaches

Evolving treatment strategies for head and neck cancer have created new surgical defects and considerations after oncological resections. Specifically, a new variety of surgical defects have been introduced by the practice of surgical salvage after failed CRT, in addition to the use of TLM for organ preservation. New reconstructive options and flaps have also emerged in the surgical armamentarium for these and other previously described defects.

32.3.1 Surgical Salvage

Historically, surgical salvage after failed primary radiotherapy treatment was primarily limited by what reconstructive options were available. Today, advances in microsurgical techniques enable more candidates to undergo resection and reconstruction, but the effects of radiation are still a major consideration before undertaking surgical salvage, in addition to what functional status and quality of life a patient may have postoperatively [112].

Radiation alters the quality of tissue at the primary site, in addition to the surrounding tissue available for reconstructive efforts. The effects of radiation on vital tissue include fibrosis, desiccation, and altered vascularity. Subsequently, patients with recurrent cancer after failed CRT or radiotherapy can have disrupted tissue planes and poor wound healing [113]. These factors must be considered in planning surgical salvage.

Local flaps and skin grafts are limited and often contraindicated in postradiated patients, but free flaps have provided reasonable success in reconstructive efforts after salvage surgery [114]. Defects can be reconstructed in a similar manner as previously outlined in this chapter, with goals of functional restoration as well as protection of vital structures. Technical advances in microsurgery have enabled more patients to undergo salvage surgery, although they have not changed the poor prognosis of patients with advanced recurrent disease [112, 115].

32.3.2 Perforator Flaps

A notable technical advance in microsurgery has been the introduction of perforator flaps [116, 117]. Research and development of the use of perforator flaps is based on the observation that a free flap of skin can be transferred without any underlying fascial plexus vessels or muscle carrier tissue if the musculocutaneous perforator vessels are carefully dissected and preserved [118]. The advantages of perforator flaps are decreased donor site morbidity, increased pliability of the flap, decreased necessity for flap revision, and improved aesthetic outcome [119]. Disadvantages are increased operative time depending on a surgeon's experience and variability in the anatomy of the perforator vessels. Perforator flaps are indicated in certain defects requiring thin, easily molded tissue, but are contraindicated in patients with perforators that are too small to safely dissect or patients who have wound healing problems or vascular disease.

Two applicable perforator flaps in head and neck reconstruction include the anterolateral thigh flap harvested as a septocutaneous flap and the large, versatile deep inferior epigastric artery perforator (DIEAP) flap harvested from the abdomen. The septocutaneous anterolateral thigh flap can be harvested with <5 mm thickness and is based off of a lateral circumflex artery perforator. It can be used for skin defects, including the auricle and neck soft tissue, in addition to other sites [120, 121]. The DIEAP flap has been described for use in the repair of glossectomy, floor of the mouth, scalp, and lateral facial defects and provides soft tissue bulk [122] (Fig. 32.7). The use of both of these, in addition to other perforator flaps, broadens reconstructive options in the head and neck, and new technologies are continuing to expand the delineation of perforator anatomy, i.e., "perforasomes," that provide individual maps to potential flaps throughout the body [123].

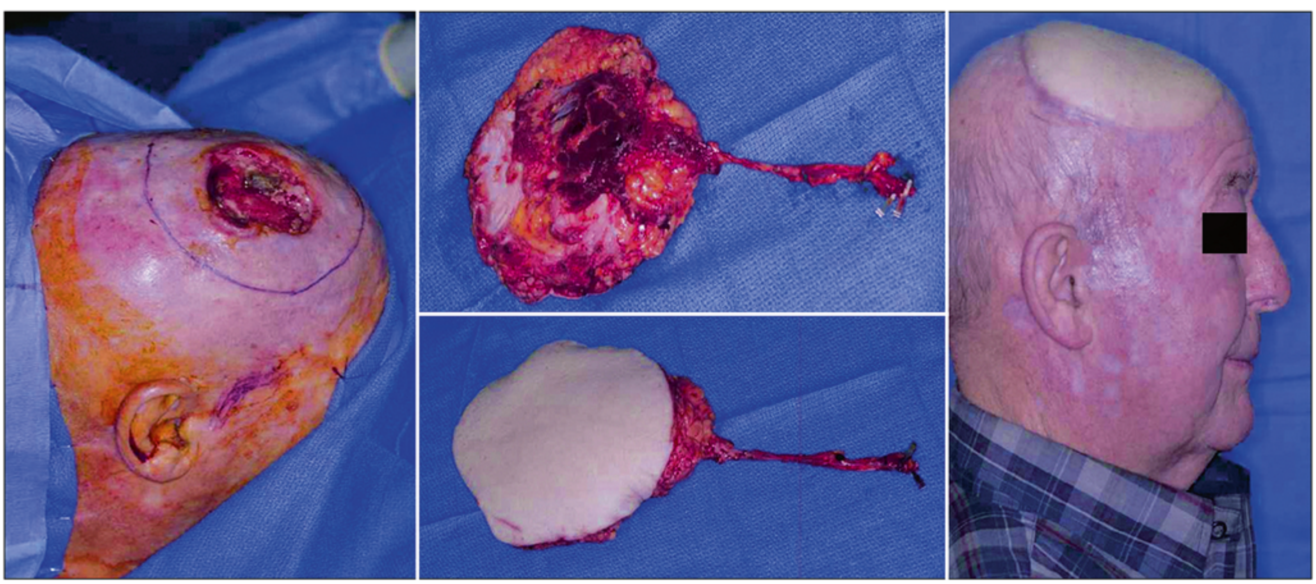

Fig. 32.7 Perforator flap for scalp reconstruction. Seventy-eight year-old gentleman who underwent resection of a squamous cell carcinoma of the scalp followed by reconstruction with a left rectus abdominis perforator free flap, in addition to an acrylic implant placed for cranial reconstruction. The preoperative view is seen on the *left*, and the dorsal and ventral surfaces of the flap in addition to the vascular pedicle are seen in the *middle images*. A postoperative view is seen on the *right*

32.3.3 Transoral Laser Microsurgery (TLM) Transnasal Endoscopic Skull Base Surgery and Transoral Robotic Surgery (TORS)

The most recent development in head and neck resectional surgery is the minimally invasive approach through natural orifices, viz., the mouth and nostrils. Various tools for resection using this approach have included retractors and endoscopes, and cutting instruments have included Bovie, laser, and cold steel. Robotic manipulation of these tools has been described for small tumors.

Data from several centers worldwide have demonstrated that transnasal endoscopic surgery performed with or without a transcranial approach is capable of achieving radical resection of selected sinonasal malignancies. As concluded by Castelnuovo et al. [124], endoscopic endonasal resection performed with or without a transcranial approach, when properly planned and in expert hands, has an accepted role with precise indications in the surgeon's armamentarium for the treatment of sinonasal and skull base malignancies.

In 2009 the outcomes report from a multi-institutional retrospective trial, led by Weinstein and O'Malley at the University of Pennsylvania, was utilized by the US Food and Drug Administration (FDA) to approve the use of the da Vinci Surgical System. TORS procedures have been described to manage pathologies at numerous anatomic sites from the glottis and hypopharynx to the nasopharynx and skull base [10–12]. The most commonly reported use of TORS for malignant disease, however, has been for oropharyngeal cancer, particularly tongue base or tonsillar cancer. Growing experience in TORS led to clear definitions of contraindications and better understanding of the technique [125]. Moreover, the transoral robotic approach pushed interesting new smaller and more handy technologies [126] since the da Vinci System is far bulky.

The operative procedures to routinely remove large tumors of the upper aerodigestive tract are currently restricted to the transoral laser microsurgical (TLM) method, in which the tumor can be taken out in pieces, with precise visualization and control of the margin at many areas around the tumor's perimeter [127]. When the volume or surface area of the defect left behind is large, tissue reconstruction will accelerate wound healing and minimize functional loss. Various local advancement flaps, such as the SCARF approach [41], have been reported. Limited advancement at the pharyngeal wall and for graft inset can also be accomplished transorally (Fig. 32.8). Free flaps are also suitable under specific circumstances. The conditions where I have used free tissue transfer for reconstructions are (a) soft palate defects, full thickness, half or greater; (b) oral tongue defects, greater than hemiglossectomy, or total deep base of tongue; and (c) full-thickness pharyngeal wall and parapharyngeal space defects with exposure of the internal carotid artery.

In brief, the free flap needs to be thin, so that the radial forearm donor site has proven the best available, although the ALT flap has been used successfully on patients with appropriate habitus (see Fig. 32.4). Vessel access and anastomosis are accomplished via the neck dissection, and a small pharyngotomy, if not already present from the resection, is created to pass the pedicle from the oral cavity or pharynx to the neck. Sometimes, this is enlarged slightly for posteroinferior suture placement. Most of the inset, however, is accomplished by transoral suturing using the same retractor systems (Dingman, Feyh-Katzenbauer) as were used for the resection. Although not technically simple, the functional advantages for extensive defects are obvious, especially in the reduction of severe velopharyngeal incompetence for soft palate resections. The indications for and techniques of reconstruction following minimally invasive resections continue to evolve.

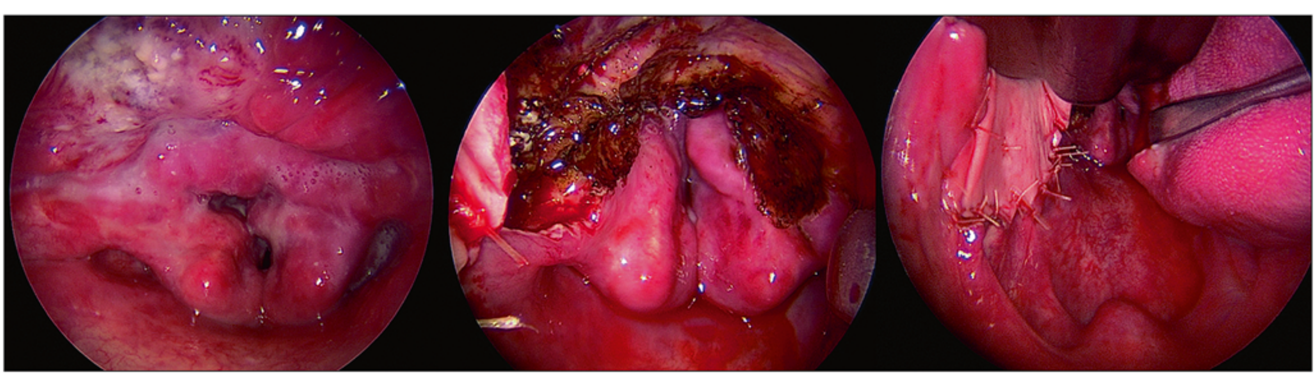

Fig. 32.8 Transoral laser microsurgery. Patient with history of radiotherapy for supraglottic squamous cell cancer presented with a second primary involving the base of tongue and pharyngeal wall (*top left*). The patient subsequently underwent transoral laser microsurgery (*middle*), with pharyngeal flap and AlloDerm graft (*top right*)

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