Interdisciplinary plastic and reconstructive surgery of head and neck squamous cell carcinomas

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ABSTRACT

Squamous cell carcinomas are the most common malignancies in the oral cavity, pharynx, and larynx. Even in the age of the most modern drug treatment methods, radical resection of these tumors is and currently remains the therapeutic gold standard. The loss of anatomical structures associated with surgery inevitably increases the functional deficits caused by the tumor itself. In this context, the extent of functional deficits is largely determined by the extent of resection. Complete organ resections, such as glossectomy, complete palate resection, laryngectomy, or transverse pharyngo-laryngectomy, lead to severe functional deficits, such as swallowing disturbances with life-threatening aspiration and articulation disorders up to the inability to speak. With the help of plastic reconstructive surgery, the lost tissue can be replaced and the specific functions of the upper aerodigestive tract can be preserved or restored.

In recent decades, reconstructive surgical procedures have developed enormously in the treatment of malignant tumors of the head and neck. In order to make optimal use of them, a comprehensive, interdisciplinary therapy concept is a prerequisite for positive oncological and functional outcome. In addition to general medical and social parameters, surgical parameters play a crucial role in the choice of the reconstruction method. The extent to which the surgical measures must be interdisciplinary depends on the localization of the defects in the head and neck region and on the type of replacement tissue required. Here, the expertise of plastic surgery, oral and maxillofacial surgery, and abdominal surgery comes into play in particular. The use of different tissues, the combination of different grafts and flaps, or the preforming of donor regions allow reconstructions far beyond the level of simply restoring surface integrity. The functional results and thus the quality of life of patients after surgical therapy of extensive tumors of the mentioned localizations depend decisively on the type of reconstruction. Therefore, in the following review, special emphasis will be placed on the choice of reconstruction method and reconstruction technique for tissue loss after resections of HNSCC.

Contents

1. Introduction

Plastic reconstructive surgery is used to restore functions of the human body that have been impaired or completely lost as a result of deformities, trauma, tumor resections, and other diseases.

The most common reason for plastic reconstructive procedures in the head and neck region, especially in the upper aerodigestive tract, is the resection of malignant tumors.

Dysfunction primarily caused by the tumors themselves is often further exacerbated by tumor resection.

In general, complete organ resections such as glossectomy, complete palate resection, laryngectomy, or transverse pharyngolaryngectomy leave the most severe functional deficits. These include disorders of oral and pharyngeal swallowing [1–6] with poor oral hygiene [5, 6], life-threatening aspiration [1, 7–11], and nasal regurgitation [12, 13], as well as articulation disorders [1, 6, 8, 14, 15] and disorders of vocal sound production [16–21].

However, even partial resections beyond a certain size can lead to persistent disturbances of oropharyngolaryngeal functions. Severe swallowing problems, for example, must be expected if more than 50 % of a structure involved in the swallowing act has to be resected [2, 22–24].

Depending on the tumor location, different functions can be impaired in isolation or in combination. Resections of the oral part of the tongue and the anterior floor of the mouth primarily lead to disturbances of articulation and the preparatory phase of the swallowing act [3, 6, 25–28]. Affected are bolus preparation, bolus lateralization and bolus retention [6, 25].

In contrast, after partial losses of the base of the tongue, there is a decrease in tongue thrust, resulting in changed pharyngeal propulsion [6, 27]. Resections in the region of the soft palate and tonsil have similar negative functional effects on bolus propulsion. Loss of substance in this region leads to pressure leakage into the nasopharynx due to velopalatine insufficiency [12, 13, 27, 29].

Resections of the suprahyoid floor of the mouth muscles destroy the anterior suspension apparatus of the larynx and impede normal laryngeal elevation during the pharyngeal swallowing phase [3, 6, 25, 28, 30]. The deficient or absent laryngeal movement forward and upward inadequately opens the pharyngoesophageal sphincter and the lack of “suction pressure” impedes the normal swallowing act [6, 31].

Loss of substance in the larynx results in disruptions of the closure mechanisms of the upper airway. These mechanisms exist in the form of “closure valves” at three levels:

- Epiglottis level (with aryepiglottic folds)
- Vestibular fold level
- Vocal fold level [32]

Resections in the region of these structures generally pose a risk of life-threatening aspiration [3, 23, 25, 32, 33]. Furthermore, in most cases, the generation of the primary vocal sound is impaired or completely lost.

Because of the serious functional disturbances described, there is an absolute necessity to restore the anatomy or reconstruct lost tissue and organ parts after extensive tumor resections in the upper aerodigestive tract. This has led to the development of numerous reconstruction methods in the past, with autologous tissue replacement usually being favored.

In the mid-1960s, it was the regional flaps, such as the deltoid [34], frontal [35], or temporalis [36] flaps, that were used to close these defects. This required multisession surgical procedures over many weeks.

Progress was made in the late 1970s with the development of myocutaneous island flaps. The myocutaneous pectoralis major flap [5, 37, 38], the sternocleidomastoid flap [39] or the latissimus dorsi flap [40] made it possible for the first time to restore the anatomy in the region of extensive defects with single-stage reconstructions.

At the same time, there was a surge in the development of microvascular tissue transplantation, which was first performed in humans as early as 1959 by Seidenberg and colleagues [41].

Refinements in microsurgical instrumentation and improvements in vascular suturing techniques resulted in the first clinical successes, which triggered focused research into new donor sites.

In the years from 1979–1984, the iliac crest [42], forearm [43], humerus [44], scapula [45], and parascapular [46] grafts were described.

Today, a large number of grafts with different tissue components from different donor regions are available. In addition, recent developments in microsurgical transfer of autologous tissue grafts supplied by single vascular arteries or perforator vessels have entered clinical practice.

Due to this variety of reconstructive options, lost anatomical structures can be optimally replaced, especially from a functional point of view. The use of different tissues, the combination of different grafts and flaps, if necessary with preforming of donor regions, nowadays allow reconstructions far beyond the extent of the mere restoration of surface integrity. The type of reconstruction depends on the extent of resection, localization, and the desired functional outcome, which is crucial for the patient's quality of life [3, 4, 8, 10, 47, 48].

In order to make optimal use of the surgical options for the treatment of malignant tumors in the head and neck region, which have developed enormously in recent decades, a comprehensive, interdisciplinary therapy concept is the prerequisite for oncological and functional success. In cooperation with surgeons, anesthesiologists, radiologists, radiation therapists, speech therapists, etc., the therapeutic path must be individually coordinated and determined accordingly.

The extent to which the necessary surgical measures have to be carried out on an interdisciplinary basis depends, on the one hand, on the localization of the defects in the head and neck region and, on the other hand, on the type of replacement tissue required. In addition, our own specialist surgical options can be usefully extended by close interdisciplinary cooperation in the interests of oncological and functional outcomes. The most important cooperation partners of the ENT surgeons for this are:

- Maxillofacial surgeons (maxillary and mandibular reconstruction)
- Plastic surgeons (graft harvesting, microvascular anastomoses)
- Vascular surgeons (microvascular anastomoses, replacement of the carotid artery)
- Abdominal surgeons (jejunum graft)
- Neurosurgeons

Basically, plastic reconstructive procedures in the head and neck region become necessary after extensive resections of T3 and T4 tumors. They pursue 2 goals:

- Restoration of the shape (anatomy)
- Preservation or restoration of the function

In order to fully meet these objectives, various general medical, social and, above all, surgical parameters must be taken into account when selecting the reconstruction method. The more demanding, the more complex, and the more time-consuming the reconstruction is, the greater the requirements on the patient, the therapy team and the aftercare:

General medical parameters: The general condition and age of the patient have a primary effect on the postoperative complication rate. However, old age is not a fundamental contraindication for these procedures. On the other hand, alcohol-related diseases with reduced cardiac, pulmonary, and hepatic function limit the indication considerably.

Social parameters: The patient's compliance and social environment play a decisive role in the choice of therapy. The following principle applies: The stronger the patients' motivation, the greater the understanding of their disease, and the better their social environment, the more tolerated are costly reconstructions with often protracted rehabilitation phases.

Surgical parameters: The most important surgical parameters include the location, size, and shape of the defect. In addition, the reconstruction method is largely determined by the type and volume of the tissue to be replaced. Also crucial for the surgical procedure is whether it is a primary or secondary intervention and whether surgery must be performed in an area that has already been irradiated.

The latter surgical parameters often require close interdisciplinary cooperation with the above-mentioned surgical disciplines. Thus, the restoration of occlusion after resections in the bony jaw including graft harvesting (fibula, iliac crest) must be performed by colleagues from oral and maxillofacial surgery. Elevation of mucosal grafts, such as jejunum or colon can only be performed by abdominal surgeons. In the case of very complex multi-layered defects, the broad expertise of plastic surgery in graft harvesting helps to implement the principle of "replacing tissue with equal tissue".

2. Head and neck squamous cell carcinoma *(Lehnhardt, Puscz)*

Head and neck squamous cell carcinomas (HNSCC) develop from the mucosa of the oral cavity, pharynx, and larynx and are the most common malignancy in this location [49]. In Germany, they rank 15th (women) as well as 7th (men) among the most common tumor entities [50]. Regarding the mortality rate, they were responsible for 1,479 (women), respectively 3,888 deaths (men) in 2019 [50]. The main risk factors are nicotine as well as heavy alcohol consumption, but also poor oral hygiene. In addition, there are strong associations with human papillomavirus (HPV) infections, especially the subtype HPV-16. HNSCC are therefore now classified as HPV-associated and non-HPV-associated [51], with HPV-associated carcinomas tending to have a better prognosis for patients [52]. This is due to the mostly younger and healthier patients who, unlike non-HPV-associated HNSCC, usually do not have comorbidities from years of nicotine and/or alcohol abuse.

There are no general early symptoms that can indicate the presence of HNSCC. Rather, any symptoms are based on the anatomical locations of their occurrence. For example, chronic ulcers, dysphagia, dysphonia, respiratory obstruction, and even cranial nerve deficits may indicate the presence of HNSCC. Furthermore, the symptoms that are unspecific for all malignancies, such as unclear weight loss, pain and fatigue, may occur.

When HNSCC is suspected, non-specific lymph node swelling should be looked for in addition to the obligatory, detailed history. Furthermore, mirror examination or flexible laryngoscopy is part of the diagnostic standard. Initial staging includes panendoscopy with fine-needle or incisional biopsy to confirm the histopathologic diagnosis and contrast-enhanced computed tomography of the head, neck, thorax, and abdomen. In addition, sonographies and PET-CT scans can be performed.

The classification of these tumors is based on the current TNM or UICC systematics and can be consulted in detail in the respective guidelines. The TNM or UICC classification is also used to determine the therapy regime. This procedure should always be discussed and determined in a multidisciplinary team, e. g., within the framework of an interdisciplinary tumor conference.

In addition to surgical resection, which is the focus of this paper, radiotherapy and systemic therapy are available. Early tumor stages can usually be treated curatively by surgical or radiotherapeutic measures alone. In the case of advanced tumors or non-curative treatment approaches, the focus is on radio- and systemic therapy.

3. Microsurgery *(Lehnhardt, Puscz)*

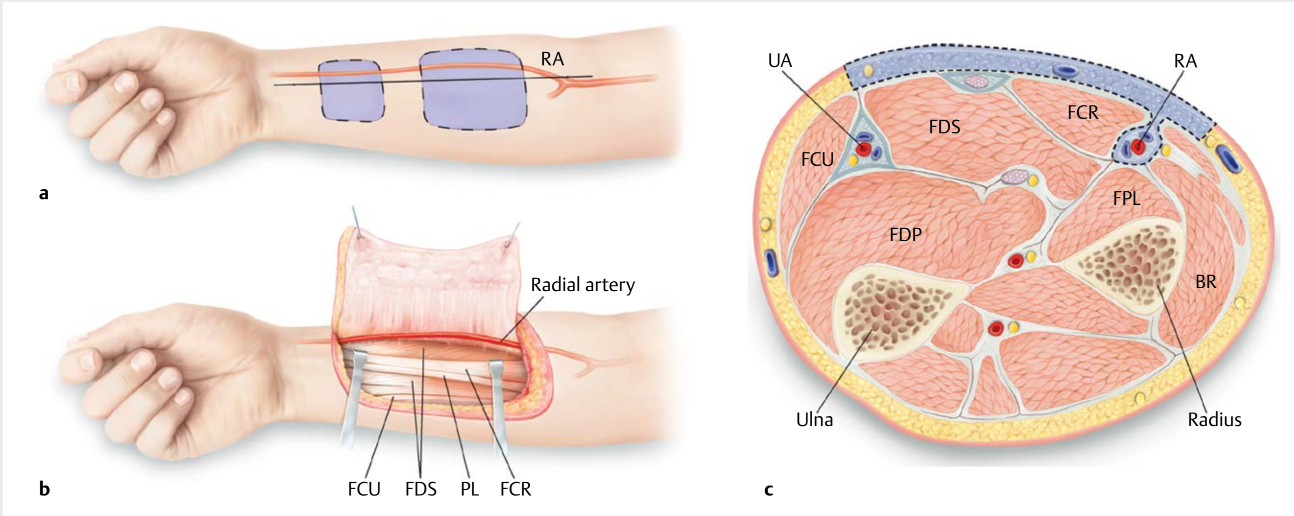
Microsurgery, in the broadest sense, is a term for delicate surgical interventions on very fine tissue structures that are used in numerous surgical disciplines. It is characterized in particular by the fact that it enables various surgical interventions on the smallest anatomical structures with the aid of very high magnification optical vision aids. In addition to various magnifying glasses systems, which usually allow magnification of up to 6x, special surgical microscopes equipped with effective light sources are usually used as magnification instruments for this purpose. On average, these achieve magnifications of between 6 and 40 times. In conjunction with special surgical instruments and very fine suture materials, it is therefore possible to treat the smallest structures, e. g. the union of arterial, venous or lymphatic systems by microvascular anastomoses in the transplantation of tissues in reconstructive surgery.

The history of microsurgery has always been closely linked to the history of microscopy. The invention of the first microscopes is attributed to Janssen in Holland in 1590, and the description of a blood circuit by Harvey in 1628 and by Hooke gave rise to scientific interest in microscopy. Antonie van Leeuwenhoek, who built over 500 microscopes, first published a paper on his observations of microorganisms under the microscope in 1678 [53]. Since Paré, who introduced ligation of injured vessels in 1552 in addition to the method of conduction blockade by briefly squeezing nerves for wound care that he propagated, the care of vascular injuries has consisted of ligation. Lambert described as early as 1761 in his monograph entitled “A new technique of treating an aneurysm” that Hallowell had not ligated an injured brachial artery in 1759, but reconstructed it by suturing. Between 1800 and 1900, thanks to the efforts of Eck, Carrel, Czerny, and Guthrie, variations of vascular surgical connections were described. The first end-to-end vascular anastomosis dates back to Jassinowski in 1899. In addition to end-to-end or end-to-side anastomoses, interposition of autologous vein grafts was subsequently established. The history of modern microsurgery as it is understood today is generally associated with the first use of a static monocular microscope for inspection of the ear by the Swedish otolaryngologist Carl-Olof Siggesson Nylén (1892–1978). Nylén first used a tripod microscope he had specially modified for surgical purposes in 1921 for intraoperative inspection of the exposed endolymphatic tube in the semicircular canal of the ear in a rabbit. His teacher Holmgren then used the microscope in clinical use on a patient during the surgical treatment of otosclerosis in the same year. Nylén had used a modified monocular Brinell-Leitz microscope for this purpose. His colleague Gunnar Holmgren (1875–1954) developed a binocular microscope in 1923 and created the conditions for spatial vision during surgical dissection. However, the use of such surgical microscopes and the clinical use of optical magnification were initially reserved for a small circle of otologists and limited to a few indications.

Ultimately, it was not until the early 1950s that the Carl Zeiss company initiated a constructive development of the surgical microscope, which resulted in a fundamental spread in various surgical fields. The prerequisite was a microscope body that could be moved in practically all planes of space and allowed different magnification at the same working distance. While initially a very bulky microscope body with limited mobility and a small operating field as well as a limited depth of field limited the possibilities, modern microscopes are now much lighter in construction. Appropriate solid and movable mobile stands have resulted in practical applicability in various operating rooms, which has contributed decisively to the triumph of microsurgical technology in many surgical disciplines. An essential improvement was the construction of a stereoscopic microscope with its own coaxial light source, which, mounted on a sufficiently stable stand and with freely movable optics, as well as continuously adjustable different magnifications at a constant working distance, allows availability in different operating rooms and at various working distances and anatomical localizations. Furthermore, fixed ceiling-mounted microscopes as well as motor-driven adjustable objectives were added. Modern surgical microscopes are easy to move or position due to ceiling installations. Cold light sources have significantly improved the illumination of the microsurgical operating field. The position of the microscope can be changed at will either with sterile hand grips or via pedals. The head of the microscope can be tilted in any plane so that the respective position can be adapted to the surgical field. The focus for the depth of field allows a larger working field, and the magnification factors required alternately during the various phases of surgery can be changed continuously during the operation using, for example, foot switches between 6x and 40x magnification. Today’s equipment also allows the assistant to observe the surgical procedure in the same quality as the surgeon. In addition, image signals can of course be tapped and projected, transmitted or recorded.

For the rapid development of microsurgery, in addition to general developments in the surgical art of healing and the increasing clinical use of surgical microscopes, the development and perfection of micro-instruments, micro-sutures and micro-needles were subsequently decisive. The manufacture of fine micro-instruments, originally derived from watchmaking and precision mechanics’ tools, as well as the high-precision production of the thinnest suture materials with special atraumatic micro-needles, led to an expansion and constant further development of microsurgery.

As a result of permanent technical progress and the goal of handling and treating ever finer structures, the limits of what is surgically possible have thus consistently shifted toward the smaller. The clinical establishment of perforator flap surgery, which will be discussed below, and the development of lymphatic surgery are the main driving forces [54, 55]. Regarding further technical innovations, a new field has emerged in recent years with robotic-assisted microsurgery, which will further influence and optimize microsurgery in the upcoming decades. For example, although only two commercially available surgical robots are available for microsurgery to date, initial clinical studies on perforator flap plasty [56] and lymphatic vessels [57] show promising results. In particular, downs-



▶ **Fig. 1** Surgical sketch of a radial artery flap on the right forearm. (a) The flap plasty can be lifted along the marked flap axis (marked in blue) and is located medial to the radial artery (RA). (b) The flap (marked in blue) is placed below the fascia at the lateral edge of the tendon of the flexor carpi radialis (FCR) muscle. PL, M. palmaris longus; FDS, M. flexor digitorum superficialis; FCU, M. flexor carpi ulnaris. (c) Cross-section of the right forearm with the plane of flap elevation marked in blue. FPL, flexor pollicis longus muscle; FDP, flexor digitorum profundus; BR, M. brachioradialis; UA, A. ulnaris. Source: Beredjiklian PK et al. 2020. Hand Surgery, page 400. DOI: 10.1055/b-0040–177493.

caling of the natural tremor allows to extend the limits of what is surgically possible.

4. Frequently performed flaps in otorhinolaryngology *(Lehnhardt, Puscz)*

Due to the exploration of donor sites with axial vascularization, numerous grafts with different tissue components are available today. In the head and neck region, the forearm graft, the anterior thigh graft (ALT), and the free fibula graft are the preferred choices.

In the following, these flap plastics will be discussed.

4.1 Radialis flap

The radialis flap is a fasciocutaneous flap that is particularly suitable for the reconstruction or closure of smaller defects (up to approx. 8 x 16 cm). Since the flap can even be folded, three-dimensional designs are also possible. The flap is named after its main supplying vessel, the radial artery. Preoperatively, it is therefore essential to check the blood supply to the donor arm using the Allen test. However, even a positive test result is not an absolute contraindication to harvesting, since the radial artery can be reconstructed with a retrograde cephalic or saphenous vein graft. Osteocutaneous variants of this graft have also been predescribed and are thus also suitable for reconstruction of bony defects [58]. The donor arm is usually located on an arm table. An upper arm tourniquet can be presented, but should not be used regularly for intraoperative perfusion control. The radial border of the flap is usually the radial artery; ulnarward, the flap may occupy up to two-thirds of the volar forearm. This also has the advantage that the skin on the volar ulnar forearm is often less hairy. If a tendon is to be integrated into the flap, the tendon of the palmaris longus muscle can be integrated. The dissection usually starts from distal and goes down to the fascia antebrachii, which is elevated as well. However, peritendinous tissue should be left in place to avoid postoperative adhesions. The radial artery and its accompanying vein are exposed and ligated. The flap is then dissected proximally, and it is essential to pay attention to the dorsal branch of the radial nerve, which passes through the brachioradialis muscle to the distal forearm at this point. If the radial vein is weak in caliber, the cephalic vein can also be integrated into the flap. This allows the flap to be elevated to the proximal third of the forearm. The elevation defect must usually be closed with split skin; primary closure is rarely possible. Postoperatively, it should be noted that the hair growth on the flap plastic remains, so that laser epilation may be necessary in the further course (▶ **Fig. 1**).

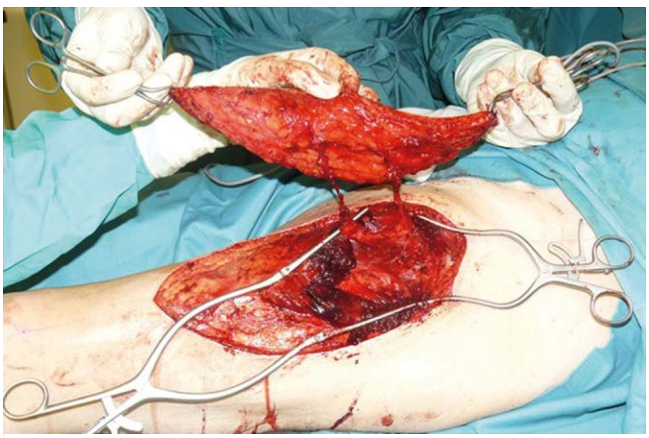
4.2 Anterolateral thigh flap plasty (ALT)

The ALT flap plasty is one of the most widely used flap plasties in reconstructive surgery. Due to its versatility, it has established itself as a so-called “workhose flap” in many different anatomical regions as well as in different specialties [59]. The initial description of this flap was made in 1984 by Song and colleagues [60]. In the meantime, numerous anatomical studies [61, 62] and circumscribed surgical variants [63, 64] of the ALT exist, so that the surgical method is well established.

The ALT is a fasciocutaneous perforator flap taken from the anterolateral thigh. The arterial supply is provided by perforators from the descending branch of the lateral circumflex femoral artery. These perforators can be marked preoperatively by color-coded duplex sonography and are often located in the middle third on an imaginary line from the anterior superior spina iliaca to the lateral patellar rim (▶ **Fig. 2**).

Depending on the donor as well as the recipient region, flap sizes of up to 8 x 25 cm are possible. The perforators run either as septocutaneous perforators in the intermuscular septum between the Mm. rectus femoris and vastus lateralis or as musculocutaneous

▶ **Fig. 2** Preoperative marking of the planned ALT harvesting point togetherwith marked perforators and flap design.



▶ **Fig. 3** Intraoperative finding of an ALT flap plasty before transection of the supplying perforators.

perforators through the M. vastus lateralis. Accompanying the descending branch of the circumflex femoris lateralis artery are one or more nerve muscular branches to the vastus lateralis arising from the femoral nerve. Sensory innervation of the ALT flap is provided by branches of the lateral cutaneus femoris nerve, which can be included in the flap plasty and coapt in the recipient region if necessary. Elevation of the ALT flap plasty is usually performed in the supine position. The flap plasty is first planned over the area previously shown by Doppler sonography. A mostly straight incision is then made at the medial edge of the flap plasty. After dissection onto the femoral fascia, either an epifascial or subfascial dissection is performed laterally. The extent to which the fascia is included in the flap plasty depends primarily on the necessities at the recipient site. During the lateral preparation, the existing perforators are identified and visualized. Depending on their location, the necessary length of the vascular pedicle and the individual anatomical conditions, the flap plasty can still be performed in the craniocaudal direction at this point. In addition, as described above, the perforators necessary for perfusion of the flap plasty are identified (▶ **Fig. 3**).

After cutting the superfluous perforators, the vascular pedicle is then traced from peripheral to central. The preparation layer is always directly on the vessel and never with a "safety distance", because such a distance rather increases the risk of injury to the pedicle. Dissection through the intermuscular septum is usually straightforward, but in the case of musculocutaneous perforators, dissection down to the descending branch may be difficult and laborious. In this case, prior visualization of the descending branch in the intermuscular septum under the rectus femoris muscle may be helpful to more easily identify the anatomic relationships and confluence of the perforator with the vascular axis. Care should be taken to spare the accompanying nerves when dissecting the vascular pedicle centrally/proximally. After complete isolation of the ALT flap plasty on the descending branch, it is first ligated caudally and removed. If sufficient capillary bleeding from the flap edge and timely recapillarization is observed after a "run-in" period of several minutes, the flap plasty can be resected arterially and then venously and transferred to the recipient site.

4.3 Free fibula graft

The free fibula graft is an osteofasciocutaneous flap plasty, which is characterized in particular by its modularity, since it can be used both as a pure bone transfer, but also as described above with skin island and muscle. It was first described in 1975 by Taylor and colleagues [65], who, however, still applied a posterior approach to elevate the graft. However, the lateral approach by Gilbert [66], described a few years later, has prevailed in clinical reality. Due to its elongated shape and high cortical content, the fibula represents a good donor bone, e. g. for mandibular reconstruction. The blood supply of the bone is provided by the homonymous artery and vein (A./V. fibularis also: A./V. peronea). Preoperatively, however, a CT-guided angiography of the donor leg should be performed to visualize any vascular anomalies or supply patterns. Initially, the proximal and distal ends of the fibula and the bone axis are marked. If a skin island is needed, it can be drawn along the bone axis. However, it should be at least 5 cm away from the distal fibular edge. If only the fibula is to be elevated, the incision is made along the posterior fibular rim. The dissection extends to the fibula and the bone is dissected. A small muscle cuff, a few millimeters wide, remains attached to the bone. Once the proximal and distal osteotomy sites are marked, a retractor is used to tightly encircle the bone. During osteotomy, be sure to preserve the distal 6 cm to avoid instability in the upper ankle. In addition, the proximal course of the peroneal nerve is marked on the fibula neck to spare it. If the osteotomy is performed with an oscillating saw or a Giggly saw, Homan hooks should be used to protect the soft tissues. Bone clips can be placed at the superior and inferior ends of the flap to allow anterior and posterior traction on the membrana interossea. The membrana interossea is transected, and the fibular artery and associated veins are exposed. The distal portion of the artery and veins are ligated and transected, and the flap can then be lifted upward on the vascular pedicle and removed.

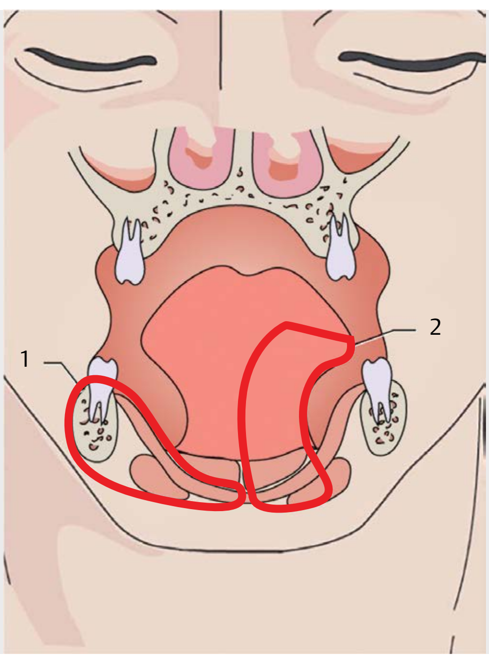
5. Reconstruction techniques *(Remmert, Sack)*

In the following, surgical methods for the restoration of anatomy and function are presented for extensive defects in the ENT area, which are mainly performed in interdisciplinary collaboration.

Different reconstruction methods are applied in the area of the following functional units

- Floor of the mouth

▶ **Fig. 4** Minimal elevation defect after removal of an ALT flap plasty at the left thigh.



▶ **Fig. 5** Reconstruction of a defect after resection of a T4 tumor of the floor of the mouth with a neuromuscular muscle fascia flap and a forearm graft. Resection size of a T4 tumor of the floor of the mouth in red. Source: Remmert S. Expertise Funktionelle Wiederherstellung der oberen Luft- und Speisewege. Stuttgart : Thieme; 2015. DOI:10.1055/b-005-143303.

- Tongue
- Soft palate
- Larynx and pharynx

and discussed, taking into account organ-specific anatomy and function.

5.1 Defects of the floor of the mouth and neighboring structures

Cross-organ tumors of the floor of the mouth (T4) grow primarily into the external tongue muscles or break into the mandibular bone (▶ **Fig. 5**).

Tumors of the floor of the mouth infiltrating the tongue muslces

If the tongue body is involved, the tongue volume is replaced with an infrahyoid muscle fascia flap (▶ **Fig. 6** and ▶ **Fig. 7a**). Reconstruction of the floor of the mouth and tongue mucosa is performed with a forearm graft (▶ **Fig. 7b**). By forming a fold between the inferior side of the tongue and the new floor of the mouth, the mobility of the tip of the tongue is preserved (▶ **Fig. 7c**).

Tumors of the floor of the mouth infiltrating the mandible

It is not uncommon for T4 oral tumors to infiltrate the mandible. In these cases, the planning and execution of the surgery must be performed in an interdisciplinary manner together with the oral and maxillofacial surgeons. Usually, reconstruction of the mandible is performed in one step with tumor resection and soft tissue reconstruction. Alternatively, however, a two-stage procedure is also possible for the reconstruction of the mandible. In this case, the bone defect is bridged with a reconstruction plate and only the soft tissue defect is treated in the first step. Because of the better functional and cosmetic results and the lower complication rates, a single-stage procedure is to be favored.

In particular, if the chin region of the mandible is lost during tumor resection, primary bone reconstruction is the method of choice, since as a result of "soft tissue load" or muscle traction, allogeneic material regularly perforates the soft tissues. This results in scarring retraction of the soft tissues, which makes subsequent reconstruction considerably more difficult.

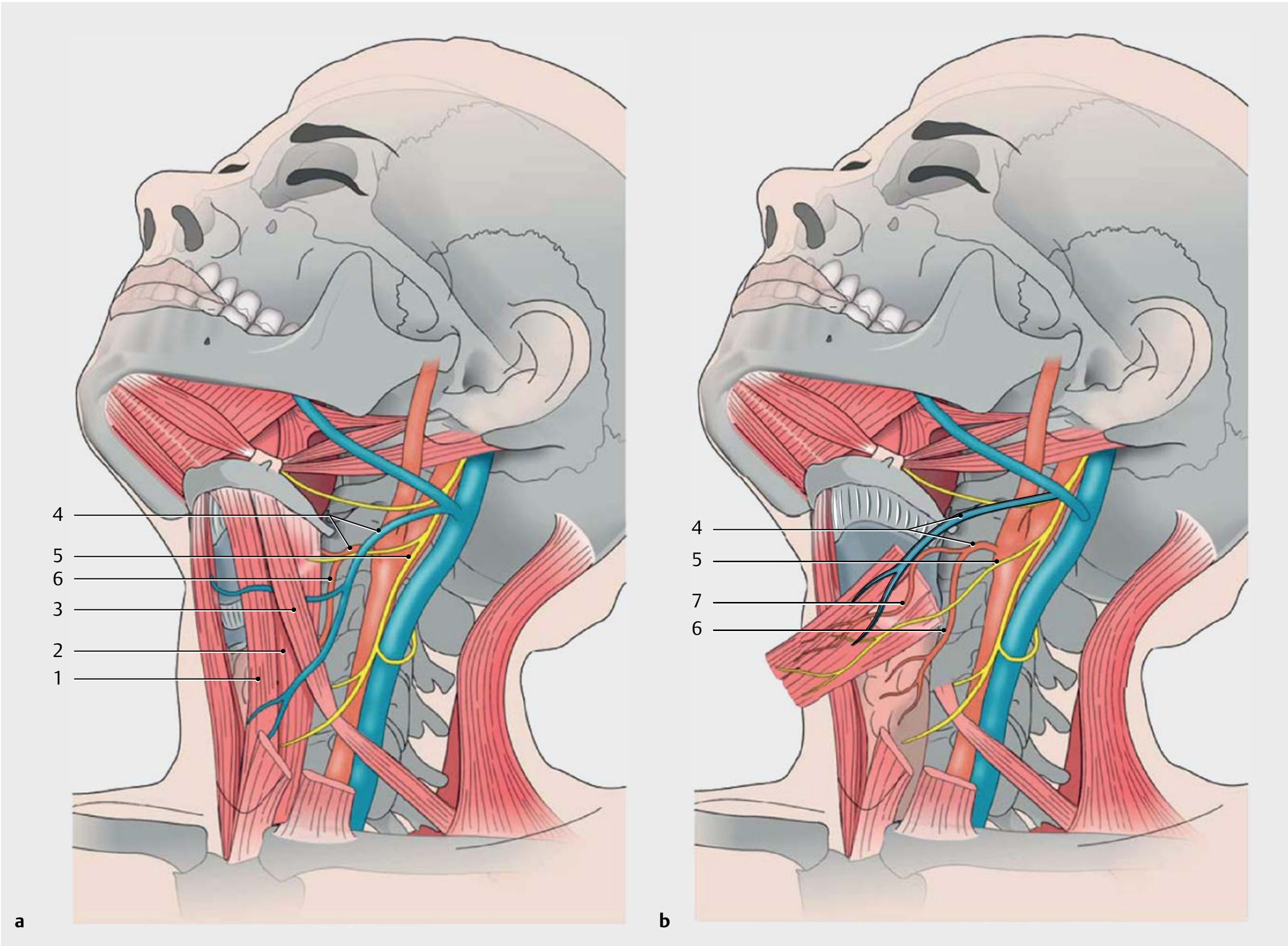
In the single-stage procedure, the floor of the mouth is first detached caudally from the hyoid bone and the mandibular bone is dissected bilaterally at a safety margin from the tumor (▶ **Fig. 8a**). Afterwards, the now mobile tumor conglomerate can be clearly removed from the oral cavity with a security margin to the tongue (▶ **Fig. 8b**).

The oral and maxillofacial surgeons reshape the fibula graft with the skin island according to the tumor resectate (▶ **Fig. 9a** and ▶ **Fig. 9b**) and perform the osteosynthetic reconstruction. The skin area from the lower leg harvested with the fibula ideally replaces the soft tissues of the floor of the mouth and the gingiva (▶ **Fig. 9c**).

Tumors of the floor of the mouth infiltrating the mandible and breaking through the skin

The reconstructive measures are even more extensive if the carcinoma breaks through the skin to the outside (▶ **Fig. 10a**). As in the previous case, the reconstruction of the floor of the mouth, the gingiva and the mandible is performed by a fibula graft with skin island (▶ **Fig. 10b**).

For contouring the outer soft tissues of the chin, a large-area, voluminous graft is required. The lateral humeral graft offers these properties very well (▶ **Fig. 10c**). Because of the use of two grafts – one fibula and one humeral graft – twice the number of vascular



▶ **Fig. 6** Anatomy of the infrahyoid muscle group and the infrahyoid muscle fascia flap. **a** Infrahyoid muscle group. **b** Neurovascular infrahyoid muscle fascia flap. Source: Remmert S. Expertise Funktionelle Wiederherstellung der oberen Luft- und Speisewege. Stuttgart : Thieme; 2015. DOI:10.1055/b-005-143303.

anastomoses is necessarily required. In addition, the larynx must be brought into a position that is favorable from the point of view of swallowing physiology. For this purpose, it is fixed to the reconstructed mandible by means of wire sutures. In this way, a forward and upward movement corresponding to the laryngeal elevation is achieved. With this high level of reconstructive effort, acceptable functional and cosmetic results can be achieved even with extensive tumors (▶ **Fig. 10d** and ▶ **Fig. 10e**).

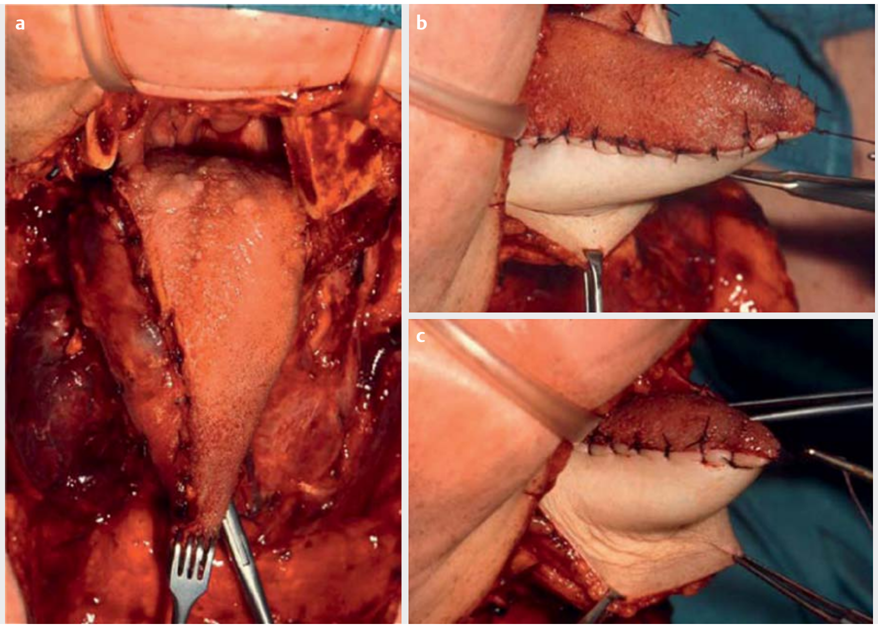
5.2 Defects of the floor of the mouth and neighboring structures

The choice of the reconstruction method must take into account the anatomical structure of the tongue and the specific functions of the organ. The following reconstruction parameters are of crucial importance:

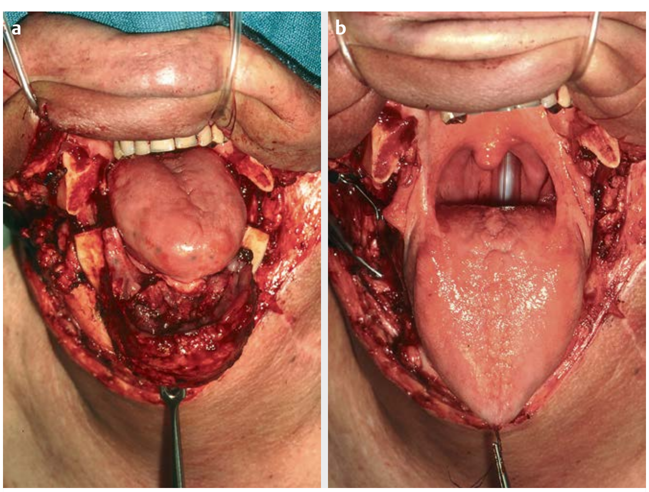
- Preservation or restoration of a buccoalveolar or glossoalveolar sulcus.These folds are an important prerequisite for the mobility of the neo-tongue and for a dental prosthetic restoration.
- Contact of the neo tongue with the palateOnly contact between the tongue and the palate enables bolus transport and bolus retention.
- Reduction of oral cavity dead spaceThe reduction of the dead space is achieved by restoring the volume of the tongue.
- Avoiding atrophy and scarring.

Due to the mainly muscular defect, the restoration of an adequate tongue volume to reduce the oral cavity dead space should be performed with innervated muscles as far as possible. In the form of the infrahyoid muscle flap (IHL), a myofascial flap with a constant vascular-nerve pedicle is available, which can be harvested in the immediate vicinity of the defect via the usual neck dissection approach [67, 68].

Forearm grafts are particularly suitable for mucosal replacement, for the shaping of a glossoalveolar sulcus and for reconstruction of the neighboring regions (lateral oropharyngeal wall, soft palate, floor of the mouth) if local flap plasty does not allow functionally adequate closure of the defect. Compared with jejunal grafts, they offer the advantages of higher resistance to mechanical stress, lower morbidity graft harvesting, and possible resensitization by micronerve suturing between the antebrachial cutaneous nerve and the lingual nerve.



▶ **Fig. 7** Reconstruction of a defect after resection of a T4 tumor of the floor of the mouth with a neuromuscular muscle fascia flap and a forearm graft. **a** Neurovascular infrahyoid muscle fascia flap for reconstruction of the tongue volume. **b** Forearm graft for reconstruction of the tongue mucosa. **c** Shaping of the fold and the floor of the mouth. Source: Remmert S. Expertise Funktionelle Wiederherstellung der oberen Luft- und Speisewege. Stuttgart : Thieme; 2015. DOI:10.1055/b-005-143303.

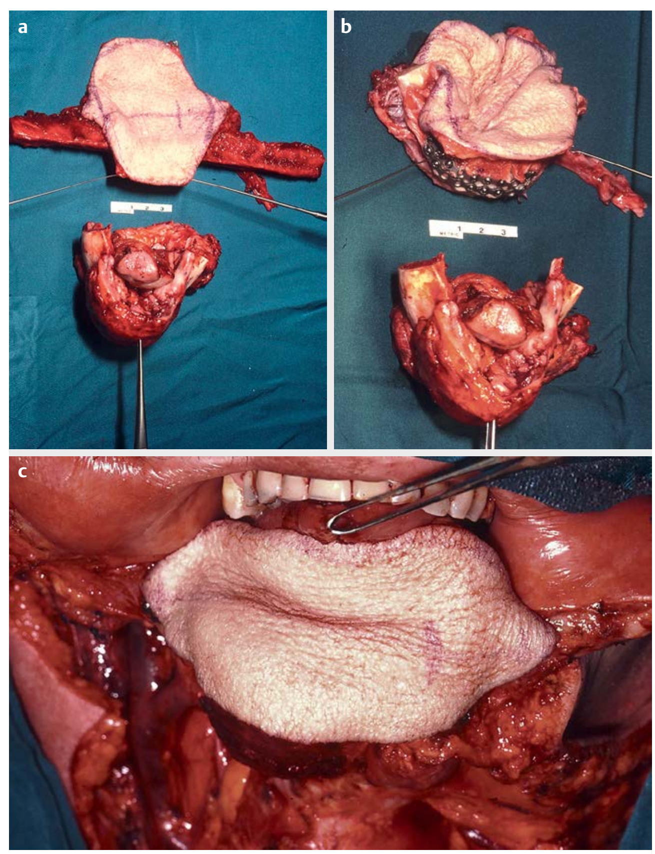


▶ **Fig. 8** Tumor resection of a T4 tumor of the floor of the mouth infiltrating the mandible. **a** T4 tumor of the floor of the mouth after dissection of the mandible. **b** Situation after complete tumor resection [78]. Source: Remmert S. Expertise Funktionelle Wiederherstellung der oberen Luft- und Speisewege. Stuttgart : Thieme; 2015. DOI:10.1055/b-005-143303.

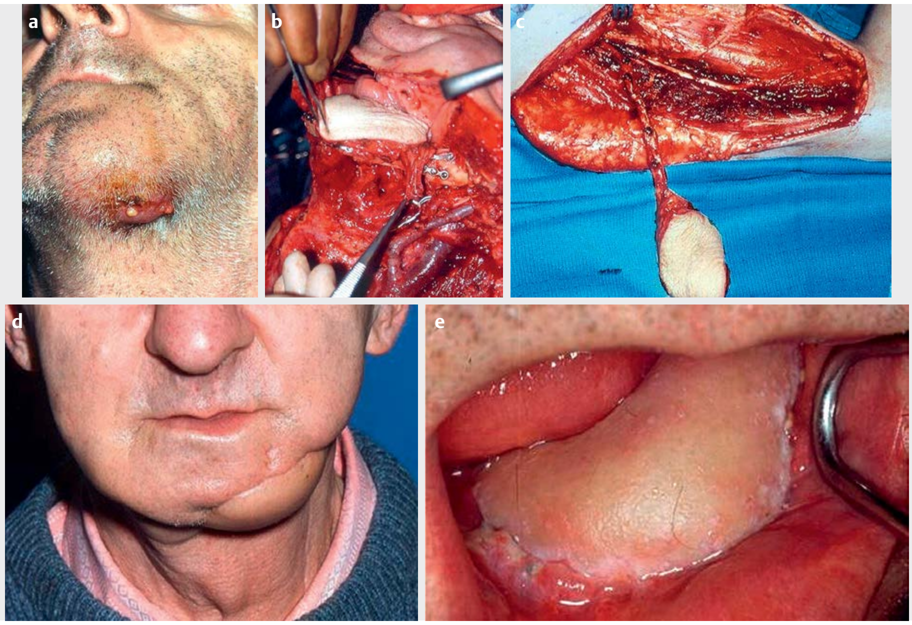
Defects of the mandible in combination with tongue defects are preferably reconstructed primarily osseously (donor region: fibula, iliac crest or scapula) in interdisciplinary cooperation with maxillofacial surgeons.

Tumors of the oral tongue without infiltration of neighboring structures

In case of loss of the complete oral tongue, reconstruction is performed by transposition of an infrahyoid muscle flap (IHL) from



▶ **Fig. 9** Reconstruction of the mandible and the floor of the mouth (case as in ▶ **fig. 7**) with a fibula graft. **a** Fibula graft with skin island and tumor resection specimen. **b** Fibula graft after bone transformation. **c** Reconstruction of the mandible, the floor of the mouth, and the gingiva [78]. Source: Remmert S. Expertise Funktionelle Wiederherstellung der oberen Luft- und Speisewege. Stuttgart : Thieme; 2015. DOI:10.1055/b-005-143303.



▶ **Fig. 10** Reconstruction after resection of a T4 tumor of the floor of the mouth breaking through the skin to the outside. **a** T4 tumor of the floor of the mouth breaking through the skin. **b** Reconstruction of the floor of the mouth, the gingiva, and the mandible with a fibula graft with skin island. **c** Lateral upper arm graft at the still intact vascular pedicle. **d** One year after reconstruction with fibula and upper arm grafts. **e** In the area of the gingiva, incorporated skin island of the thigh one year after reconstruction [78]. Source: Remmert S. Expertise Funktionelle Wiederherstellung der oberen Luft- und Speisewege. Stuttgart : Thieme; 2015. DOI:10.1055/b-005-143303.

both sides in combination with a forearm graft. In this procedure, the muscle flaps are transposed into the oral cavity at the posterior border of the mylohyoid muscle, attached to the muscles of the base of the tongue and to each other in the midline by suturing. A forearm graft is placed to cover the transposed muscle flaps and sutured to the mucosa of the residual tongue and the mucosa of the alveolar ridge (▶ **Fig. 11a–f**). Although sprouting of sensitive nerve fibers from the periphery into the graft occurs regularly, a nerve anastomosis between the lingual nerve and a sensitive graft nerve can improve the quality of tactile sensation.

Tumors of the base of the tongue without infiltration of neighboring structures

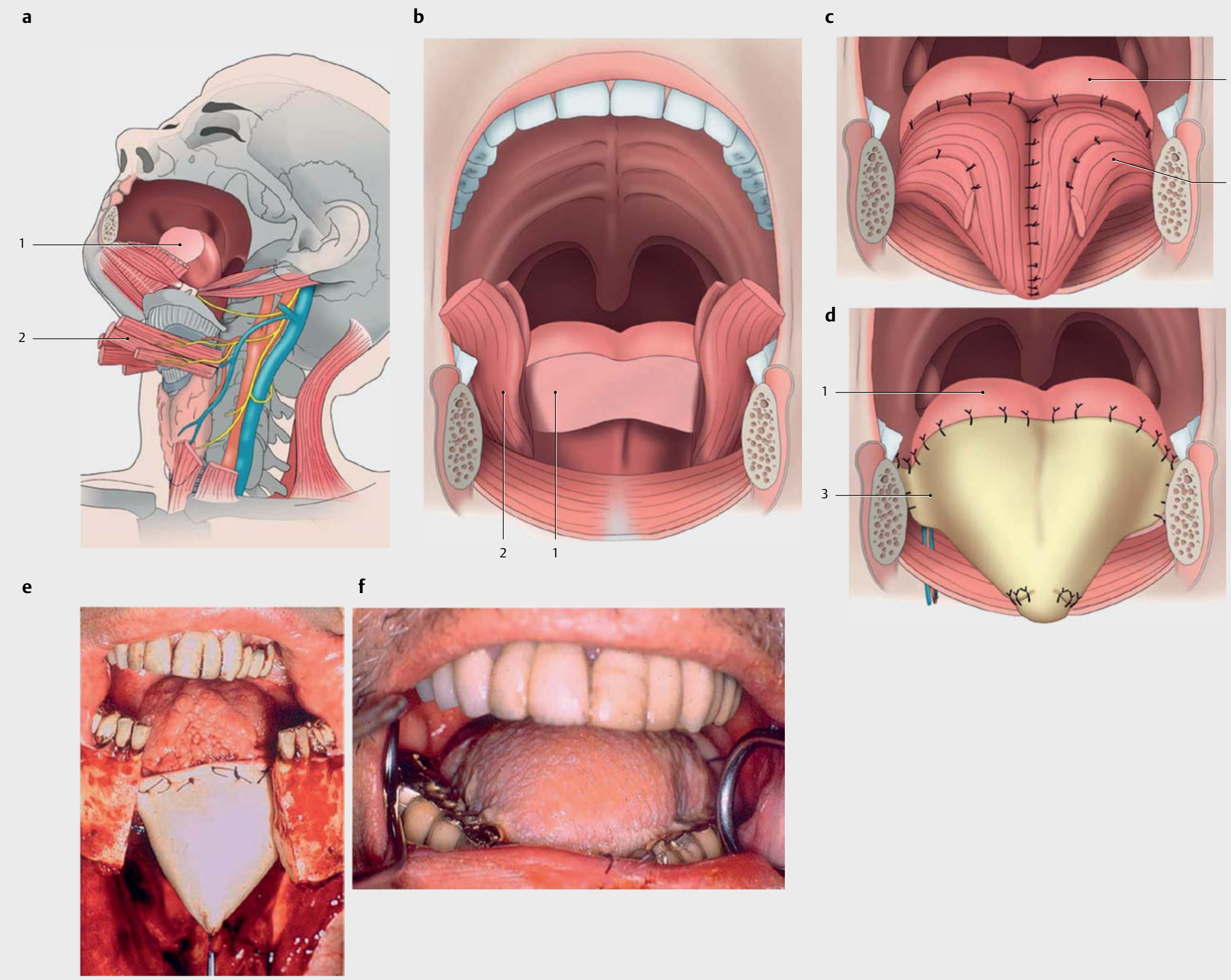
In complete resection of the base of the tongue, the loss of both lingual arteries means that the oral portion of the tongue is no longer supplied with blood. This tumor-free, functionally important tongue remnant can be reperfused and preserved by interposition of a vein segment between the arterial stumps of one side. Residual motor function can be expected by protection of individual fibers of the hypoglossal nerve. The base of the tongue is reconstructed by transposition of an IHL from both sides in combination with a forearm graft. In this procedure, the muscle flaps are fixed to the muscles of the oral tongue remnant and to each other in the midline by suturing. For stable traction of the new tongue base over the laryngeal inlet, the upper belly of the omohyoideus muscle is rotated 90° into the tonsillar bed and sutured. This provides secure protection of the laryngeal inlet to prevent aspiration. A forearm graft is placed to cover the transposed muscle flaps and sutured to the mucosa of the residual tongue and the lateral oropharyngeal walls (▶ **Fig. 12a–g**).

Tumors of the base of the tongue infiltrating neighboring structures

Base of tongue defects may be combined with tissue loss in the soft palate, lateral oropharyngeal wall, supraglottis, or mandible. If the lateral oropharyngeal wall is involved, the forearm graft for the mucosal replacement of the tongue base must be planned and shaped accordingly larger (▶ **Fig. 13**). These additional graft portions are sutured into the oropharyngeal wall or palatal area. If the mandible is involved, the maxillofacial surgeon also removes and models a vascularized bone graft and interposes it in the defect. Reconstructions are always performed from the inside out. After resection of the tumor, the base of the tongue is first filled with an IHL and the mucosa of the base of the tongue and the soft palate are reconstructed with a forearm graft. The reconstructive measures are completed by interposition of the bone graft by means of osteosynthesis. Even 18 months after surgery and postoperative radiotherapy, no significant graft shrinkage occurs. The reconstructed soft palate retains its functionally important flexibility and volume (▶ **Fig. 14a–f**).

Tumors of the oral tongue and base of the tongue without infiltration of neighboring structures

In a complete glossectomy, the tongue is reconstructed by transposition of an IHL from both sides, in combination with a forearm graft. In this procedure, the muscle flaps are fixed to each other in the midline and to the pre-epiglottic tissue with sutures. For a stable traction harness of the new tongue base over the laryngeal inlet, the upper belly of the omohyoideus muscle is rotated 90° into the tonsillar bed and sutured in place. A forearm graft is placed to cover the transposed muscle flaps and sutured to the mucosa of the gin-



▶ **Fig. 11** Reconstruction of the complete oral tongue. **a** Preparation of the infrahyoid muscle fascia flaps. **b** Transposition of the muscle flaps at the posterior edge of the mylohyoid muscle into the oral cavity. **c** Fixation of the muscle flaps in the midline and at the tongue base by sutures. **d** Placing and suturing of the forearm graft with the mucosa of the remaining tongue as well as the mucosa of the alveolar crest. **e** Placing and suturing of the forearm graft with the mucosa of the remaining tongue as well as the mucosa of the alveolar crest. **f** 12 months after surgery. (1 = remaining tongue, 2 = neurovascular infrahyoid muscle fascia flap, 3 = forearm graft) [78]. Source: Remmert S. Expertise Funktionelle Wiederherstellung der oberen Luft- und Speisewege. Stuttgart : Thieme; 2015. DOI:10.1055/b-005-143303.

giva as well as the lateral oropharyngeal walls. The vascular pedicle is guided into the vascular sheath at the posterior margin of the mylohyoid muscle (▶ **Fig. 15a–g**).

The aim of restoring a normal tongue base and oral tongue volume with formation of a tongue tip as well as a glossoalveolar sulcus is to ensure laryngeal protection and the possibility of closing the isthmus faucium. In addition, the reconstruction must allow passive mobility of the neo tongue for contact with the palate and with the anterior dentition. This passive mobility is achieved by contraction of functional residual muscles in the floor of the mouth and pharynx. Motor innervation of the transposed muscles should prevent atrophy in the long term.

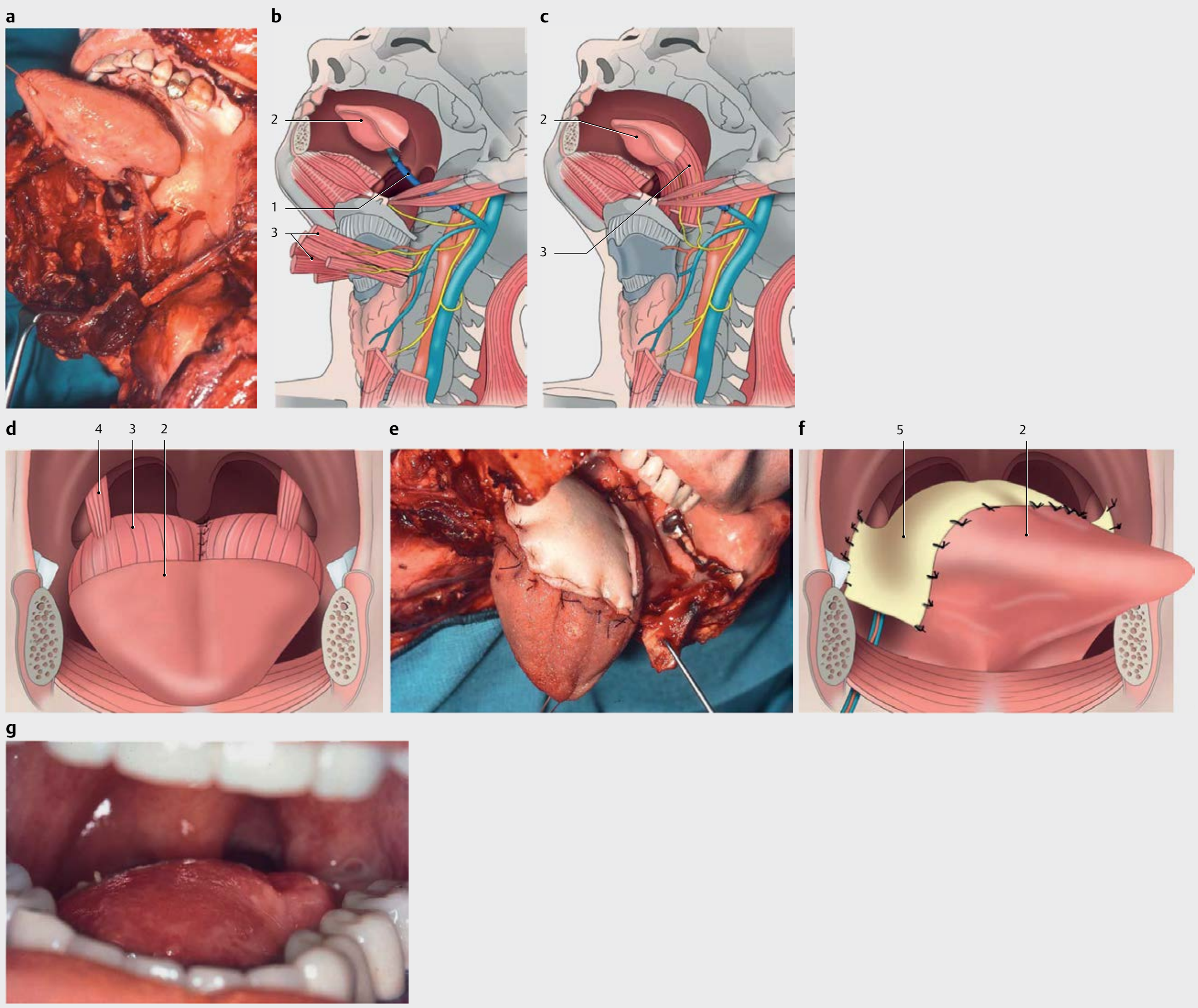
Tumors of the oral tongue and base of the tongue infiltrating neighboring structures

Complete glossectomies may be associated with tissue loss in the floor of the mouth and gingiva with or without mandibular involvement, defects in the supraglottic region, and defects in the lateral oropharyngeal wall.

Reconstruction of a functional glossoalveolar sulcus is performed in cases of major loss of the floor of the mouth and gingiva with an exposed mandible using the forearm graft necessary to replace the mucosa of the resected tongue. If the lateral oropharyngeal wall is involved, the forearm graft can be planned, harvested and sutured similar to ▶ **Fig. 16**.

In cases of mandibular involvement, a bone graft is harvested, sculpted and interposed into the defect. In this case, a skin island for reconstruction of the gingiva should also be included in the graft harvest. By separately replacing the lingual mucosa (forearm graft) and the gingiva (skin island of the bone graft), a glossoalveolar sulcus can be shaped (▶ **Fig. 17a–c**).

If transposition of the IHL is not possible after previous surgery and/or after radiation, a combined graft (latissimus dorsi and sca-



▶ **Fig. 12** Reconstruction of the complete tongue base. **a** Reconstruction of the lingual artery with vein interposition. **b** Reconstruction of the lingual artery with vein interposition. **c** Transfer of the muscle flap. **d** 90° rotation of the upper belly of the omohyoid muscle into the tonsillar beds on both sides. **e** Reconstruction of the mucosa with a forearm graft. **f** Reconstruction of the mucosa with a forearm graft. **g** 12 months after surgery. The remaining oral tongue reveals a discrete volume loss. (1 = vein interposition for reconstruction of the lingual artery, 2 = tumor-free residual tongue, 3 = neurovascular infrahyoid muscle flap, 4 = upper belly of the omohyoid muscle, 5 = forearm graft) [78]. Source: Remmert S. Expertise Funktionelle Wiederherstellung der oberen Luft- und Speisewege. Stuttgart : Thieme; 2015. DOI:10.1055/b-005-143303.

pular graft) can be used on a vascular pedicle to reconstruct the complete tongue and lateral oropharyngeal wall.

The skin island of the latissimus dorsi graft should be incised 1–2 cm larger than the underlying muscle. This muscle-free skin area is nourished by diffusion and is a prerequisite for shaping the tongue body and a glossoalveolar sulcus. Resection of Burow triangles at the skin level allows the tip of the tongue and the floor of the mouth to be sculpted.

The cutaneous scapular graft is used to build up the oropharyngeal wall (▶ **Fig. 18a–d**).

5.3 Defects of the soft palate

To restore the anatomy as well as the function of the soft palate, the following reconstruction parameters must be included in the planning of the reconstruction method:

- Adequate volume replacement for the soft palate
- Ensure dorsal closure of the oral cavity as a prerequisite for bolus retention.
- Flexibility and mobility of the reconstructed palate to the nasopharyngeal end.

Tumors of the palate without infiltration of neighboring structures

For complete palatal defects, the forearm graft is the tissue of choice [69–72]. This graft fully meets the required reconstruction parameters mentioned at the beginning. To avoid scarring due to secondary epithelialization in these resections as well, the graft should be folded. In this way, the back of the palate can also be reconstructed primarily with epithelium. In this case, the planning

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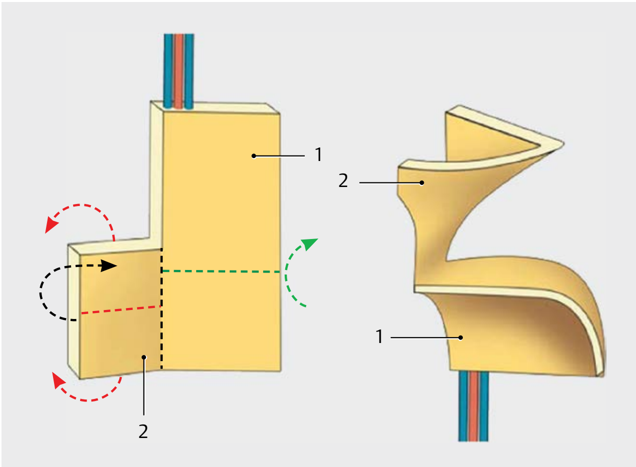
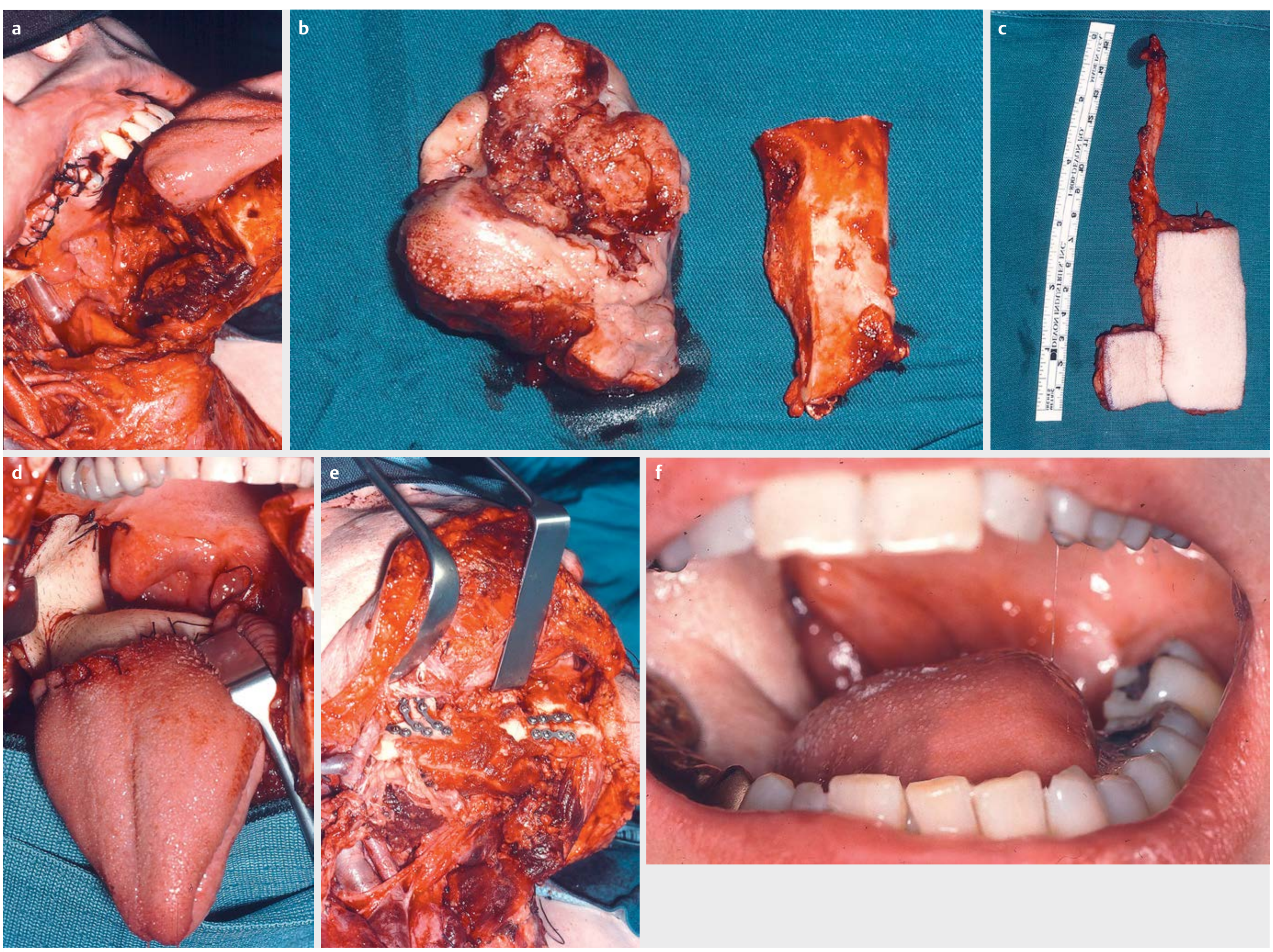


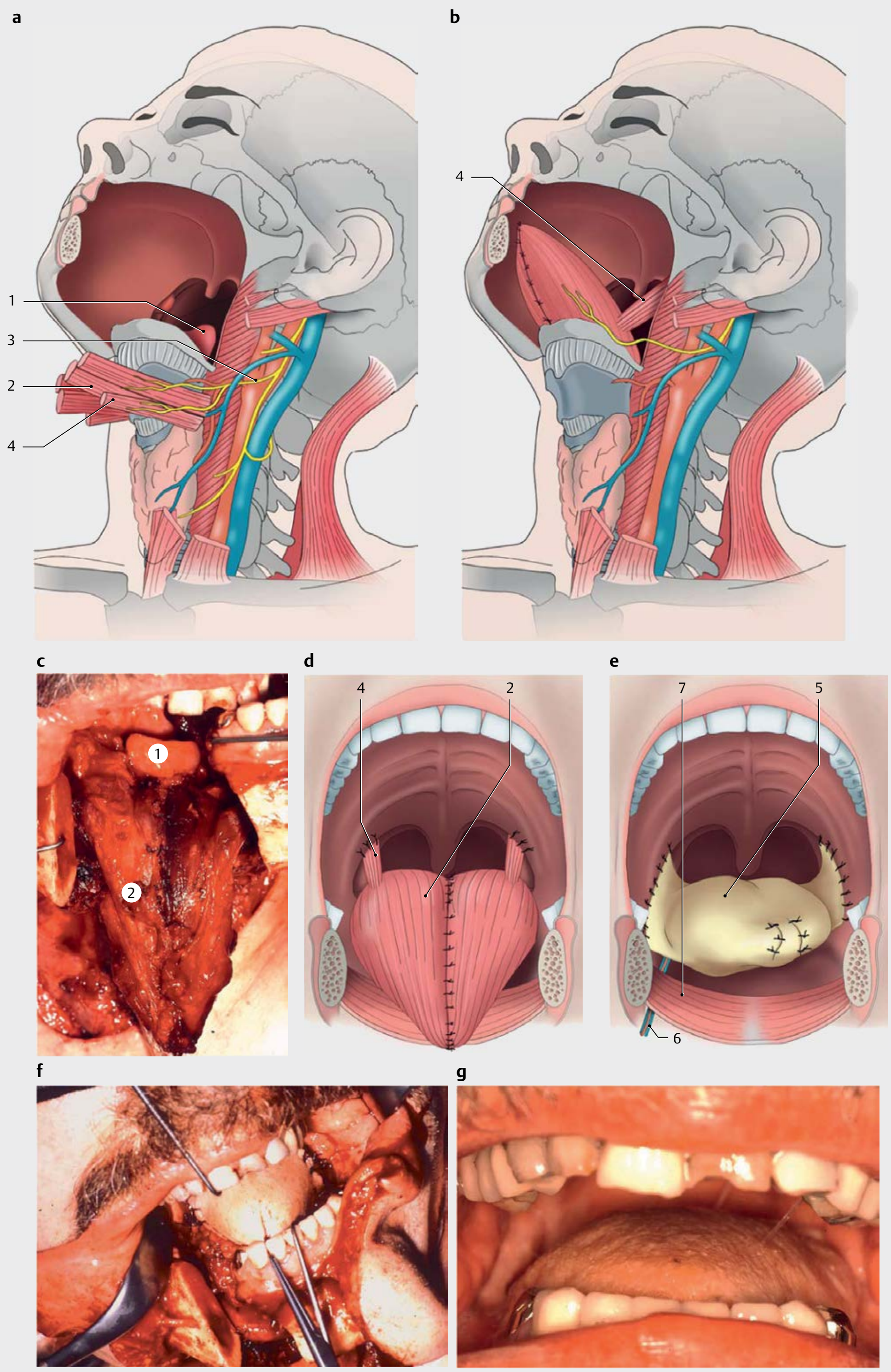
▶ **Fig. 13** Forearm graft for reconstruction of the tongue base and the soft palate. The dotted line shows the axes around which the graft has to be rotated (arrows). 1 = tongue base, 2 = soft palate [78]. Source: Remmert S. Expertise Funktionelle Wiederherstellung der oberen Luft- und Speisewege. Stuttgart : Thieme; 2015. DOI:10.1055/b-005-143303.

of the shape and size of the graft must take into account that the folding must be performed longitudinally around the vascular pedicle. Folding transversely to the vascular pedicle kinks it and highly jeopardizes the blood supply, especially venous drainage (▶ **Fig. 19**).

Incorporation of the graft into the defect is usually performed transorally. First, the skin for the posterior palatal surface must be fixed to the upper defect margin with single button sutures. Successive posterior sutures follow along the lateral and medial margins of the defect. After folding the graft, the sutures of the palatal anterior wall can be easily placed. Threads can also be placed as an alternative for suturing the posterior surface of the palate. ▶ **Fig. 20a–d** show this procedure after laser surgical complete palate resection without reconstruction due to squamous cell carcinoma. In order to correct the velopharyngeal insufficiency with all resulting functional losses, the soft palate was secondarily reconstructed. ▶ **Fig. 20d** demonstrates the postoperative result with a very good palatal volume with high flexibility and functionality. Approximately 60 % of the normal pressure is built up from the tongue



▶ **Fig. 14** Reconstruction of the complete tongue base, the soft palate, and the mandible. **a** Resection defect. **b** Soft tissue and bone resectate. **c** Shape of the forearm graft. **d** Forearm graft sutured into the palate and tongue base defect. **e** Osteosynthesis of a fibula graft. **f** 18 months after surgery [78]. Source: Remmert S. Expertise Funktionelle Wiederherstellung der oberen Luft- und Speisewege. Stuttgart : Thieme; 2015. DOI:10.1055/b-005-143303.



▶ **Fig. 15** Reconstruction after complete glossectomy without involvement of neighboring structures. **a** Transposition of the infrahyoid muscle fascia flap (schematic illustration). **b** Fixation of the muscle flaps in the midline and at the pre-epiglottic tissue. **c** Construction of the muscular tongue body. **d** Tension belting of the new tongue base. **e** Reconstruction of the tongue mucosa. **f** Reconstruction of the tongue mucosa and the cover folds. **g** 18 months after surgery. (1 = epiglottis, 2 = neurovascular infrahyoid muscle fascia flap, 3 = ansa cervicalis, 4 = upper belly of the omohyoid muscle, 5 = forearm graft, 6 = vascular pedicle, 7 = mylohyoid muscle) [78]. Source: Remmert S. Expertise Funktionelle Wiederherstellung der oberen Luft- und Speisewege. Stuttgart : Thieme; 2015. DOI:10.1055/b-005-143303.

thrust behind the reconstructed velum with a downward pressure gradient [72].

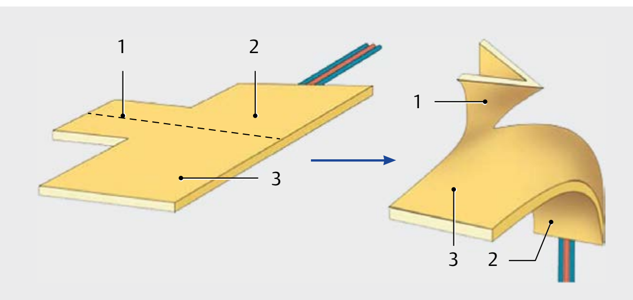
Since secondary reconstructions are usually not followed by post-irradiation, more or less disturbing hairiness of the graft may occur (► **Fig. 20e**).

After irradiation, this phenomenon is not seen because the skin appendages are destroyed. In contrast, the volume and flexibility and thus the functionality remain almost unaffected (► **Fig. 21**).

Tumors of the palate infiltrating neighboring structures

Most commonly, carcinomas of the soft palate infiltrate the tonsillar bed and pharyngeal walls. In rarer cases, all oropharyngeal walls are carcinoma-infiltrated in addition to the soft palate. Then a so-called circular oropharyngeal defect develops as a result of the resection (► **Fig. 22a**). The forearm graft is also most suitable for this situation due to its excellent formability. A graft of approximately 14 cm length for the lower oropharyngeal circumference and approximately 5–6 cm width for the height of the soft palate must be planned. Since the epipharyngeal circumference is considerably smaller, the upper graft margin is shortened accordingly (► **Fig. 22b**). Then, first a tube of 2–3 cm length with the epithelium facing inward for the later mucosal replacement of the oropharynx is formed. Then, the free, unsutured graft corners are folded back and sutured together in the middle. This results in an epithelialized palatal anterior surface. Modeling is performed on the still intact vascular pedicle on the forearm (► **Fig. 22c**). After dissection of the vessels, the remodeled graft is sutured into the defect (► **Fig. 22d**). It retains its shape even after postoperative irradiation and ensures a sufficient velopalatine closure function without nasal regurgitation and without rhinophonia aperta (► **Fig. 22e**).

In the case of bony involvement, the mandibular angle is usually affected by carcinoma infiltration. With sufficient safety margin, the bone must be resected en bloc with the soft tissue tumor. The tongue base volume is built up with an IHL. The reconstruction of the tongue base mucosa, the lateral oropharyngeal wall, the tonsillar bed as well as the soft palate is performed with a forearm graft. The reconstructive measures are completed by osteosynthetic restoration of mandibular continuity with a vascularized bone graft. The cosmetic result 15 months after surgery shows a symmetrical mandibular contour (► **Fig. 23a–e**).



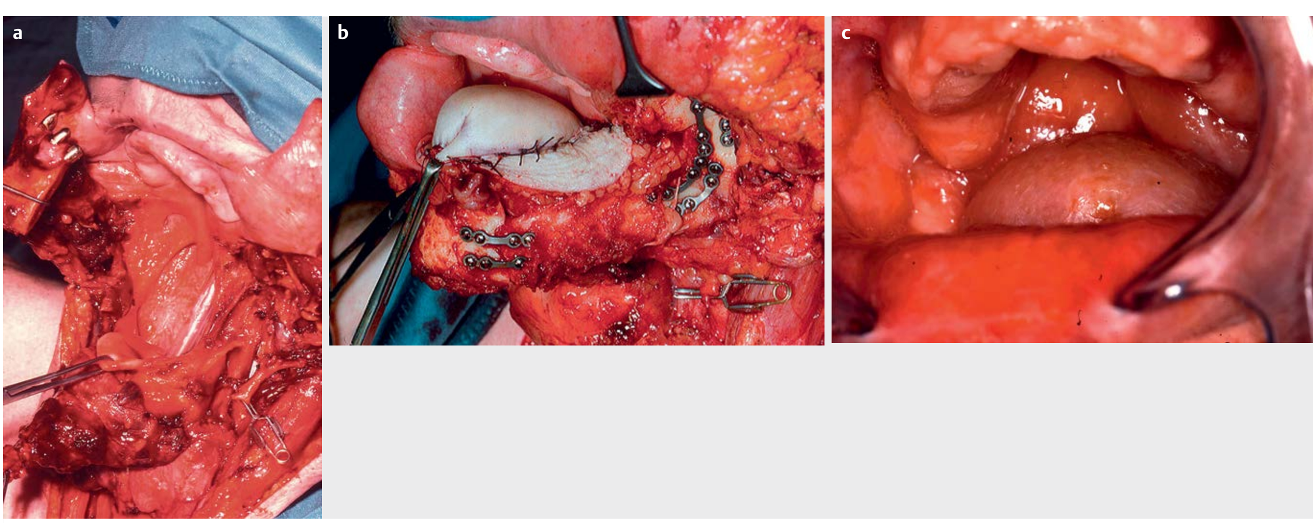
► **Fig. 16** Planning of a forearm graft for reconstruction of tongue base, the oral tongue, and the soft palate. (1 = soft palate, 2 = tongue base, 3 = oral tongue) [78]. Source: Remmert S. Expertise Funktionelle Wiederherstellung der oberen Luft- und Speisewege. Stuttgart : Thieme; 2015. DOI:10.1055/b-005-143303.

5.4 Defects of the larynx and pharynx

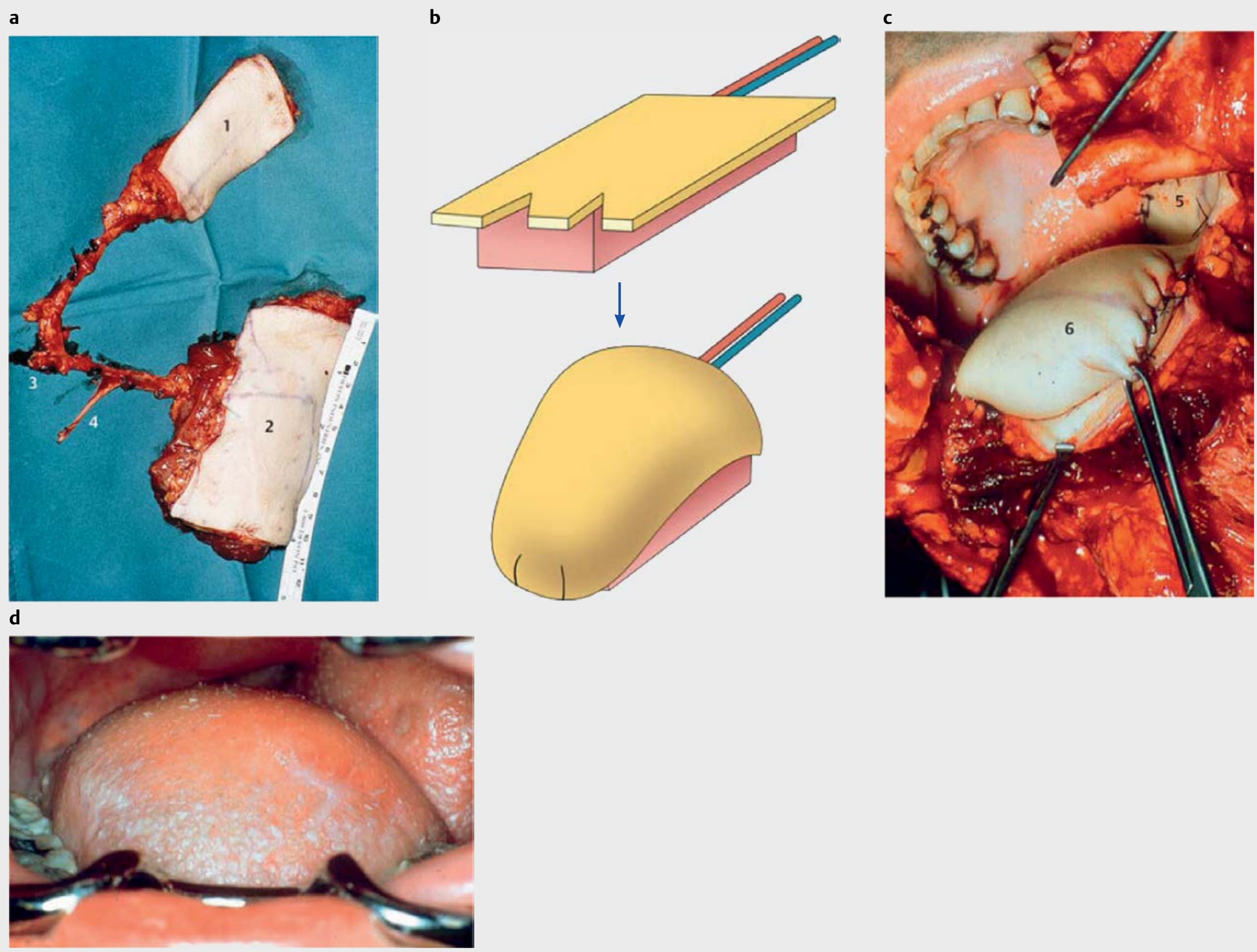
After extensive partial resections in the setting of T3 and T4 tumors, the goals and nature of reconstructive measures and the duration of postoperative rehabilitation differ from those after complete organ loss.

Reconstructions after partial laryngeal resections are complicated and complex. They are intended to restore phonation and the separating function of the larynx for an aspiration-free swallowing act and are necessary when at least one arytenoid cartilage has been resected or defects in the thyroid or cricoid cartilage threaten the stability of the laryngeal framework. The return of function, especially an aspiration-free swallowing, usually requires a lengthy training process of weeks to months and a high compliance of the patient.

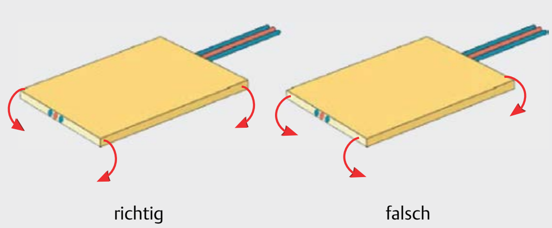
Reconstruction methods after laryngectomy without resections of neighboring structures (pharynx, base of tongue) are focused



► **Fig. 17** Reconstruction after complete glossectomy and partial resection of the mandible. **a** Defect after tumor resection. **b** Osteosynthesis of fibula graft and shaping of the glosso-alveolar sulcus after reconstruction of the tongue with neurovascular infrahyoid muscle fascia flaps on both sides and with forearm graft. **c** 24 months after surgery. Source: Remmert S. Expertise Funktionelle Wiederherstellung der oberen Luft- und Speisewege. Stuttgart : Thieme; 2015. DOI:10.1055/b-005-143303.



▶ **Fig. 18** Reconstruction after complete glossectomy and partial resection of the palate (recurrence surgery). **a** Combination of myocutaneous latissimus dorsi graft and cutaneous scapula graft at a common vascular pedicle. **b** Reshaping of a latissimus dorsi graft to a tongue (schematic illustration). **c** Construction of the soft palate and the tongue. **d** 12 months after surgery. (1 = scapula graft, 2 = latissimus dorsi graft, 3 = vascular pedicle, 4 = motor nerve of the latissimus dorsi muscle, 5 = soft palate (scapula graft), 6 = tongue with floor of the mouth (latissimus dorsi muscle graft) [78]. Source: Remmert S. Expertise Funktionelle Wiederherstellung der oberen Luft- und Speisewege. Stuttgart : Thieme; 2015. DOI:10.1055/b-005-143303.



▶ **Fig. 19** Graft planning for the reconstruction of the complete soft palate. When folding the graft (arrows), the course of the vascular pedicle must be observed [78]. Source: Remmert S. Expertise Funktionelle Wiederherstellung der oberen Luft- und Speisewege. Stuttgart : Thieme; 2015. DOI:10.1055/b-005-143303.

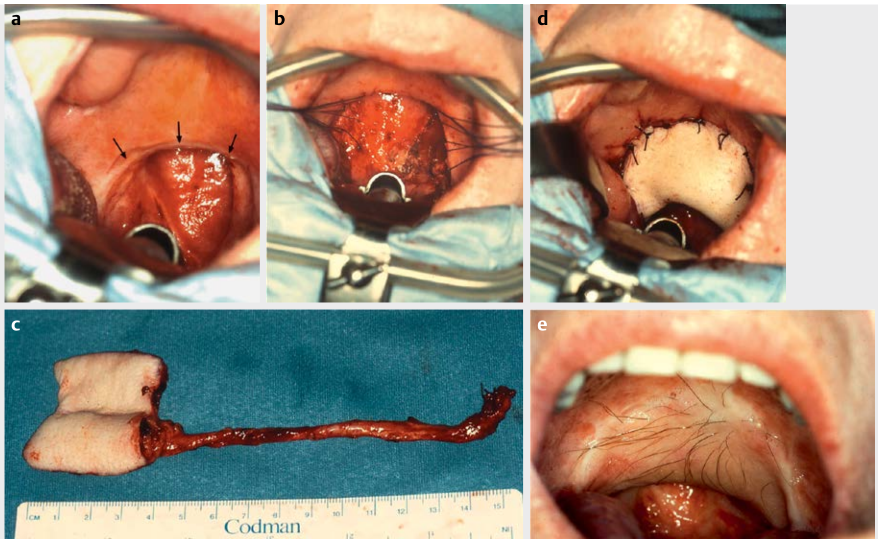
exclusively on the generation of the primary voice sound. All methods of surgical voice rehabilitation are “voice shunts”. They eliminate the separation of the respiratory and digestive pathways, potentially creating the risk of aspiration. The rehabilitation period of a few days to weeks until the return of phonation is usually short.

Tumors of the larynx infiltrating neighboring structures (pharynx)

In advanced tumors of the larynx and pharynx, transverse laryngopharyngectomy continues to be part of the therapeutic options. Especially in younger patients, modern reconstructive options can be used to achieve a significant improvement in quality of life within a short rehabilitation period.

The reconstructive measures are focused on swallowing and voice rehabilitation. Both goals can be achieved very well with a combination of a forearm graft and a voice prosthesis.

After transverse laryngopharyngectomy, a voice prosthesis is placed at the level of the tracheostoma. The prosthesis should be



▶ **Fig. 20** Situation after laser surgical resection of the complete soft palate. **a** Without reconstruction with velopalatine insufficiency and permanent swallowing disorders. The arrows show the useless scar plate. **b** Pre-positioned threads for fixation of the graft skin on the posterior surface of the palate. **c** Forearm graft for secondary reconstruction of the palate. The skin is folded around the longitudinal axis of the vascular pedicle to form the anterior and posterior surfaces of the palate. **d** Folded forearm graft placed into the defect. **e** One year after secondary reconstruction of the palate with a forearm graft [78]. Source: Remmert S. Expertise Funktionelle Wiederherstellung der oberen Luft- und Speisewege. Stuttgart : Thieme; 2015. DOI:10.1055/b-005-143303.

▶ **Fig. 21** Reconstruction of the complete soft palate with a forearm graft. Situation 2 years after surgery and irradiation. The volume is insignificantly reduced with functional loss [78]. Source: Remmert S. Expertise Funktionelle Wiederherstellung der oberen Luft- und Speisewege. Stuttgart : Thieme; 2015. DOI:10.1055/b-005-143303.

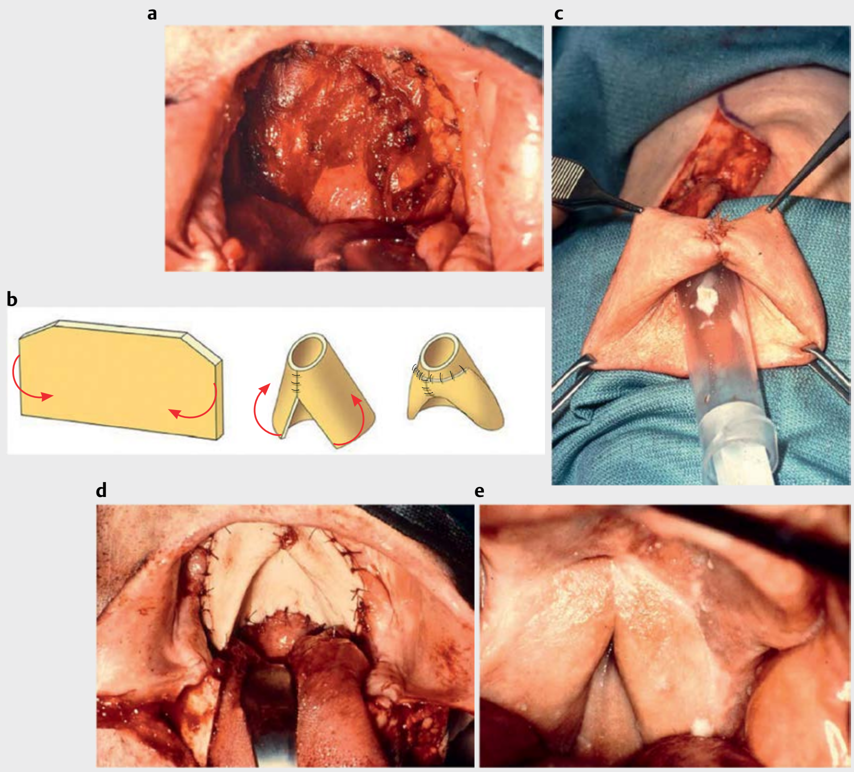
positioned below the pharyngeal defect to be reconstructed in the tumor-free esophageal anterior wall (▶ **Fig. 24a**).

A forearm graft is then used to restore the continuity of the esophageal pathway. For a wide pharyngeal tube, an 8–10 cm x 5–6 cm graft must be elevated and sutured transversely between the oropharynx and the esophageal inlet. Closure to form a tube is achieved by single button sutures in a vertical direction. Thereby, the vascular pedicle pulls in a circular-horizontal course around the neopharynx. With the given graft dimensions, a sufficiently wide digestive pathway can be reconstructed. The excess of circumference for the anastomosis with the esophagus should not be reduced or only to a very limited extent in order to prevent stenosis (▶ **Fig. 24a–d**).

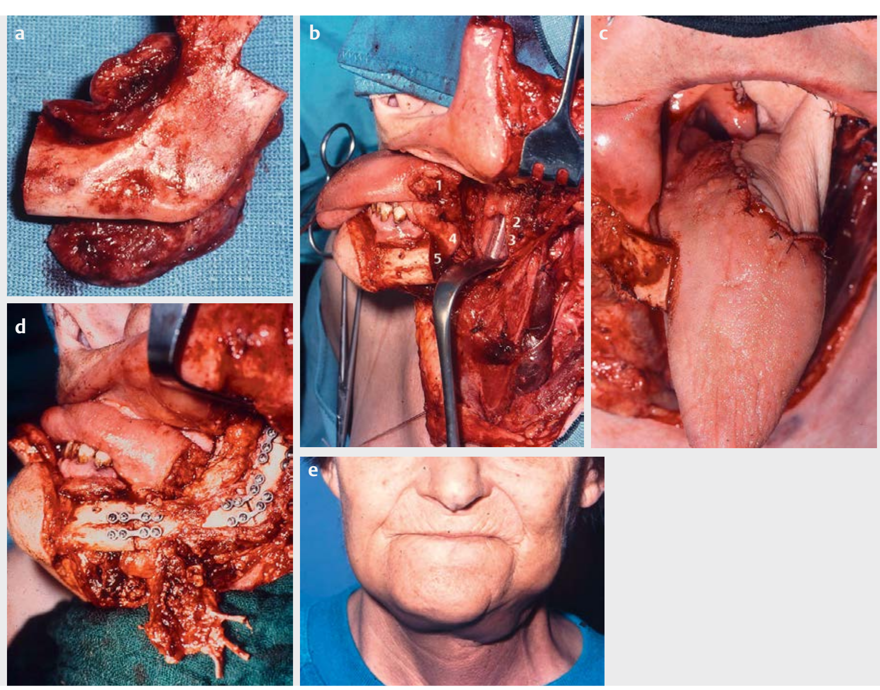
Another suitable graft for reconstruction of the alimentary tract is the jejunum graft. It offers an almost unlimited graft length, is a mucosal graft and tubular (▶ **Fig. 25a**). Taking advantage of these characteristics, an extra-long jejunum segment can be used to reconstruct the cervical esophageal pathway with simultaneous creation of a vocal shunt [73]. After transverse laryngopharyngectomy, the esophageal pathway is interrupted from the base of the tongue to the esophageal inlet. In contrast to classic laryngectomy, 1–2 cartilage rings are preserved above the tracheostoma as a tracheal chimney. To accommodate the oropharyngeal circumference, the aboral end of the jejunal graft must be incised longitudinally opposite the mesenteric fat. This ensures that the vascular supply is maintained and a funnel-shaped anastomosis with the oropharyngeal mucosa is possible. This is performed with single button sutures penetrating through all wall layers of the graft. A second continuous suture between the small intestinal serosa and the oropharyngeal muscles completes the oral anastomosis.

Under pretension, the jejunal tube is then fixed downward on the prevertebral fascia with sutures and turned 180° at the level of the esophageal entrance (caudal hypopharyngeal resection margin). At the point of kinking, the bilayer anastomosis with the esophageal inlet is performed after transverse incision of the intestinal tube. The now upward directed intestine is again turned by 180° below the floor of the mouth and led downward to the tracheal chimney via a biventer reins. There, the anastomosis of the oral bowel end with the tracheal chimney completes the reconstruction. The peristalsis and thus the mucus transport are directed from the trachea to the neopharynx (▶ **Fig. 26a–g**).

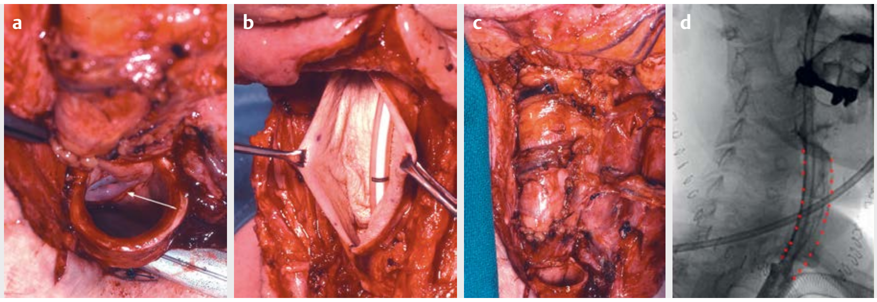
Patients usually start oral food intake 10 days after surgery and speech training after 14 days. During expiration, the airflow is di-



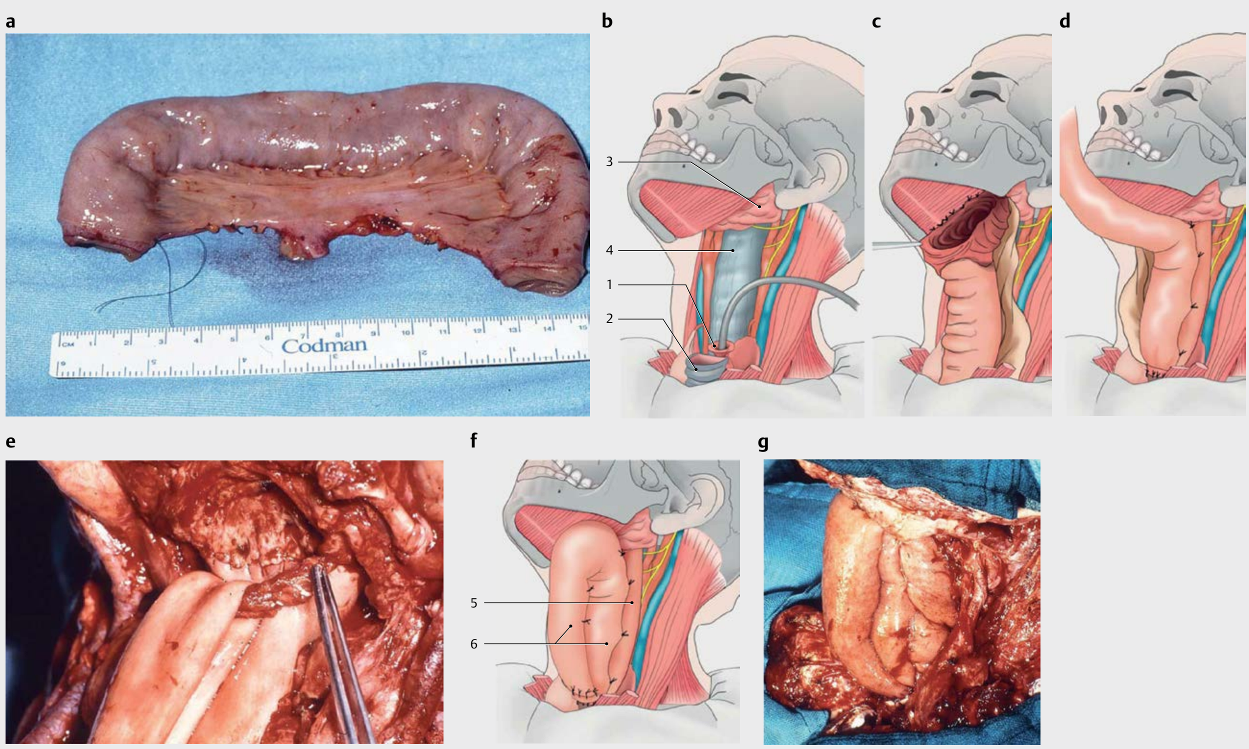
► **Fig. 22** Circular oropharyngeal defect after resection of a T4 carcinoma of the palate. **a** Defect. **b** Graft shaping. **c** Graft shaping at the intact vascular pedicle in the forearm area. The injection syringe serves as placeholder for forming the epipharyngeal circumeference. **d** Implementation of the pre-shaped graft into the defect. **e** Situation 2 years after surgery and irradiation [78]. Source: Remmert S. Expertise Funktionelle Wiederherstellung der oberen Luft- und Speisewege. Stuttgart : Thieme; 2015. DOI:10.1055/b-005-143303.



► **Fig. 23** Reconstruction after carcinoma of the palate infiltrating the tonsils, the lateral oropharyngeal wall, the tongue base, and the mandibular angle (T4). **a** Tumor resectate. **b** Resection defect. **c** Soft part reconstruction with neurovascular infrahyoid muscle fascia flaps and forearm graft. **d** Mandibular reconstruction with fibula graft. **e** Cosmetic outcome 2 years after surgery. (1 = defect of the tongue base, 2 = defect of the tonsillar bed, 3 = defect of the lateral oropharyngeal wall, 4 = epiglottis, 5 = defect of the mandible) [78]. Source: Remmert S. Expertise Funktionelle Wiederherstellung der oberen Luft- und Speisewege. Stuttgart : Thieme; 2015. DOI:10.1055/b-005-143303.



▶ **Fig. 24** Transverse laryngopharyngectomy, reconstruction with forearm graft and voice prosthesis. **a** Placing of the voice prosthesis (arrow). **b** Reconstruction of the pharyngeal tube, before vertical suture. **c** Reconstruction of the pharyngeal tube, after vertical suture. **d** Postoperative examination with contrast enhancement after reconstruction with a forearm graft. The red dotted line shows the neopharynx. (1 = neopharynx, 2 = circular-horizontal vascular pedicle, 3 = trachea) [78]. Source: Remmert S. Expertise Funktionelle Wiederherstellung der oberen Luft- und Speisewege. Stuttgart : Thieme; 2015. DOI:10.1055/b-005-143303.

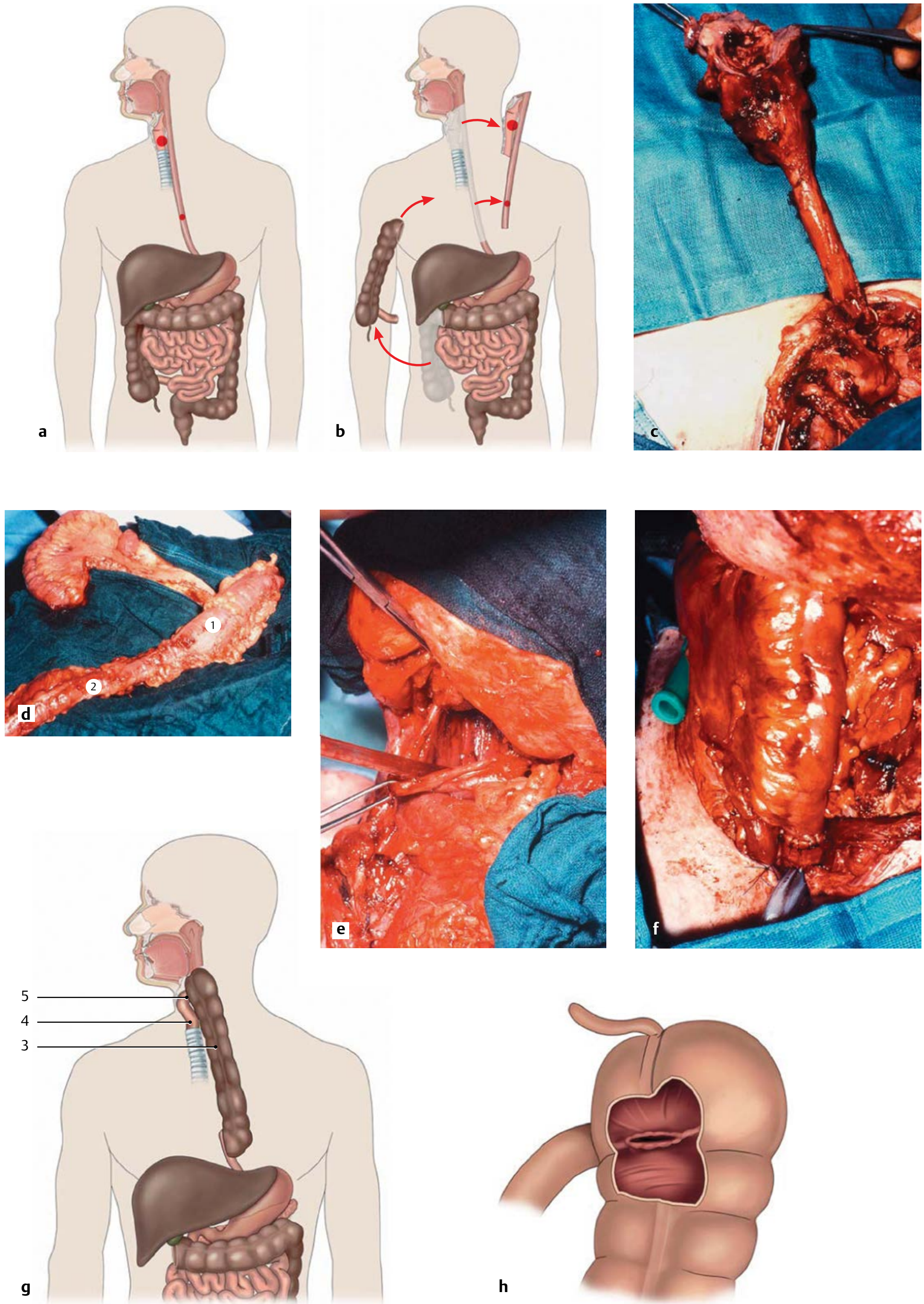


▶ **Fig. 25** Transverse laryngopharyngectomy, reconstruction of the pharyngeal tube and construction of a voice shunt with jejunum graft. **a** Oversized jejunum graft with thread marking of the aboral edge. **b** Resection defect. **c** Longitudinal incision of the aboral intestinal end and funnel-shaped anastomosis with the oropharyngeal mucosa. **d** End-to-side anastomosis with the esophageal entrance after 180 ° turn and incision of the jejunum graft. **e** Biventer reins. **f** Neopharynx and voice shunt (schematic picture). **g** Neopharynx and voice shunt. (1 = esophagus entrance, 2 = tracheal tube, 3 = base of tongue, 4 = prevertebral fascia, 5 = neopharynx, 6 = voice shunt) [78]. Source: Remmert S. Expertise Funktionelle Wiederherstellung der oberen Luft- und Speisewege. Stuttgart : Thieme; 2015. DOI:10.1055/b-005-143303.

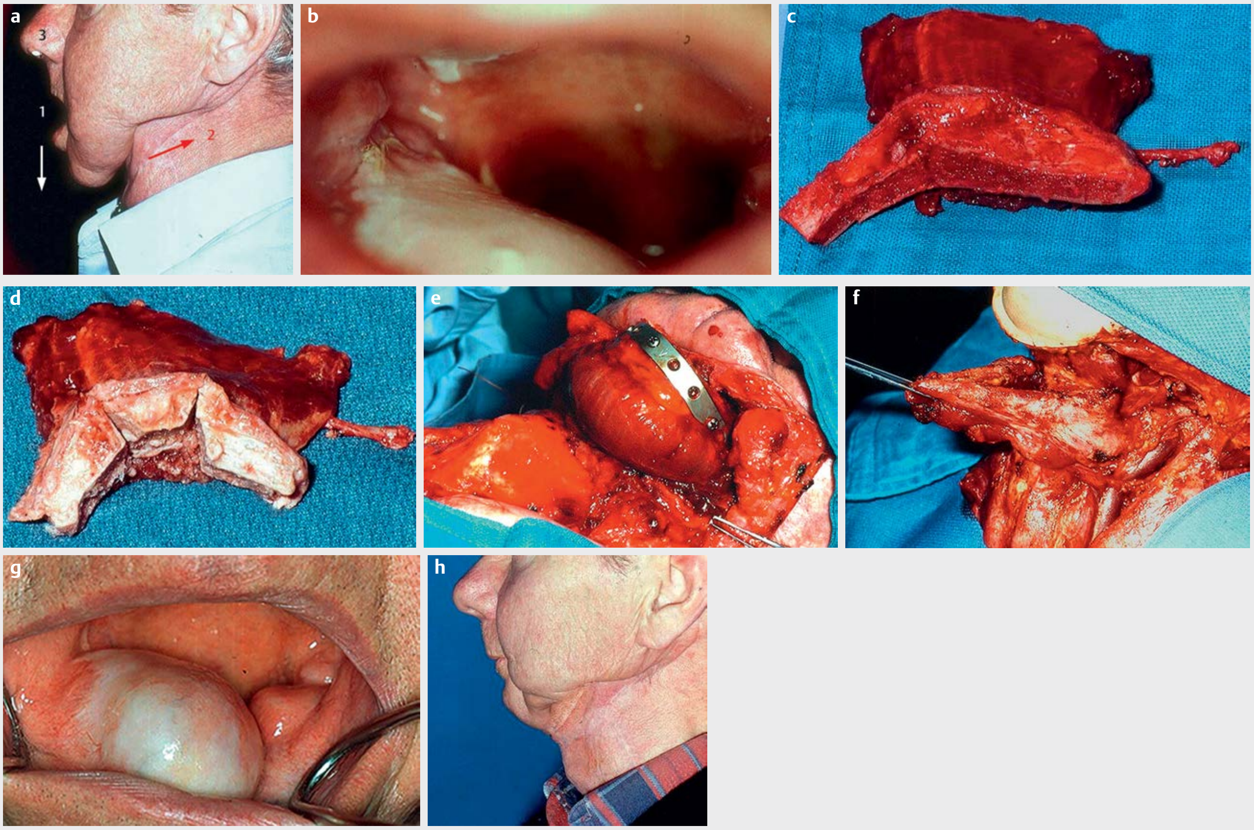
rected into the neohypopharynx via the voice shunt by closing the tracheostoma. Oscillations of the system result in the formation of a primary voice sound. Patients are able to speak comparably quickly, as after fitting with a voice prosthesis.

Secondary carcinomas occur in approximately 20 % of cases of laryngeal and pharyngeal carcinomas [74]. If this second carcinoma is localized in the esophagus and diagnosed simultaneously with laryngeal-pharyngeal carcinoma, young patients with a desire for surgery may be offered highly complex interdisciplinary surgery in individual cases [75–77].

The larynx, the pharynx and the complete esophagus are resected transcervically and transabdominally. The reconstruction of the esophageal pathway is performed with the ascending colon pedicled at the dextra colic artery, and the construction of the vocal



► **Fig. 26** Reconstruction after hypopharynx-larynx carcinoma with simultaneous secondary carcinoma of the esophagus. **a** Tumor location (red dots). **b** Transverse laryngopharyngectomy with esophageal resection and reconstruction planning. **c** Transverse laryngopharyngectomy with esophageal resection (intraoperative image). **d** Preparation of the ascending colon with terminal ileum. **e** After incision of the cecum, end-to-side anastomosis with the oropharynx. **f** Anastomosis of the ileum and the trachea. **g** Reconstructed esophagus, voice shunt, and neoglottis. **h** Ileo-cecal valve as neoglottis. (1 = colon ascendens, 2 = ileum, 3 = reconstruction of the esophagus with ascending colon, 4 = reconstruction of the voice shunt with terminal ileum, 5 = ileo-cecal valve as neoglottis) [78]. Source: Remmert S. Expertise Funktionelle Wiederherstellung der oberen Luft- und Speisewege. Stuttgart : Thieme; 2015. DOI:10.1055/b-005-143303.



▶ **Fig. 27** Secondary reconstruction after complete glossectomy, partial mandibular resection and reconstruction with pectoralis major flap. **a** Preoperative analysis: functional loss (1, 2, and 3) and deficient esthetic outcome. **b** Preoperative analysis: atrophic pectoralis major flap as tongue replacement. **c** Reconstruction: pelvic crest graft with abdominal internal obliquus muscle. **d** Reconstruction: pelvic crest graft with abdominal internal obliquus muscle after shaping. **e** Reconstruction: Restoration of the mandibular continuity and construction of new floor of the mouth. **f** Reconstruction: preparation of the neurovascular infrahyoid muscle fascia flaps. **g** Outcome: neotongue after augmentation with neurovascular infrahyoid muscle fascia flap. **h** Outcome: sufficient closure of the mouth, physiological position of the larynx, no feeding tube, and normal esthetics. (1 = insufficient closure of the mouth due to missing mandibular support, 2 = tracheal obstruction of the swallowing pathway due to missing laryngeal suspension, 3 = permanent feeding tube) [78]. Source: Remmert S. Expertise Funktionelle Wiederherstellung der oberen Luft- und Speisewege. Stuttgart : Thieme; 2015. DOI:10.1055/b-005-143303.

shunt is performed with the laterally descending terminal ileum. Since the blood supply via the colic dextra artery is insufficient to supply the small bowel segment, microvascular anastomoses of the ileal artery and vein must be performed with appropriate neck vessels. The ascending colon is rotated 180° and caudally anastomosed end-to-end with the stomach. After passing through the thorax into the neck and making an incision in the cecum, an end-to-end anastomosis with the oropharyngeal walls is performed. The connection of the ileum to the trachea completes the construction of the voice shunt. In this process, the ileocecal valve (Bauhini) functions as a neoglottis for phonation and as a closure valve for aspiration prophylaxis (▶ **Fig. 26a–h**).

It is in these complex cases and the need for the associated restoration of function that the potential of interdisciplinary collaboration becomes particularly apparent.

The impact of the lack of interdisciplinary collaboration on postoperative function and quality of life is illustrated by the following case after glossectomy and partial mandibular resection.

In the initial surgery, a complete glossectomy and resection of the bony chin were performed due to a T4 carcinoma. The intraoral soft tissue defect was closed with a pectoralis major flap without reconstruction of the mandible. The patient was unable to swallow for six years and could not speak intelligibly.

Due to the missing mandible, the soft tissues of the chin had no support and fell down. This resulted in complete oral closure insufficiency. The loss of anterior suspension to the mandible (via the floor of the mouth muscles), resulted in displacement of the larynx into the swallowing pathway toward the spine (▶ **Fig. 27a**). In addition, laryngeal elevation during the swallowing cycle was impossible. The oral cavity showed an atrophic pectoralis major flap (▶ **Fig. 27b**). Closure of the oral cavity to the soft palate and thus bolus retention as well as bolus transport were impossible.

Mandibular continuity was restored with a composite osteomyocutaneous iliac crest graft. V-shaped excisions were used to match the bone to the shape of the chin. The obliquus internus abdominis muscle associated with the graft replaced the floor of the mouth. Two IHLs were placed between this new diaphragma oris and the atrophic pectoralis major flap, creating sufficient volume of neo tongue to serve as a punch for bolus transport and as a closure to the soft palate.

Laryngeal elevation with fixation to the reconstructed bony chin placed the larynx in a physiologic swallowing position.

Reconstruction resulted in esthetic and functional rehabilitation with oral food intake and intelligible articulation (▶ **Fig. 27a-h**).

With modern reconstruction procedures, the anatomy as well as the specific functions can be restored after partial and complete organ losses. Especially for the quality of life, it is crucial that therapy planning, surgical implementation and aftercare are carried out in an interdisciplinary manner, particularly in the case of complex defects.

Conflict of interest

The authors declare that they have no conflict of interest.

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