9 Oral and Maxillofacial Reconstruction

Satoshi Yokoo and Tadaaki Kirita

Abstract

The content of this chapter does not include general textbook or ordinary items understandable by everyone. No general flap elevation or reconstruction method is described. Described are practices of pre- and postoperative management of oral and maxillofacial reconstructive surgery and in the operation room. The sole objective of the practices is to clarify how to prepare reconstruction materials reliably, safely, and efficiently, to restore defecting oral and maxillofacial regions, and maintain the reconstructed condition. This chapter has been written for reconstructive surgeons already performing surgeries at the forefront of the field of oral and maxillofacial reconstructive surgery.

Keywords

Biological life and Social life • Step-Surgery Concept • Functional Unit Reconstruction • Stereolithographic mandibular model (SLMN)

9.1 General Principles

9.1.1 Disability/Rehabilitation Medicine and Maintenance of Social Life

Considering the importance of maintaining QOL in recent medical care and its social implications, resection of a lesion with the aim of only prolonging life has become a thing of the past, even in cancer therapy. The oral and maxillofacial system is important for not only the maintenance of life, such as food ingestion, mastication, and swallowing, but also communication through conversation and facial expression, i.e., social interaction. Although resection of oral cancer lesions prolongs and maintains the "biological life" of patients, impairment causes economic difficulty attributed to inability to work and social isolation. Oral and maxillofacial reconstruction and rehabilitation, i.e., resumption of "social life," has to be carried out with the aim of "disability medicine"-based "holistic rehabilitation (right to live a normal life)" [1, 2] (Fig. 9.1).

Impairment of function after extensive resection of oral cancer can be anticipated when "cancer" is diagnosed, surgery can be planned upon the occurrence of impairment [1, 2], and a rehabilitation plan can be designed before the impairment. These steps provide a clear advantage not available upon sudden onset of cerebrovascular disorders or accidents.

After surgical treatment of oral cancer, subsequent pre- and postoperative rehabilitation by specialists (otorhinolaryngology-head and neck surgeons, oral and maxillofacial surgeons, plastic and reconstructive surgeons, speech-language-hearing therapists, nurses, and clinical psychologists) is essential. It is therefore necessary for medical professionals to cooperate with one another for the benefit of the patients to whom they provide medical care and to facilitate their return to normal social life.

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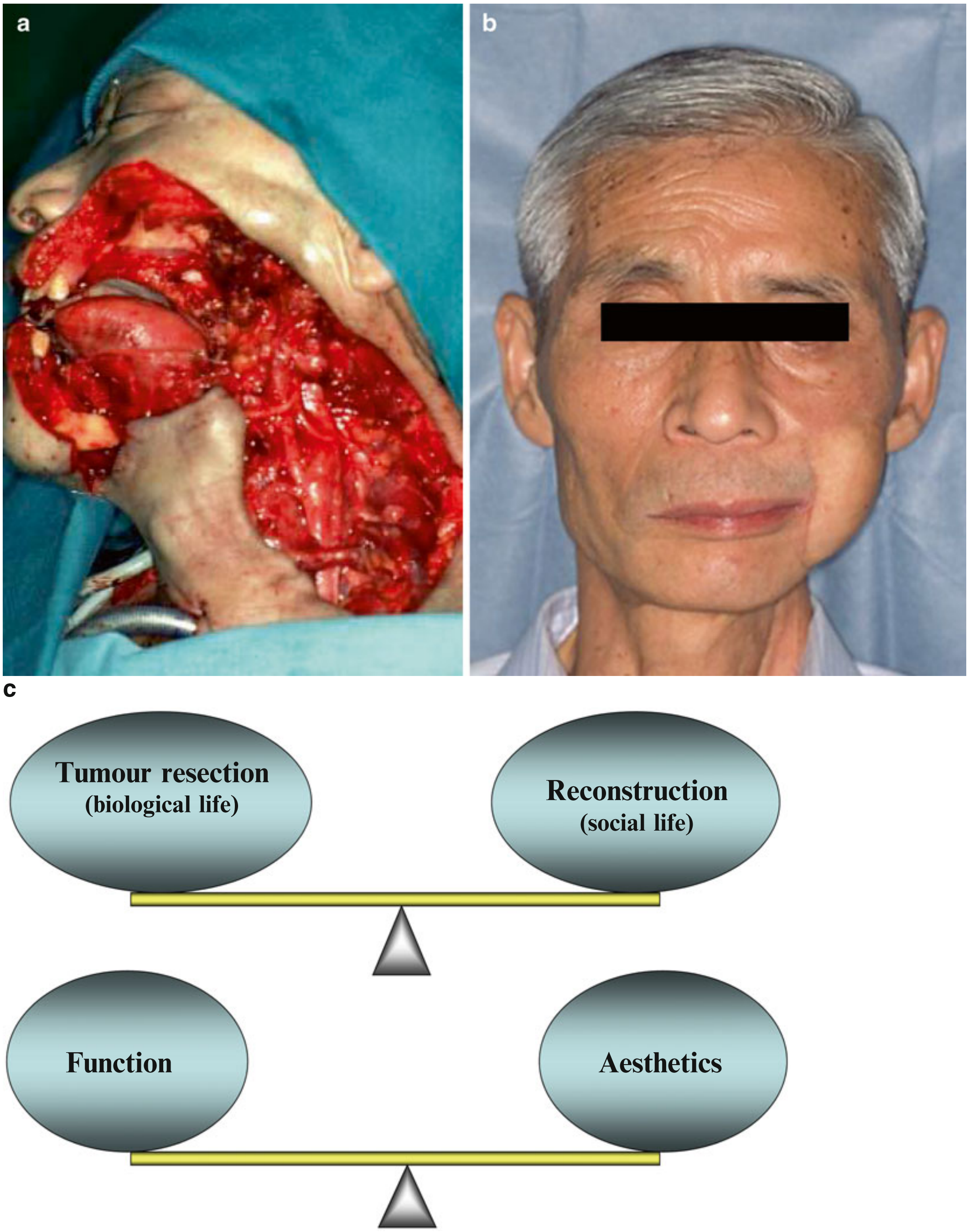


Fig. 9.1 Disability/rehabilitation medicine and maintenance of social life. (**a**) Tumor resection: maintenance of biological life. (**b**) Reconstruction and disability/rehabilitation medicine: maintenance of social life. (**c**) Oral cancer therapy today: treatment of the cancer itself and disability/rehabilitation medicine for any resulting impairment are essential, just like a set of wheels, and reconstructive surgery fills the role of an axle connecting these wheels

In cancer treatment, "treatment of the cancer itself" and "disability/rehabilitation medicine" for any resulting impairment are essential, just like a set of wheels, and reconstructive surgery fills the role of an axle connecting these wheels.

Reconstructive surgery is a science and an art. To achieve favorable outcomes, surgeons need to select transplantation procedures through which they can perform to their best and utilize their skills. Oral and maxillofacial reconstruction requires both functionality and aesthetics to which due consideration is requisite, despite the difficulties of the reconstruction.

9.1.2 Step-Surgery Concept

In oral and maxillofacial reconstructive surgery, there are two concepts regarding the principle of facial reconstruction methodology: (1) restoration of defects with facial and neck tissue, particularly with adjacent tissue if possible, and (2) unit principle, that is, reconstruction of each facial unit with color and texture. The former is feasible with regard to color and texture compatibility. The latter is subdivided from the aesthetic units [3] to sub- [4, 5] and mini-units [6]. Initial reconstruction with adjacent facial and neck tissue (applying the unit principle as needed) is conducive to acceptable outcomes for small facial defects. For moderate or more severe defects, however, the outcome of this initial reconstruction with adjacent tissue has often been unsatisfactory. Particularly, when the defect extends over 2 or more units or full thickness, reproducing the outline of each unit and its three-dimensional contour using the skin flap and graft is challenging because predicting and controlling three-dimensional changes induced by postoperative contracture and gravity is difficult. Moreover, when the optimum adjacent tissue for the reconstruction of the defect has already been used in the initial surgery, the most desirable outcome cannot, in many cases, be obtained by repeated revisions.

As a therapeutic policy for moderate or more severe full-thickness facial defects, we propose the step-surgery concept: (1) In *the initial step*, only filling and transplantation of minimum supporting tissue necessary for the restoration of function by free flap transplantation is carried out, and the surrounding tissue is conserved, (2) in *the touch-up step*, aesthetic surgery by transplantation of necessary supporting tissue is carried out with the use of a local facial/neck flap and skin graft, (3) as much cutaneous surface exposed on the face as possible is replaced with the facial/neck skin in *the touch-up step*, and (4) all the steps are planned as a series before surgery. Treatment based on this concept provides two advantages: (1) the free skin and musculocutaneous flaps transplanted in *the initial step* serve as a host side with abundant blood circulation, making secondary aesthetic surgery with a local skin flap easy, and (2) since the exposed cutaneous surface is resected after confirming time-course changes in the transplanted free flap, and since secondary surgery is carried out accordingly, the outline and contour are readily reproduced. When the cutaneous surface of the free flap is exposed on the face, differences of color match, texture, and thickness between the flap and the surrounding tissue present serious aesthetic problems; replacing the free flap with skin of the face/neck is desirable [7, 8]. When free flaps are used in reconstructive surgery, the importance of aesthetic outcomes should be taken into consideration.

The case presented here is of a 51-year-old man with recurrent squamous cell carcinoma of the left buccal mucosa after external irradiation (65 Gy). Resection of the full-thickness cheek, oral commissure, and vermilion was carried out. The number of defective units was 3, and there was no supporting tissue. The defects of full thickness of the cheek, upper lip, and oral commissure were reconstructed with free forearm and vermilion advancement flaps *in the initial step*, and aesthetic revision with a malar flap and a skin graft was carried out in the *touch-up step*. The outcome was acceptable. For patients who receive ≥50-Gy of irradiation, as in the present case, *the initial step* with the use of free skin or musculocutaneous flaps is very important (Fig. 9.2).

Fig. 9.2 Step-surgery concept. A 51-year-old man with recurrent squamous cell carcinoma of the left buccal mucosa after external irradiation (65 Gy). The defects of full thickness of the cheek, upper lip, and oral commissure (the number of defective units was 3, and there was no supporting tissue) were reconstructed with free forearm and vermilion advancement flaps in *the initial step*, and aesthetic revision with a malar flap and a skin graft was carried out in *the touch-up step*. For patients who receive ≥50 Gy of irradiation, as in the present case, *the initial step* with the use of free skin and musculocutaneous flaps is very important

9.2 Practice of and Strategy for Oral and Maxillofacial Reconstruction

9.2.1 Free Radial Forearm Flap

9.2.1.1 Role of Perforating Vein in Vascular Pedicle

The vascularized free forearm flap reported by Yang et al. [9] is now recognized as one of the most useful means for reconstructive surgery. Because of its long length, the large diameter of the blood vessel, and the flexibility of the cutaneous portion, it is widely used, particularly for head and neck, oral, and maxillofacial reconstruction [10–12]. The radial artery is generally used as the feeding artery. Two options for the drainage vein are the cephalic vein and radial comitant vein [9, 13]. The cephalic vein is generally selected because

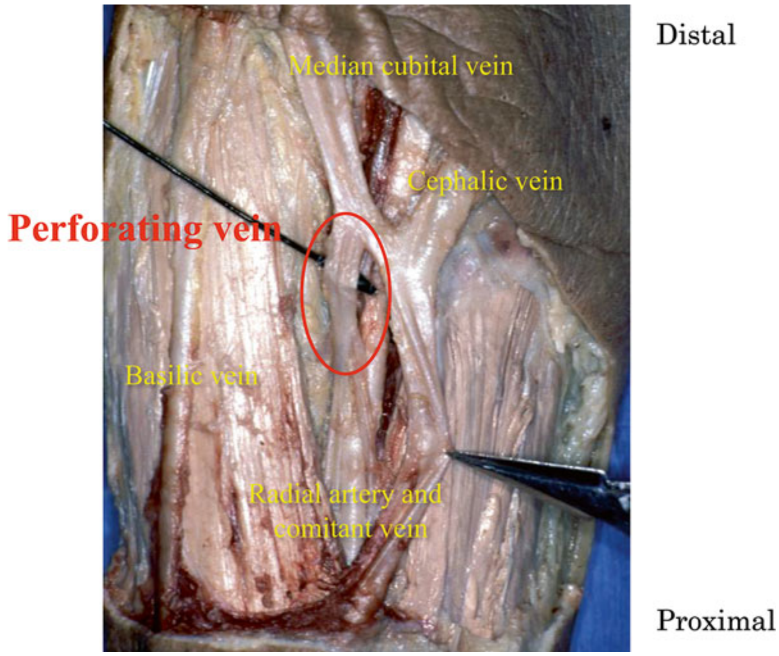


Fig. 9.3 Perforating vein. The perforating vein communicates between the radial comitant and cutaneous venous system

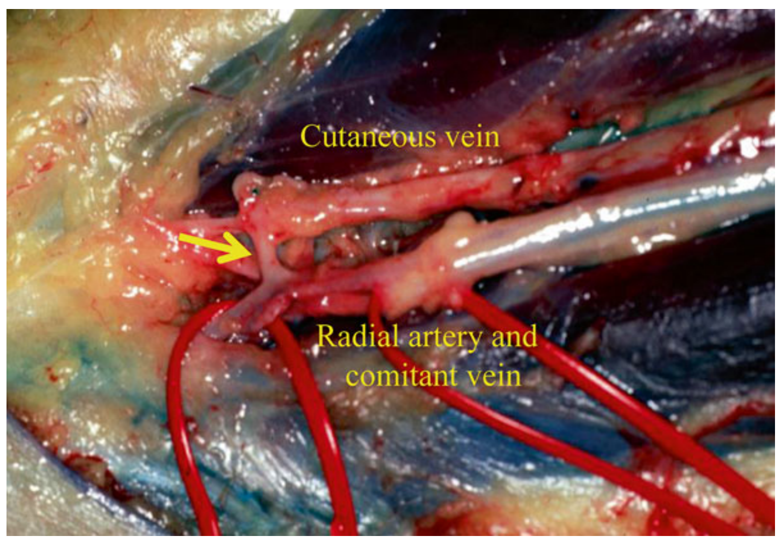


Fig. 9.4 Vascular pedicle of the forearm flap. The *arrow* indicates the perforating vein communicates between two venous systems

comitant veins in the forearm are very thin and not necessarily useful for vascular anastomosis. We have focused on the perforating vein connecting the deep venous and cutaneous venous systems since 1987 and have elevated it included in the vascular pedicle of forearm flaps. The perforating vein is situated anterior to the cubital fossa and is described in the first edition of Grant's Atlas of Anatomy (1943). It branches from the radial comitant vein at a site slightly distal to the bifurcation of the radial and ulnar arteries and joins the medial cubital or radial cephalic vein (Fig. 9.3). The deep venous system comprises the radial comitant vein and comitant vein of the proximal brachial artery. The cutaneous venous system comprises the cephalic, medial cubital, and basilic veins. Thus, the perforating vein connects the deep and cutaneous venous systems (Fig. 9.4).

In conventional elevation of the forearm flap, only one of the two drainage vein systems is used—the cutaneous or deep venous system. By including the perforating vein in the vascular pedicle, however, both systems can be used for drainage through single venous anastomosis. Soutar et al. [11] have pointed out that the two venous systems of the forearm are connected through a vein flowing into the medial cubital vein. In this context, Evans et al. [14] have also pointed out that when the vascular pedicle is dissected at a

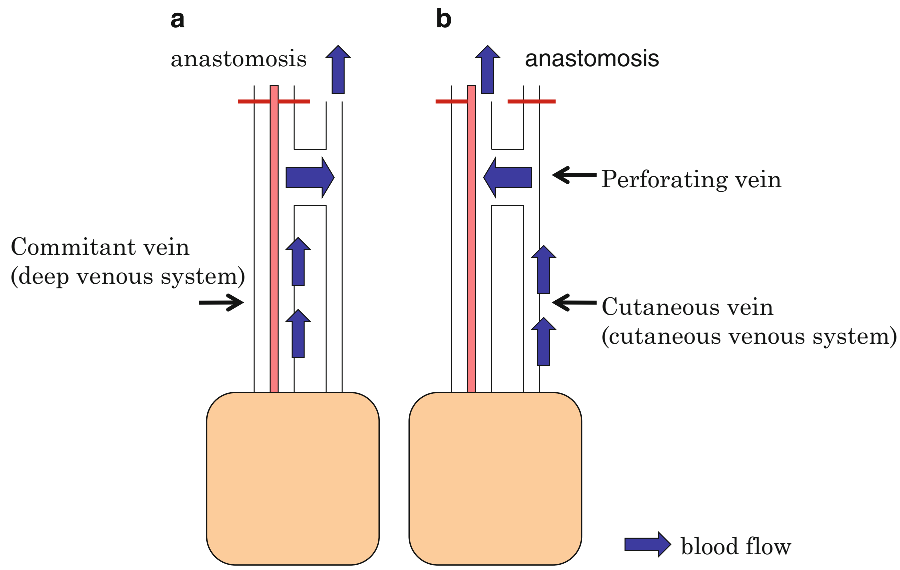


Fig. 9.5 Perforating vein as "oscillating vein." Venous drainage through the two systems is possible by anastomosis of either the cutaneous and deep vein. The absence of venous valve in the perforating vein and its surroundings has been confirmed. The blood flow of the perforating vein may differ between cutaneous and deep vein anastomosis. This corresponds to the "oscillating vein"

site more proximal than at the perforating vein, circulation of the two systems is achieved by a single venous anastomosis. Timmons et al. [15] also have described the anatomical presence of a vein with a large diameter connecting the two venous systems. Thoma et al. [16] have demonstrated that the vena comitans generally joins the cephalic vein through another vein with a large diameter at a site anterior to the cubital fossa: a venous drainage pattern connecting the two venous systems through this other vein has been shown in 65 % of head and neck reconstruction cases with forearm flaps. These anastomosed veins are identical to the perforating vein described by us.

The usefulness of the perforating vein is summarized below. Venous drainage through the two systems is possible by anastomosis of either the cutaneous or deep vein. We have confirmed the absence of a venous valve in the perforating vein and its surroundings. Therefore, blood flow in the perforating vein may differ between cutaneous and deep vein anastomosis (Fig. 9.5). This corresponds to the "oscillating vein" proposed by Taylar et al. [17]. Timmons et al. [15] have demonstrated anatomically that, generally, the direction of venous valves in the comitant vein is determined so as to maintain the direction of blood flow from the deep to the cutaneous venous system, suggesting that this is the standard direction. Accordingly, inclusion of the comitant vein in the drainage system may provide a more advantageous circulatory condition, particularly for initial drainage after reperfusion. We have demonstrated this experimentally [18, 19]. Even when only the cutaneous vein is anastomosed, the perforating vein is capable of maintaining drainage through the comitant vein and reducing congestion of the flap in the initial phase after reperfusion, compared with drainage through only the cutaneous vein. Even when a flap is elevated with the radial artery and vein, excluding the cutaneous vein in the distal forearm, the cutaneous vein with a large diameter in the cubital fossa can be used for vascular anastomosis due to the connection through the perforating vein (Fig. 9.6). For example, women with very thin cutaneous veins difficult to identify and patients with unusable forearm cutaneous veins because of chemotherapy are good candidates for this method.

The drawbacks of this method are: (1) vascular ligation up to the brachial artery and vein is complex, (2) ligation and division of a vein with a large diameter in the cubital fossa may cause edema [16], and (3) a slightly long scar is unavoidable because the skin incision is extended to the cubital fossa.

9.2.1.2 Simple Dressing Technique Using Polyurethane Foam for Fixture of Skin Grafts

Various methods of grafting skin, including tie-over dressing, are used depending on the location, area, and shape of the graft [20–23]. We use polyurethane foam (Allevyn Hydrocellular Dressing® (AHD®), Smith & Nephew, Largo, FL) and polyurethane film (Tegaderm®, 3M, St Paul, MN) to affix a skin graft to the flap-donor region of the forearm. The procedure

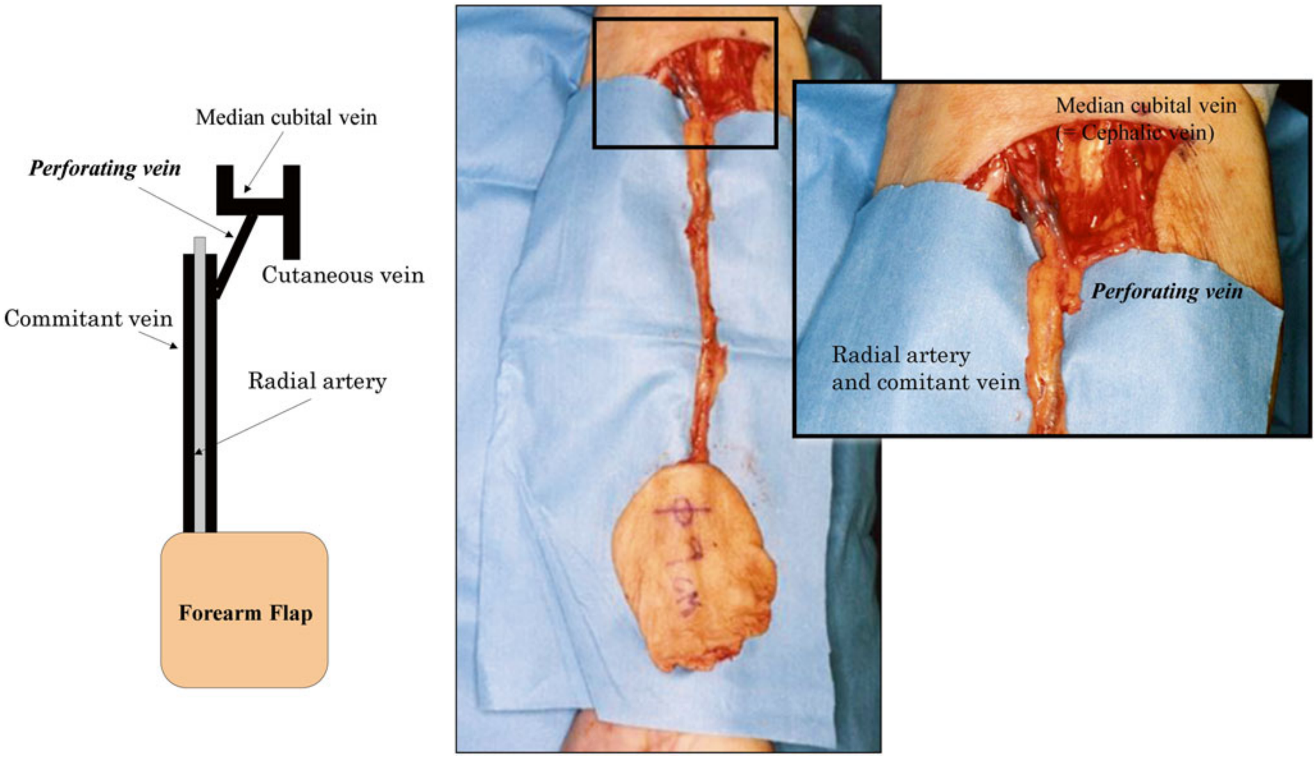


Fig. 9.6 Usefulness of the perforating vein. Even when only the cutaneous vein is anastomosed, the perforating vein is capable of maintaining drainage through the comitant vein (deep venous system). Even when a flap is elevated with the radial artery and vein, excluding the cutaneous vein in the distal forearm, the cutaneous vein with a large diameter in the cubital fossa can be used for vascular anastomosis due to the connection through the perforating vein

comprises four steps: (1), a skin graft is sutured to the wound remaining elevating a forearm flap, and the donor bed is washed well with physiological saline, and a small hole for drainage is made or a quilted suture is used, as needed (Fig. 9.7a), (2) a sheet of polyurethane foam (AHD)® of almost the same size as that of the skin graft is placed over the skin graft and covered with another sheet about 1–2 cm wider (Fig. 9.7b), (3) the two AHD® sheets are affixed with adhesive polyurethane film (Tegaderm®), and (4) the procedure is completed with bandage.

The duration of fixture is the same as that for tie-over dressing, but this is not strictly specified because the fixture can be readily repeated at bedside. When grafting skin to the forearm, heed should be paid to the formation of hematoma and to partial necrosis attributed to overpressure [24, 25]. Favorable grafts are obtained by fixtures at about 10 mmHg [26]. The surface of the wound on the forearm flap-donor region becomes uneven because of exposure of the tendon. Application of even pressure onto the wound surface is difficult, and the conventional method may exert overpressure on convex regions. In our method, elastic AHD exerts appropriate pressure on the graft. Also, since two AHD sheets are tiered, the lower sheet fits the morphology of the skin defect and rules out dead space; the slightly larger upper sheet prevents detachment of the skin graft, and the polyurethane film (Tegaderm®) fortifies the fixture. The region of the skin graft heals flawlessly under a moist healing condition, and the postoperative treatment period is short (Fig. 9.7c).

9.2.1.3 Reflex Sympathetic Dystrophy After Free Radial Forearm Flap Elevation

Reflex sympathetic dystrophy (RSD) is an intractable chronic pain syndrome whereby persistent pain, edema, and abnormal sweating develop after trauma and surgery, mainly in the injured region, and the tissue finally atrophies [27]. Clinical symptoms are observed over the entire upper limb of the forearm flap-donor region—a complication after elevating a forearm flap—to which due attention should be paid.

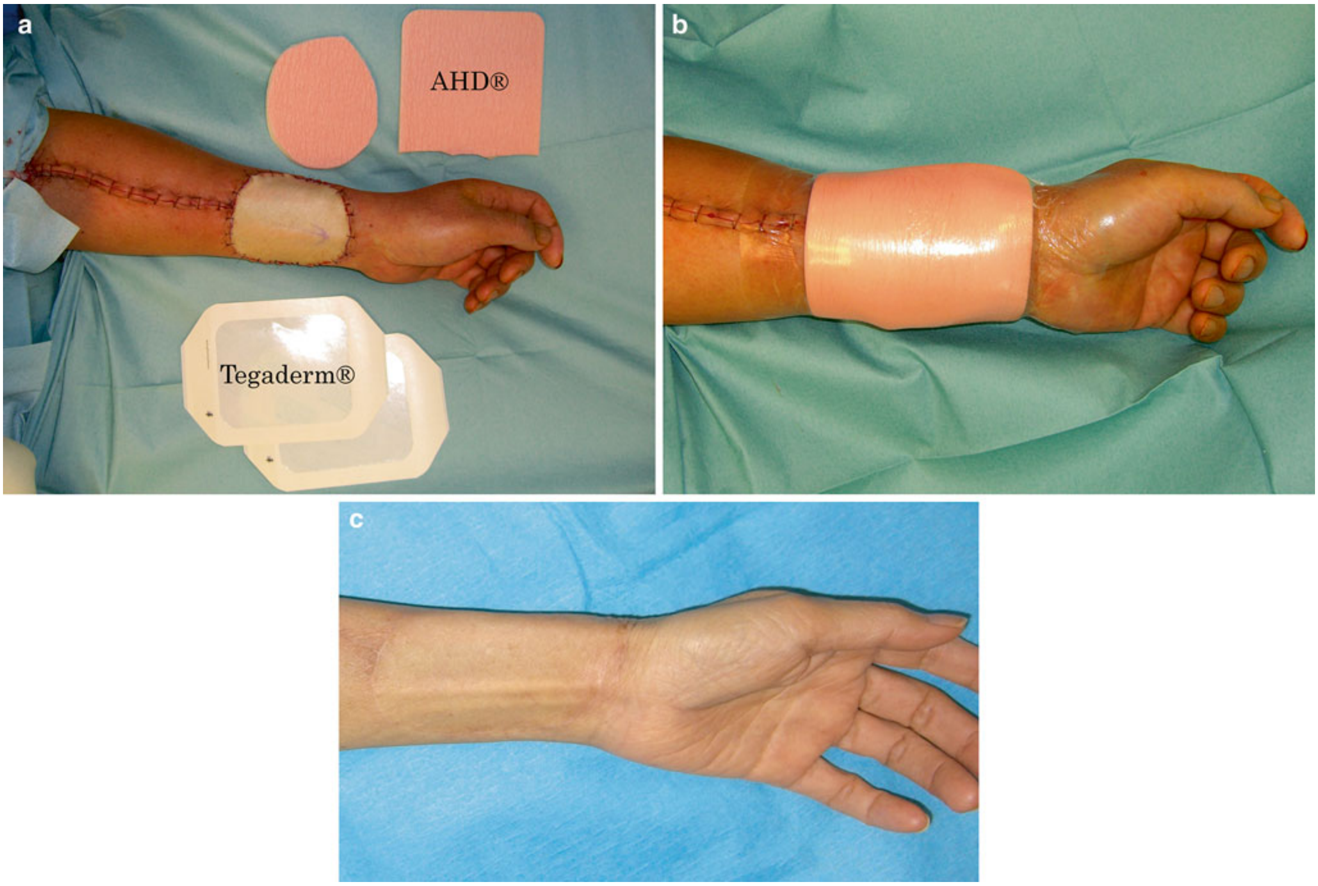


Fig. 9.7 Surgical procedure using polyurethane foam for fixture of skin graft. (**a**) The skin graft is fixed with 5-0 nylon suture and two sheets of polyurethane foam (AHD®) are placed on the skin graft: the first is one of the same size as the graft, and the second is one size larger to overlap by 1–2 cm the edges of the first sheet. (**b**) The ADHs are fixed with adhesive polyurethane film (Tegaderm®). Dressing is simple and easy without an assistant. The same procedure can be repeated at any time. (**c**) The region of the skin graft heals flawlessly, under a moist healing condition, and the postoperative treatment period is short

In the patient presented here, numbness and spontaneous pain developed mainly in the flap-donor region about 3 months after surgery (Fig. 9.8a, b). The range of symptoms gradually increased, and skin redness and edema appeared throughout the upper left limb about 6 months after surgery. One year after surgery, the patient developed a severe burning sensation throughout the limb induced by even a slight touch of clothing in the area, and then pain began to radiate to the left shoulder (Fig. 9.8c). Diagnosed with RSD at the Department of Anesthesia, the patient was treated with stellate ganglion block with 6 ml of 1 % lidocaine 3–4 times a month at a pain clinic. Skin redness and edema of the forearm remitted after 20 cycles of the treatment and were mostly resolved after 40 cycles (about 1 year)

In artificial synapse formation, a theory of the developmental mechanism of RSD, a synapse is artificially formed between nerve fibers in an injured peripheral nerve region, and sympathetic distal impulses are transmitted as pain to pain-transmitting fibers [28]. In this patient, an artificial synapse may have formed between the lateral antebrachial cutaneous nerve and the superficial branch of the radial nerve in the injured region of the forearm, inducing pain. Clinical diagnosis of RSD is based on a score established by Gibbons et al. [29] (Table 9.1). The patient's score was 5 based on the symptoms of pain hypersensitivity, burning sensation, skin color tone, and fluctuations in skin temperature, leading to our diagnosis of RSD. The principle of the management of RSD is early diagnosis and treatment, especially that progression to the chronic phase makes recovery difficult by any method of treatment. For RSD of the upper limbs, stellate ganglion block is the most effective. Edema and color change associated with the sympathetic nerve may be improved by

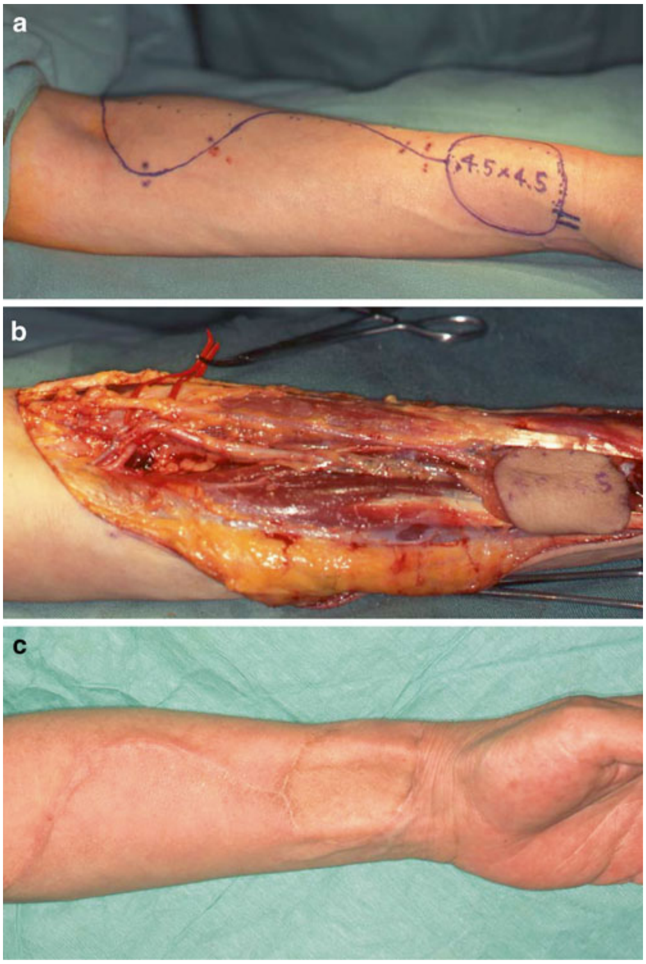


Fig. 9.8 A case of RSD after forearm flap elevation. (**a**) Design of forearm flap. (**b**) Elevation of forearm flap: lateral antebrachial cutaneous nerve and superficial branch of the radial nerve were resected in this case. (**c**) Severe burning sensation and tenderness were found at the left forearm, which rapidly spread to the upper limb after surgery

Table 9.1 RSD score

1. Allodynia or hyperpathia	1.0
2. Burning pain	1.0
3. Edema	0.5
4. Color or hair growth change	1.0
5. Sweating change	0.5
6. Temperature change	0.5
7. Radiographic change (demineralization)	0
8. Quantitative measurement of vasomotor/sudomotor disturbance	0
9. Bone scan consistent with RSD	0
10. Response to sympathetic block	0.5

For each criterion, the patient was assigned one point of positive, half-points for equivocal, and no points if the criterion was negative or not mentioned. Patients with a total RSD score of <3 were considered not to have RSD. Those with a score of 3–4.5 were considered possible RSD patients. Those with scores of ≧5 were considered probable RSD patients [21]

stellate ganglion block, but peripheral nerve block has in some studies been described as more effective.

9.2.2 Vascularized Free Rectus Abdominis Musculocutaneous Flap in the Oromandibular Region in Terms of Efficiency of the Anterior Rectus Sheath

The anterior rectus sheath is one of the firm lateral abdominal aponeuroses of the abdominal external oblique muscle. The efficiency of the sheath in reconstructive surgery has been demonstrated in the repair of full-thickness right ventricular defects after mediastinitis or sternal dehiscence [30], in the treatment of bronchopleural fistulas complicated by empyema [31], in pleural reconstruction of the chest wall [32], dural reconstruction [33], and breast reconstruction after subcutaneous mastectomy [34]. We have utilized this sheath in oromandibular reconstruction with the vascularized free rectus abdominis musculocutaneous flap (RAM). The RAM is effective in the maintenance of the formed bulge of the oral floor, prevention of the sinking of the reconstructed tongue, and prevention of the exposure of reconstruction plates after the resection of the mandibular continuity. Therefore, we consider that RAMs are absolutely indicated for these types of reconstruction (Table 9.2). As is important, the muscle attached to the rectus sheath is harvested with a 3- to 4-cm extension superiorly and inferiorly (Fig. 9.9). Extensive resection of the anterior rectus sheath caused no problems.

In the preparatory phase of swallowing, the tongue margin and the oral floor elevate, retaining the alimentary bolus in the oral cavity with glossopalatal closing function [35] (Fig. 9.10). In reconstructive flaps, however, this function is impaired: the bolus on the reconstructed oral floor cannot be moved to the dorsum of the tongue. When the oral floor is reconstructed with a thin flap, as with a forearm flap to reform it to the pre-resection state, a wide depression results, where saliva and food residues become awkwardly trapped. This makes smooth food transfer difficult, causing a time lag between glossopalatal closure and bolus transfer, as well as mistimed swallowing as a whole resulting in misswallowing [36]. For an efficient swallowing function, it is essential to raise the oral floor to a height similar to that of the tongue margin, thereby forming the preparatory phase of swallowing statically. In other words, the nonfunctioning oral floor should not be depressed. Even when the bulge of the floor is formed with thick and bulky reconstructive materials, like the musculocutaneous flap, the cutaneous and muscular portion, in time, generally sags because of gravity, resulting

Table 9.2 Purpose and devices of reconstruction with RAM

Resection procedure of primary tumor	Purpose of reconstruction	Device
Resection of the oral floor with hemiglossectomy	Preservation of swallowing	*Hammock technique*[a]
Total resection of the mobile tongue or more extensive resection	Preservation of swallowing and articulation	Money-pouch-like reconstruction[b] + *hammock technique* + cricopharyngeal myotomy + laryngeal suspension[c] + neuroanastomosis[d]
Resection of the mandibular continuity with oral defect	Prevention of reconstruction plate exposure	*Reinforcement of the muscular portion*

Italics: reconstruction on devices with anterior rectus sheath

[a]Mylohyoid muscle-like structure was reconstructed by attaching the anterior rectus sheath to the anterior and posterior mandible and hanging it in a hammock pattern

[b]Reconstructed tongue was rounded and markedly raised like a money pouch

[c]Fixation with mandible, hyoid bone, and thyroid cartilage

[d]Neuroanastomosis with the tenth intercostal and the hypoglossal nerves

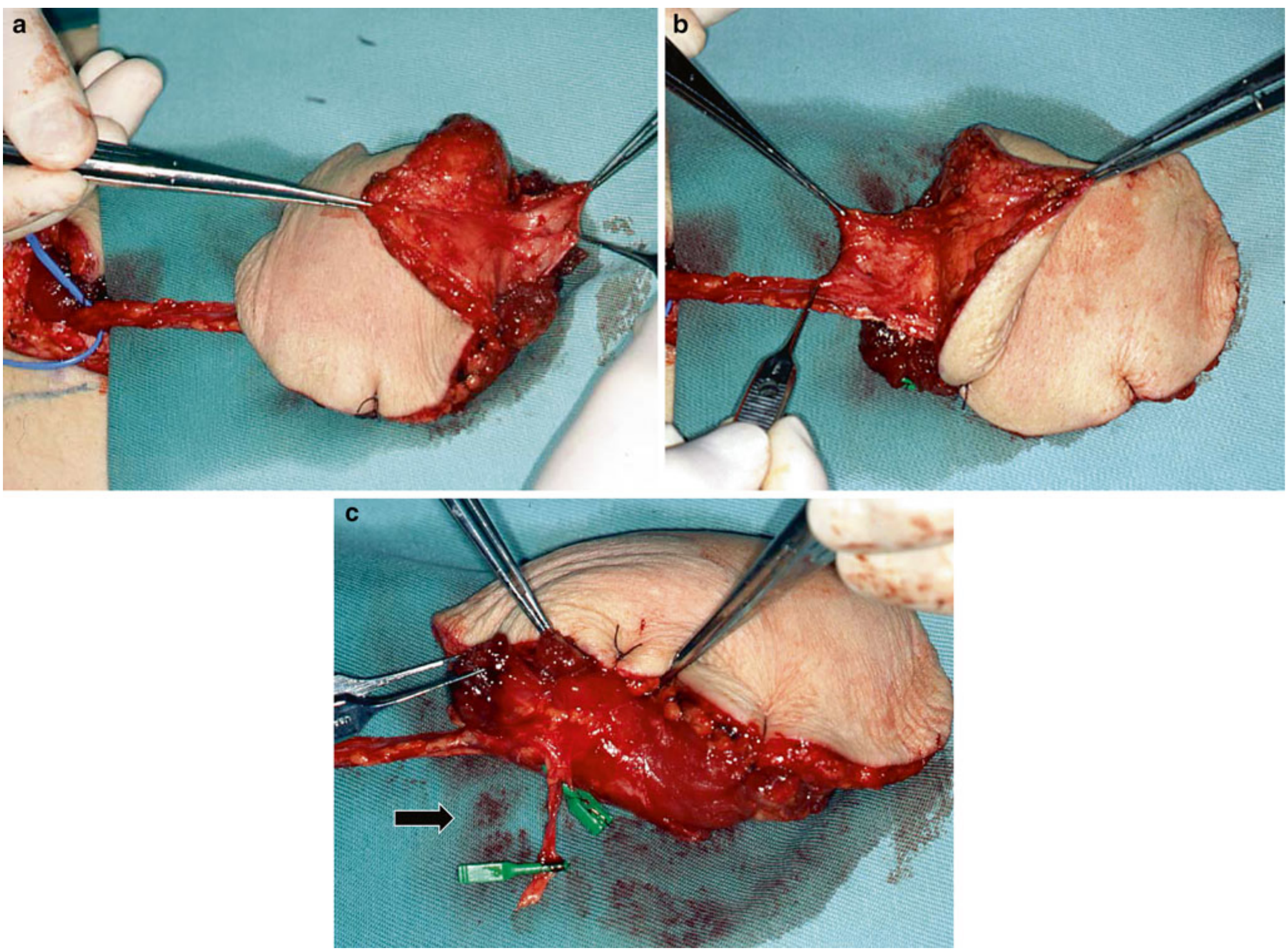


Fig. 9.9 Preparation of anterior rectus sheath and tenth intercostal nerve. Raising the RAM is designed so that the center of the flap is positioned at the paraumbilical region. The rectus sheath is obtained with proximal and distal extensions of about 3–4 cm each, which is particularly important to attain the final goal of reconstruction with the sheath (**a**, **b**). When the intercostal nerve is used in reconstruction, the tenth intercostal nerve as a motor nerve of the lower abdominal rectus abdominis muscle is carefully distinguished from the paraumbilical region (*arrow*: the tenth intercostal nerve) (**c**)

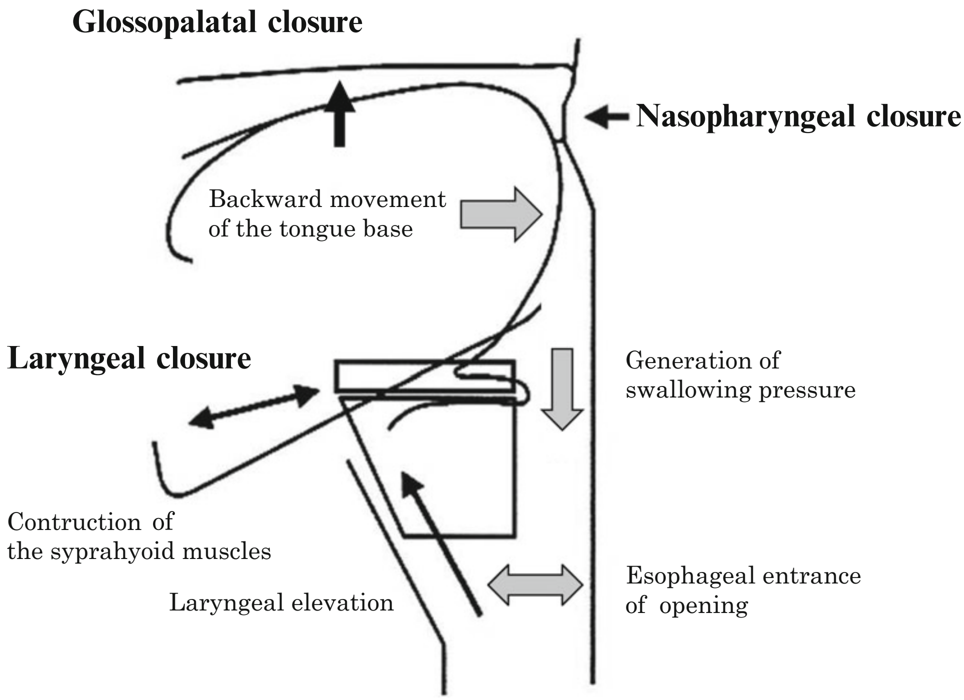


Fig. 9.10 Ideal static reconstruction of the oral and the pharyngeal phase of swallowing

in the depression of the oral floor. Therefore, we developed a method of forming the mylohyoid muscle-like tissue by fixing the anterior rectus sheath anteriorly and posteriorly to the mandibular areas in a hammock pattern. This protects the muscle from the influence of gravity, allowing the maintenance of the bulge and preventing the sinking of the reconstructed oral floor and tongue. We have termed this method *the hammock technique*, where a musculocutaneous flap with a firm anterior sheath is indispensable and where RAM is the optimal material. Although the mylohyoid muscle attaches to the hyoid bone, and elevates the oral floor and hyoid bone, in reconstructive surgery, the anterior sheath is not fixed at the hyoid bone because recovering the function by elevating the reconstructed oral floor is not possible even if such fixation is done. Conversely, fixation to the hyoid bone results in flap pulling and, consequently, in hindering the formation of the bulge of the reconstructed oral floor and the raising of the reconstructed tongue by the money-pouch-like reconstruction [37] (Figs. 9.11 and 9.12)

After total resection of the mobile tongue or more extensive resection, it is essential for the purpose of generating swallowing pressure to build the reconstructed tongue with height and roundness, to make the oropharyngeal space narrow, to provide the glossopalatal closing function, to maintain the mobility of the tongue base, and to avoid forming a gap to the posterior pharyngeal wall (Fig. 9.10). To achieve this outcome, the following techniques are essential: (1) *the hammock technique* (the bulge of the reconstructed oral floor is maintained, and the depression of the reconstructed tongue is prevented), (2) *the money-pouch-like reconstruction method* [37] (the tongue is reconstructed to give it height and roundness), (3) *neuroanastomosis* [35] [38] (the reinnervated muscle is used to maintain the bulk of the muscular portion of the RAM), (4) *cricopharyngeal myotomy*, and (5) *resection of the infrahyoid muscles* and *thyroid cartilage/hyoid bone/mandible fixation*. With these serial reconstruction procedures, the anatomical and functional structures of swallowing from the preparatory phase to the pharyngeal phase are statically reconstructed. Therefore, the residual tissues easily assist in the swallowing function.

In reconstruction after the resection of the mandibular continuity with oral defects, vascularized free osteocutaneous flaps are usually the first choice. When bone reconstruction is not possible because of insufficient conditions, however, mandibular continuity is restored with a reconstruction plate. The muscular portion and the anterior sheath are wrapped around the plate, whereby the anterior rectus sheath firmly reinforces the muscular portion. The flap margin is deepithelialized and submucosally inserted into the oral cavity; consequently the sheath on the muscular portion is further reinforced by the dermis. We term this method *the wrap-around technique* for mandibular reconstruction. To date, plate exposure has not been observed in any of the

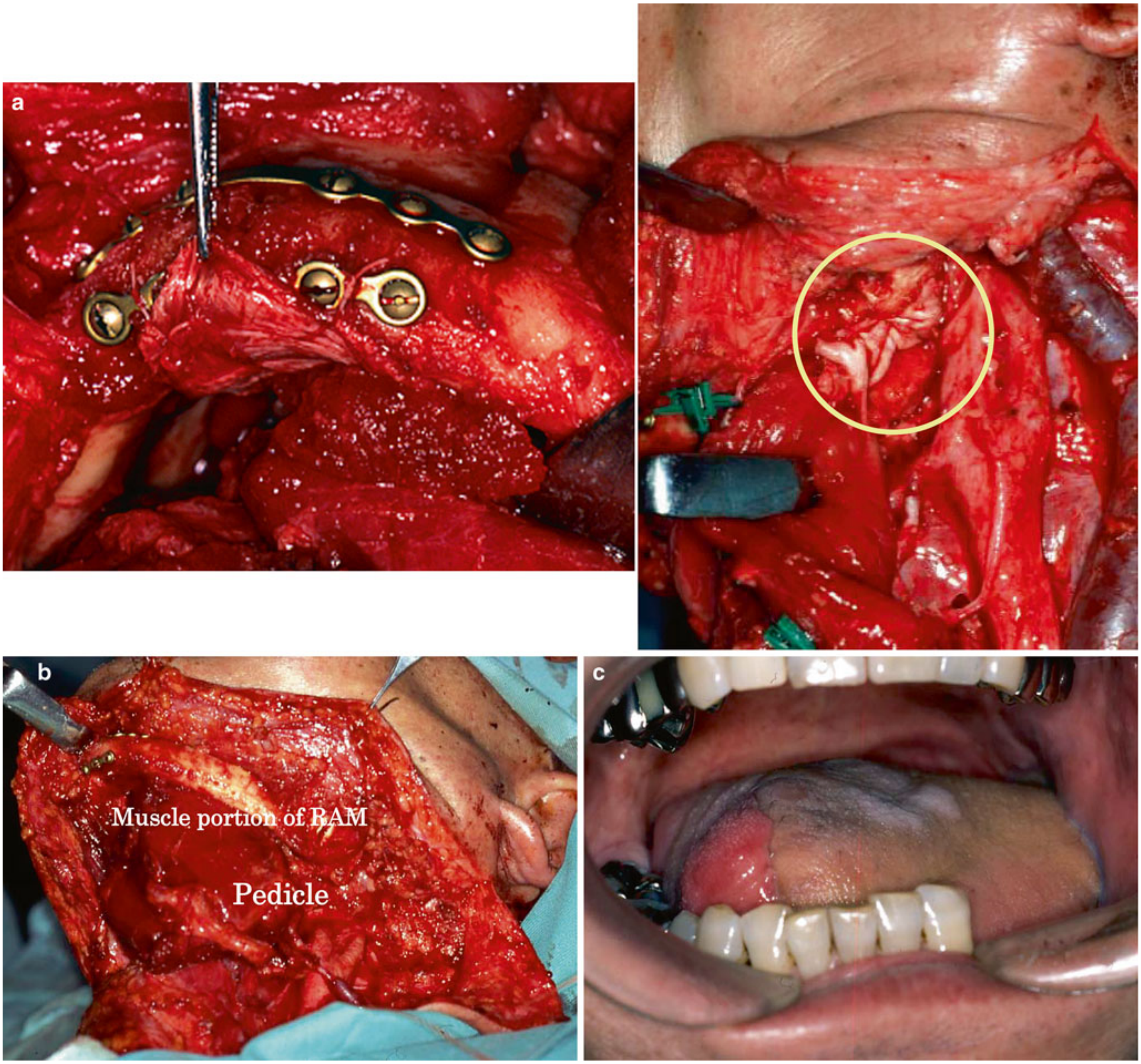


Fig. 9.11 Reconstruction after resection of oral floor with hemiglossectomy. A 67-year-old man with squamous cell carcinoma of the left oral floor (T3N1M0) underwent resection of the oral floor with hemiglossectomy and right radical neck dissection. *Hammock technique*: the anterior rectus sheath was fixed anteriorly and posteriorly to the mandible and hung in a hammock pattern (**a**, *round*: mandibular angle), forming a mylohyoid muscle-like structure (**b**). Simultaneously, the oral floor was reconstructed to form a bulge. Seven years after the operation, the bulge of the reconstructed oral floor was maintained without gravity-induced depression (**c**)

patients who underwent the procedures of this technique with the anterior rectus sheath (Fig. 9.13). After primary reconstructive surgery, usually 6 months thereafter, secondary generative mandibular reconstruction was carried out by implanting titanium mesh and particulate cancellous bone and marrow (PCBM) in the mandibular defect. A 3D model was prepared from CT images, and the mandibular morphology on the healthy side was reproduced in the defective side using the titanium mesh as a scaffold. PCBM collected from the posterior iliac crest was then buried in the rectus abdominis muscle. New bone formation was usually confirmed 3 months after the surgery, and regenerative mandibular reconstruction was completed in the next 6 months (Fig. 9.14).

Alternative to the muscle sheath alone, the tensor fascia lata flap may also serve as material for these reconstructions

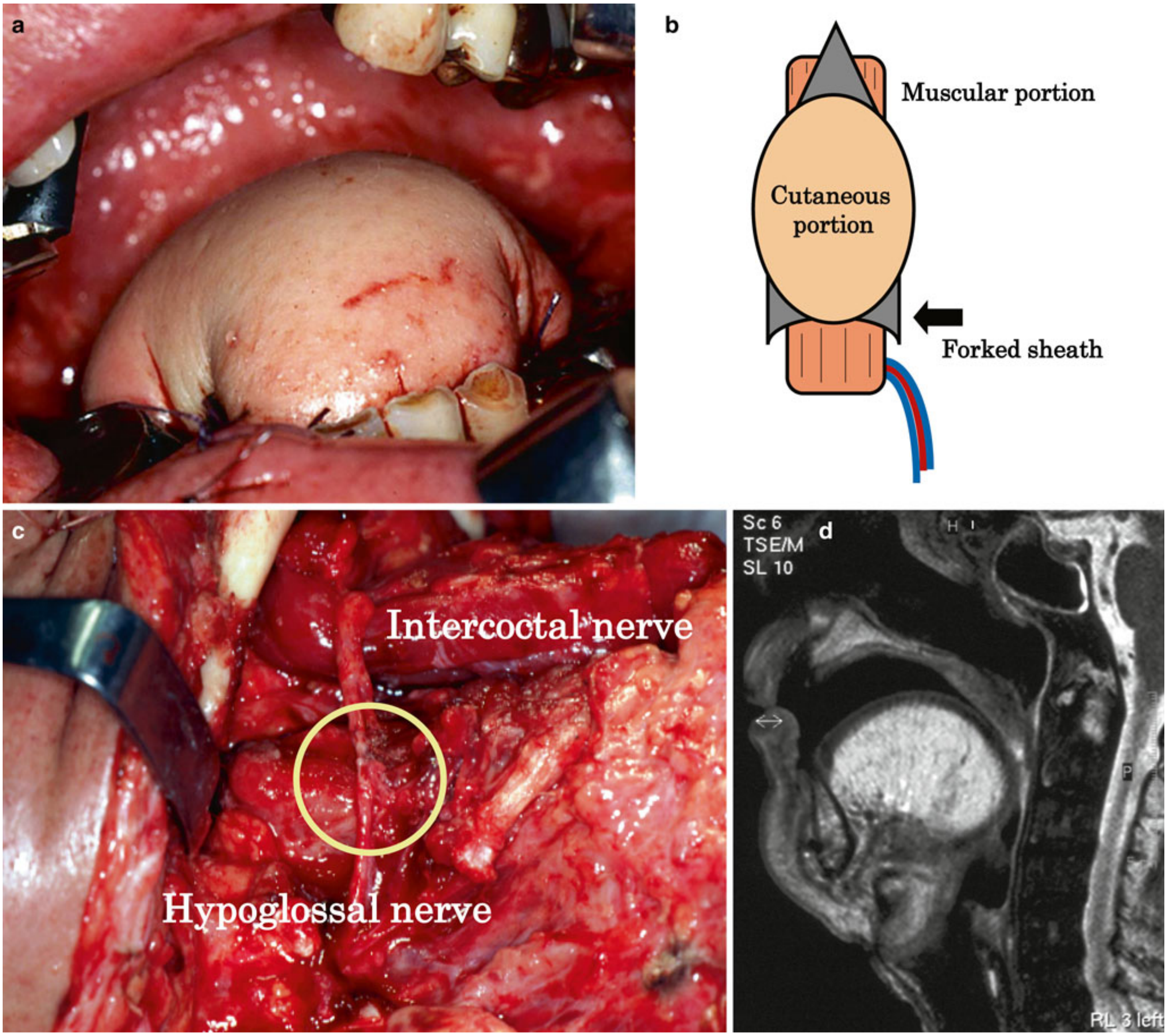


Fig. 9.12 Reconstruction after total glossectomy. A 51-year-old man with advanced squamous cell carcinoma of the right tongue (T3N2cM0) underwent total glossectomy and bilateral radical neck dissection. *Money-pouch-like reconstruction*: the reconstructed tongue was rounded and markedly raised by the money-pouch-like reconstruction method. This technique gave the reconstructed tongue glossopalatal closing, and the mobility of the tongue base was preserved (**a**). *Preparation of the proximal anterior rectus sheath*: the anterior rectus sheath was fixed anteriorly and posteriorly to the mandible, in a hammock pattern, to form a mylohyoid muscle-like structure and to prevent flap sinking. Since the posterior area is sutured to the bilateral sides of the molar areas, the sheath should be prepared in a *forked shape* (**b**). *Neuroanastomosis*: the intercostal nerve is anastomosed to the hypoglossal nerve to reinnervate the rectus abdominis muscle and to prevent fatty degeneration and atrophy (*round*: neuroanastomosis) (**c**). MRI after 6 months showing the absence of flap sinking of fatty degeneration and of atrophy of the rectus abdominis muscle (**d**)

[39]; however, RAM appears to be the most efficacious in terms of the facility of flap elevation, the wide caliber and long length of the pedicle, the flexibility of the cutaneous portion (especially, the application to three-dimensional reconstruction), and the maintenance of the bulk of the muscular portion by reinnervation.

9.2.3 Double Pedicled (DOP) and Supercharged (SUP) Pectoralis Major Musculocutaneous Flap

Although free tissue transfer is the preferred reconstruction option in most major oral and maxillofacial reconstructions, the pectoralis major musculocutaneous (PMMC) flap is

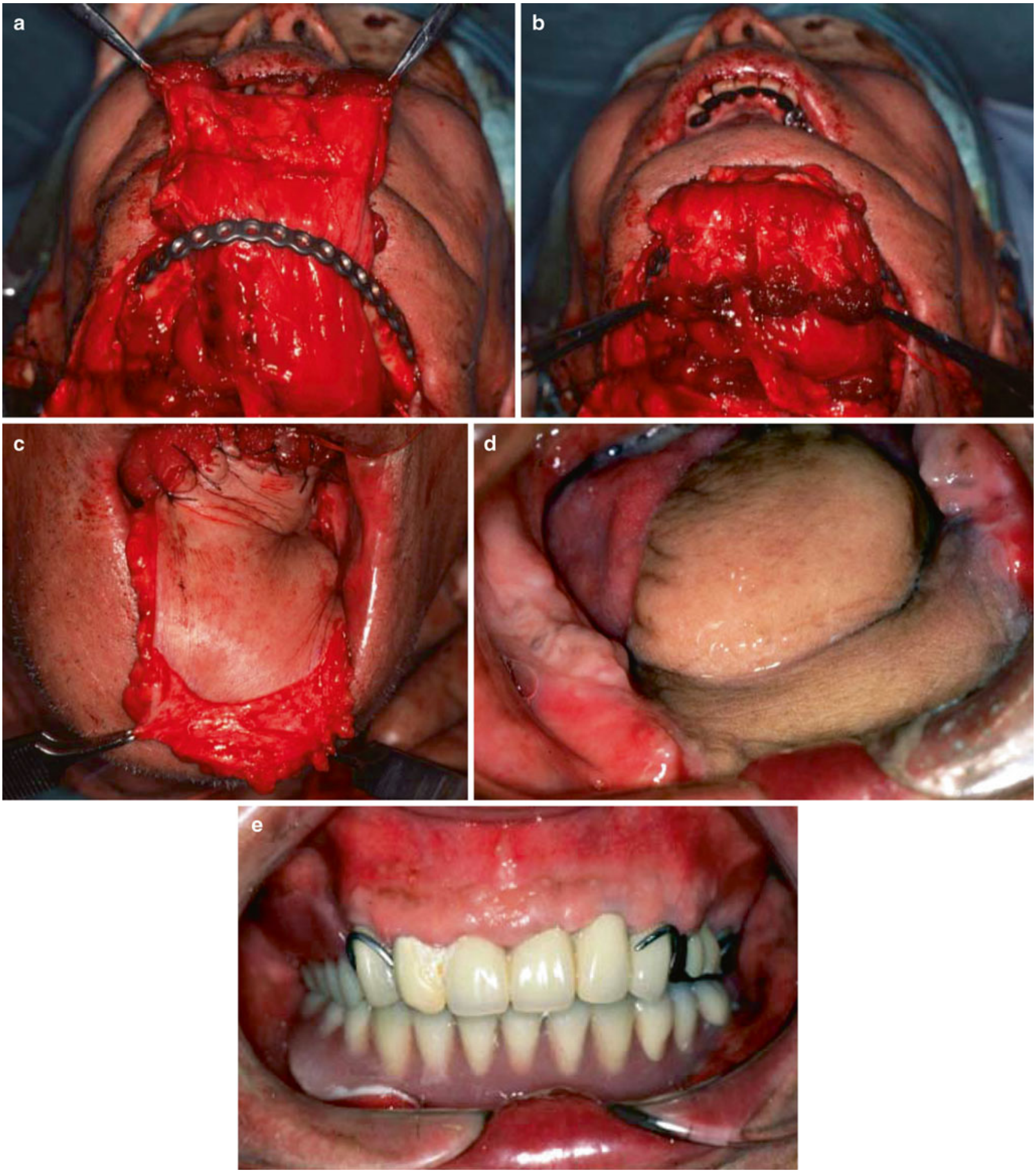


Fig. 9.13 The wrap-around technique for mandibular reconstruction. A 65-year-old man with squamous cell carcinoma of the left oral floor (T4N2bM0) underwent resection of the tumor, anterior hemoglossectomy, resection of the anterior mandibulectomy, and left radial and right supraomohyoid neck dissection. The muscular portion with the anterior rectus sheath was wrapped around the reconstruction plate. The anterior rectus sheath firmly reinforced the muscular portion (**a**, **b**). The flap margin was deepithelialized and submucosally inserted into the oral cavity, by which the sheath on the muscular portion was further reinforced by the dermis (**c**). No plate exposure was observed 4 years after operation (**d**). After mandibular denture application, masticatory function recovered (**e**)

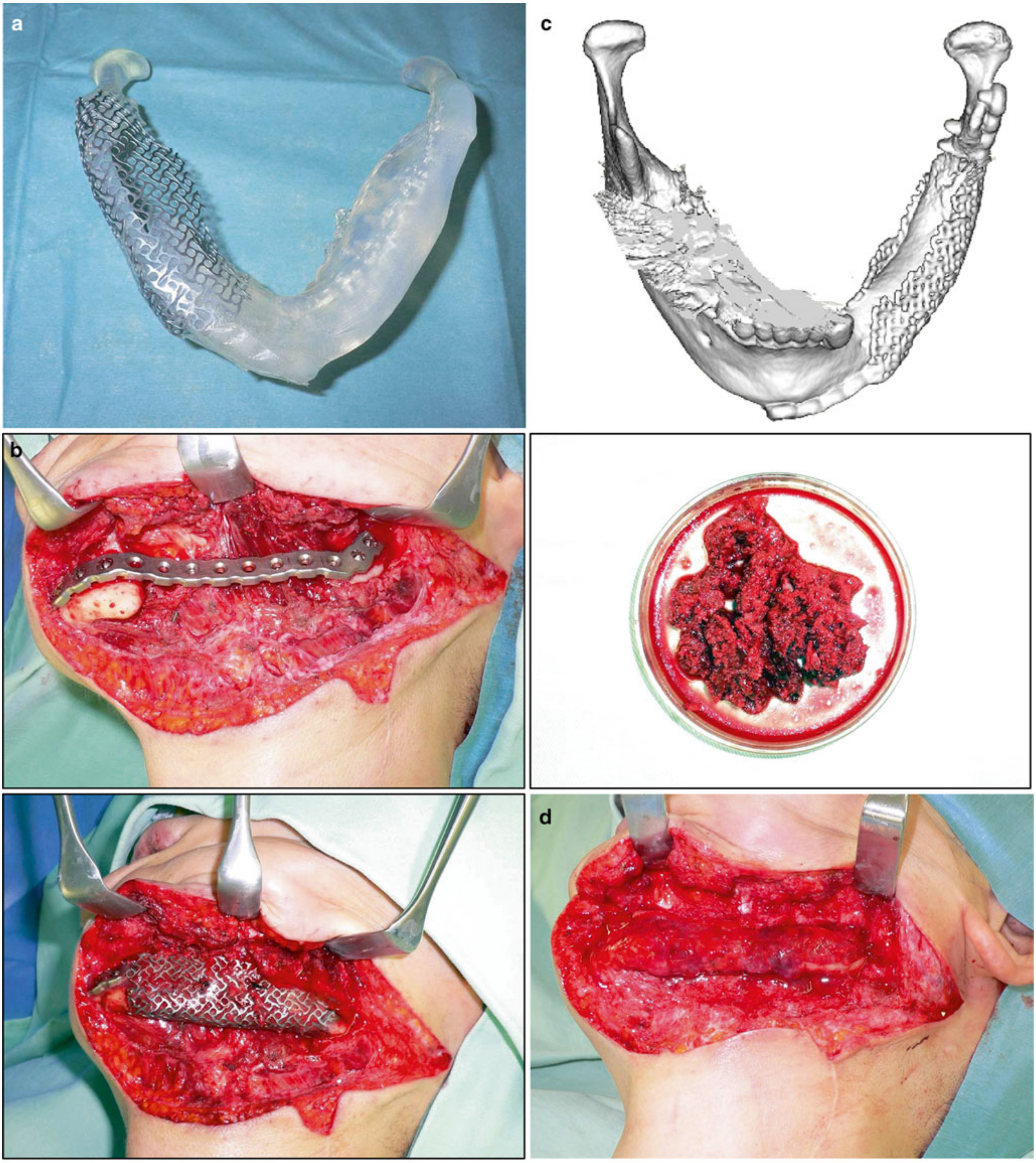
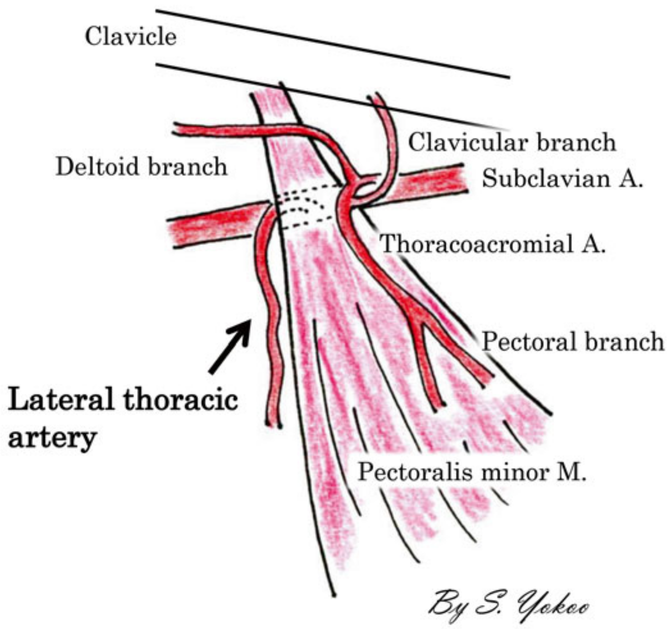


Fig. 9.14 Regenerative mandibular reconstruction. (**a**) A 3D model was prepared from CT images, and the mandibular morphology on the healthy side was reproduced in the defective side using the titanium mesh as a scaffold. (**b**) PCBM collected from the posterior iliac crest was buried in the rectus abdominis muscle. (**c**) New bone formation was confirmed 3 months after surgery. (**d**) Regenerative mandibular reconstruction was completed in the next 6 months

commonly used in the salvage of necrotic free flaps and is the first choice for patients who are not candidates for free flaps. The PMMC flap has a high incidence of distal skin necrosis, however, because of vascular insufficiency resulting in partial to total flap loss and fistula formation [40]. The pectoral branch of the thoracoacromial artery is the main blood supply to the skin island overlaying the upper part of the pectoralis major muscle. The lateral thoracic artery and the anterior



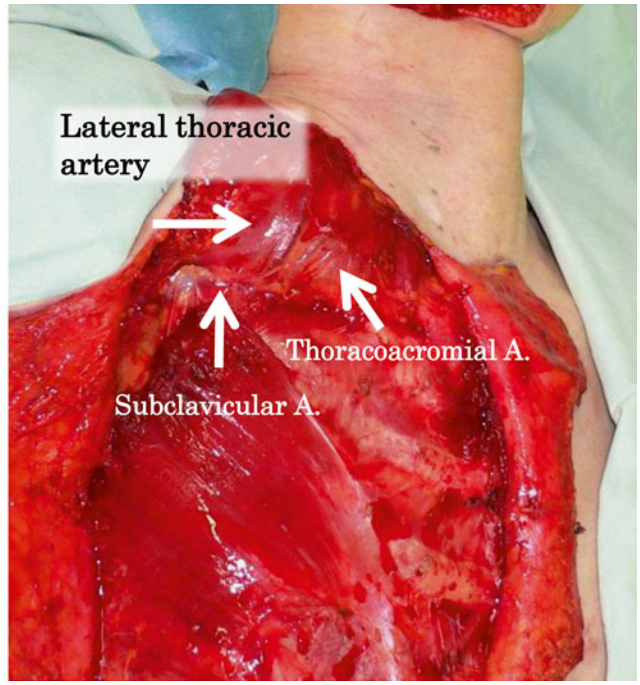


Fig. 9.15 Vascular anatomy of pectoralis major muscle. The thoracoacromial axis classically divides into four main branches: the clavicular, deltoid, pectoral, and acromial arteries. The lateral thoracic artery may also arise from this system, but, more commonly, branches out separately from the axillary artery. The thoracoacromial artery commonly divides into two major branches: the pectoral and deltoid. The acromial and clavicular arteries variably arise from either division. The deltoid arteries run in the deltopectoral groove with the cephalic vein, supplying both the pectoralis major and deltoid. It gives off a cutaneous perforator in the midpoint of the deltopectoral groove. The acromial branch contributes to a vascular plexus along with branches from the deltoid, suprascapular, and posterior humeral circumflex vessels. The clavicular branch runs a cephalad and medial course toward the sternoclavicular joint. The pectoral branch pieces the clavipectoral fascia and then runs a cephalocaudal course on the deep surface of the pectoralis major muscle, which it supplies

intercostals branches of the internal mammary artery supply the skin region overlaying the lower part of the pectoralis major muscle [41–43]. The skin island must be designed in the lower chest to attain a pedicle length sufficient for oral and maxillofacial reconstruction. In the conventional harvesting method for oral and maxillofacial reconstruction, the lateral thoracic artery and all intercostal branches from the internal mammary vessel are cut to avoid compromise of arc of rotation of the flap. The dissections of these two dominant sources of blood supply to the skin island overlaying the lower PMMC flap poses a high risk of distal flap necrosis. The PMMC flap preserves the lateral thoracic vessels in addition to the pectoral branches of the thoracoacromial artery and is, therefore, a very valid choice from the viewpoint of blood supply [41, 44] (Fig. 9.15). Cadaver dissection has also shown that the lateral thoracic artery is a more dominant pedicle of the PMMC flap than the pectoral branch of the thoracoacromial artery in approximately 6 % of all cases studied. This percentage was very close to the total rate of skin necrosis of PMMC flaps [45]. Dissecting the lateral thoracic artery as a routine harvesting technique in such cases could result in total loss of the pectoralis major skin flap.

A skin island designed in the lower chest to reach the oral and maxillofacial defect includes the fourth intercostal perforating branches [43]. The muscle is elevated from the chest wall inferiorly to superiorly. The pectoral branch of the thoracoacromial artery is included in the flap as in the conventional harvesting method of the PMMC flap. The lateral thoracic artery, identified underneath the lateral border of the pectoralis muscle in the region of the maxilla, comes out underneath the lateral border of the pectoralis minor muscle and enters the lateral part of the pectoralis major muscle [46]. The pectoralis minor muscle overlying the lateral thoracic artery is dissected completely to release the lateral thoracic artery up to the clavicle [42]. The lateral thoracic vessels are kept pedicled, not cut, if the length of the pedicle is not compromised. This is called "double pedicled pectoralis major musculocutaneous flap" or "DOP-PMMC flap." Lateral thoracic vessels should be preserved with the pedicle, not dissected, when the length of the pedicle is not compromised in oral and maxillofacial reconstruction; the flap could reach the oral cavity without limitation, when the pectoralis minor muscle is completely dissected. Compromise of pedicle length is often experienced, especially when wrapping the muscle of the PMMC flap around the titanium reconstruction plate used in segmental mandibulectomy (*wrap-around procedure*), even when the pectoralis minor muscle is completely dissected. The compromise may be due to the long distance between the thoracoacromial artery and the lateral thoracic at the bifurcation of the subclavian artery, to the short length of the lateral thoracic artery from the bifurcation of the subclavian artery to the point of entry into the pectoralis major muscle, or to the constitution of the patient—a long neck compared with the chest. In such cases, the lateral thoracic vessels are cut at the bifurcation of subclavian vessels, and then microvascular anastomosis is carried out between lateral thoracic vessels and the transverse cervical artery and external jugular vein. We named our new procedure "supercharged pectoralis major musculocutaneous flap (SUP-PMMC flap)." Thus, the lateral thoracic artery is preserved without any compromise of pedicle length, which takes into consideration the blood supply of the lower part of PMMC flaps. Lateral thoracic vessels are suitable for microvascular anastomosis as described for the free lateral thoracic flap and for the lateral thoracic perforator flap [47, 48]. It should be noted that a deficit of the lateral thoracic artery has been reported in approximately 15 % of cases [47, 49]. Although we have not been able to fully resolve the issue of compromised distal skin blood supply because of the necessity of dissecting the branches of the internal mammary artery, it is worthwhile to preserve the lateral thoracic vessel that is the major contribution to the lateral and distal PMMC flap (Fig. 9.16).

9.2.4 Platysma Flap and Cervical Island Flap

The application of a cervical skin flap to oral and cervical defects, subject of many reports, was initially described as "the apron flap" by Ward et al. in 1950 [50]. In 1969, Farr et al. [51] have described a similar flap as a cervical island skin flap. In both studies, blood circulation is described as

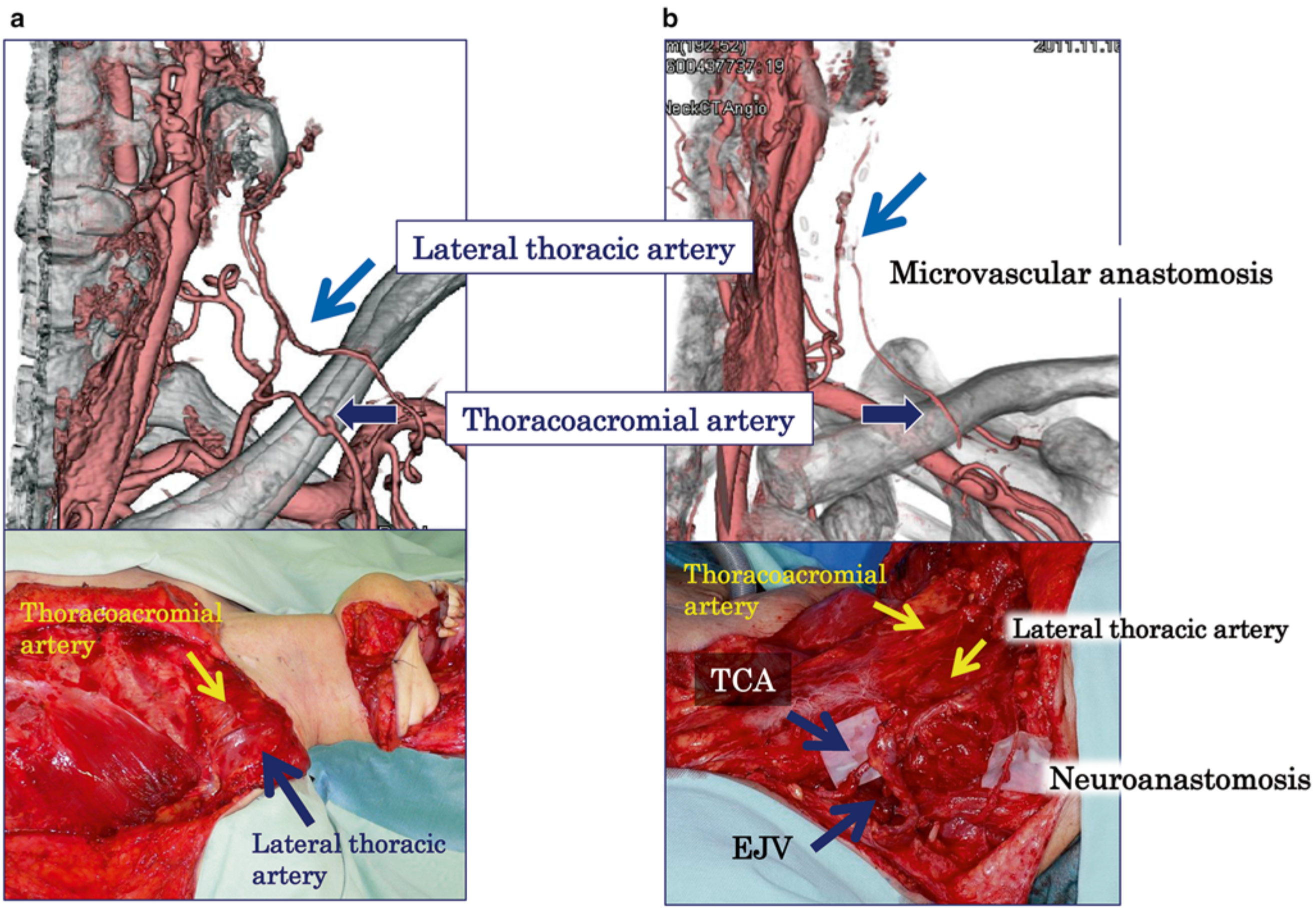


Fig. 9.16 Computer tomographic angiography of DOP- and SUP-PMMC flap. Computer tomographic angiography shows the lateral thoracic artery and pectoral branch of the thoracoacromial artery of DOP- (**a**) and SUP-PMMC flap (**b**) one year after surgery. The great auricular nerve is also anastomosed to the medial pectoral nerve to prevent muscle atrophy. *TCA* transverse cervical artery, *EJV* external jugular vein

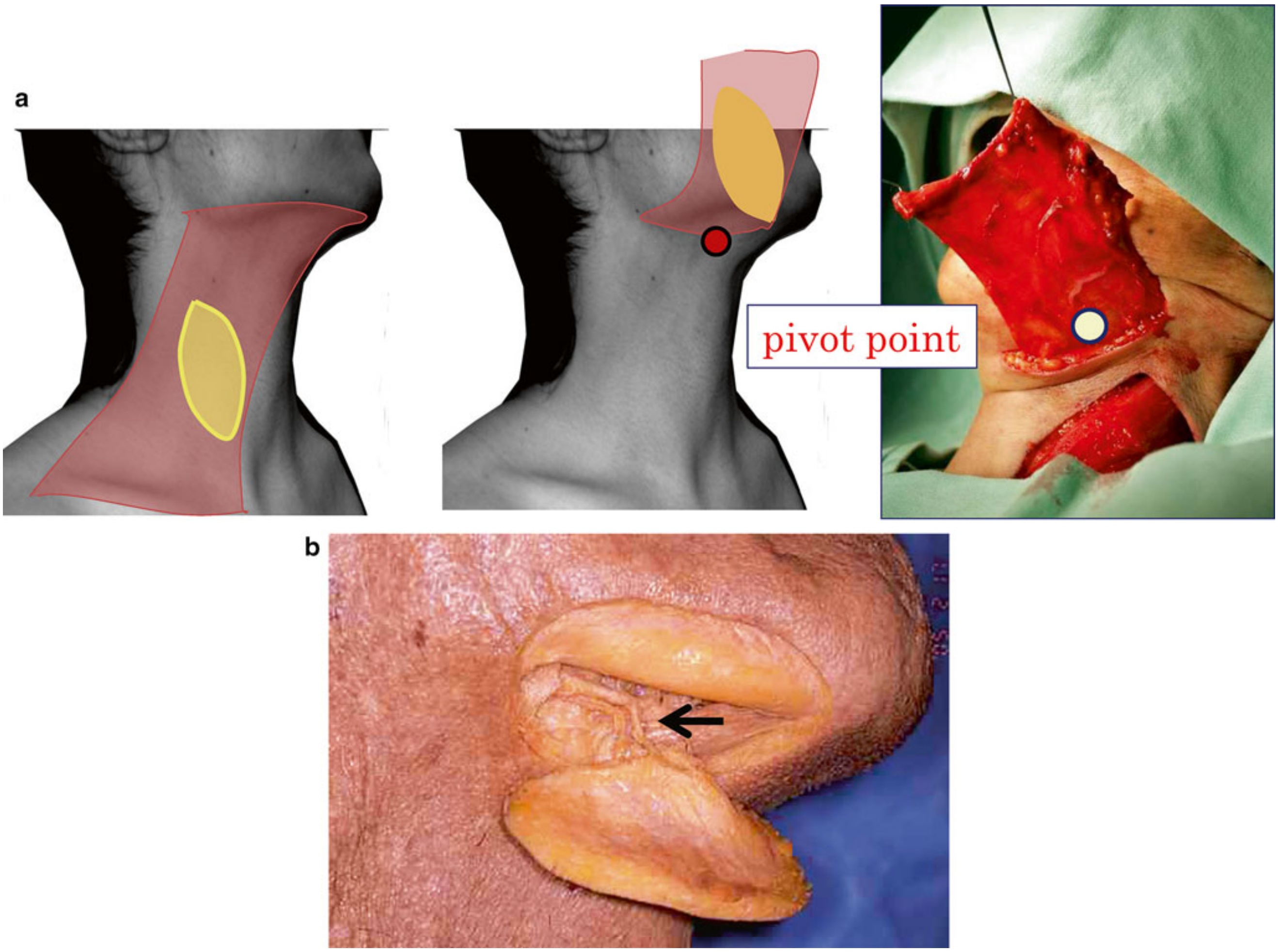


Fig. 9.17 Design of platysma flap and pivot point. Since the platysma flap is of an axial pattern that uses the submental branch of the facial artery, the arc of rotation and the pivot point is determined by this artery. (**a**) Design, arc of rotation, and pivot pointand (**b**) submental branch of the facial artery

being of a random pattern. In 1978, Futrell et al. [52] have described an axial-pattern flap by using the submental branch of the facial artery, the dominant pedicle of the platysma, for feeding the platysma musculocutaneous flap and have used it in oral reconstruction. Although the platysma flap and cervical island flaps are very similar, their circulation systems are totally different and should be clearly differentiated, yet they are still being confused in many studies [53]. By taking the circulation systems into consideration, a platysma flap can be elevated safely.

Since the platysma flap is of an axial pattern that uses the submental branch of the facial artery as the dominant pedicle, the skin flap is a complete island. The suprasternal branch of the suprascapular artery and the platysma branch of the suprathyroid artery are minor pedicles; therefore, their circulation system is Mathes's type II [54, 55]. When a skin flap is used for oral reconstruction, cutting the minor pedicle is requisite, and the skin flap is fed only by the dominant pedicle present in the upper region. Thus, the arc of rotation is determined by this artery (Fig. 9.17). The anterior region in neck skin receives blood supply from the submental branch of the facial artery, with the anterior margin of the sternocleidomastoid muscle regarded as the boundary [56]. Accordingly, a skin island of the platysma flap should be set in this region or in a region from where subcutaneous (dermal) blood flow is foreseen (Fig. 9.18). The submental branch of the facial artery and its arborization are distributed in the deep adipofascial layer and extend perforators to the platysma and skin. Thus, no axial-pattern circulation is obtainable unless this layer is conserved. Imanishi et al. [57] have shown that the dominant pedicle extends a long branch to the deep adipofascial layer and forms a vascular plexus, but it extends only a small vessel to the platysma, and no vascular plexus is formed between the platysma and skin. Thus, elevating a platysma flap as a musculocutaneous flap is risky; it should be elevated

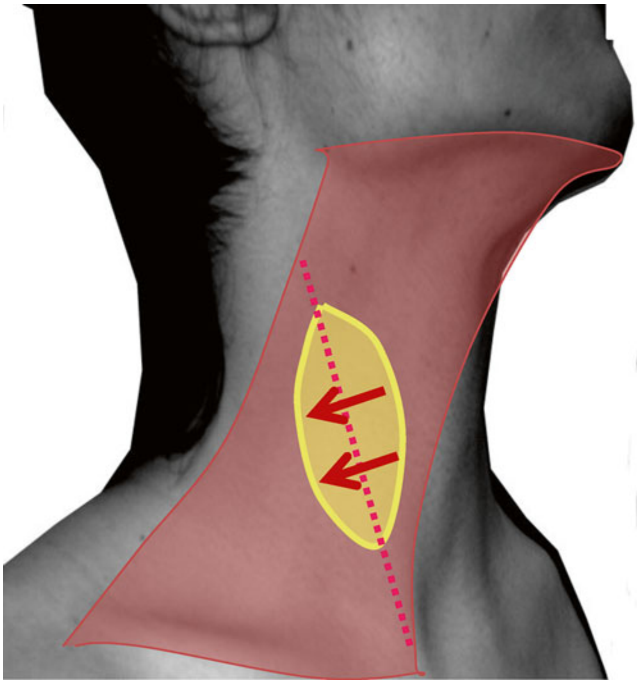


Fig. 9.18 Vascular territory of the submental branch of the facial artery and setting region of the platysma flap in the neck. The anterior region in neck skin receives blood supply from the submental branch of the facial artery, with the anterior margin of the sternocleidomastoid muscle regarded as the boundary. Accordingly, a skin island of the platysma flap should be set in this region or in a region from where subcutaneous (dermal) blood flow is foreseen

as an adipofasciomusculocutaneous flap. This anatomical fact is very important when elevating a platysma flap (Fig. 9.19). Venous circulation in the platysma flap is retrogradely drained by including the external jugular vein [56]. The deep adipofascial layer into which the jugular vein distributes is important for venous circulation. Skin loss has been reported in 20–70 % of platysma flaps [58], but has occurred in only 3 % with the use of our method of elevation. From the viewpoint of cervical lymph flow based on Harnsberger's fascia classification [59], a platysma flap destroys the structure of the cervical fascia. Moreover, since the deep adipofascial layer is present in the superficial space [59], the platysma flap includes the superficial cervical lymph node. Taken together, these conditions may induce a late neck lymph node metastasis-like abnormality. Nonetheless, we have not encountered any late metastatic case assumed to have induced an abnormality in cervical lymph flow (Fig. 9.20).

For a cervical island flap, a peninsula design is prepared in anticipation of a random pattern in the cervical region. The rule of cervical skin flap preparation (width/length = 1:2–3) is observed. The main platysma-feeding artery is the submental branch of the facial artery, and its branch is distributed in the deep adipofascial layer. Thus, no axial-pattern circulation of the platysma flap can be obtained unless this layer is conserved and unless there is a marked difference in the circulation system and flap stability from those of a cervical island flap dissected and elevated in this layer. Furthermore, since a cervical island flap is a random-pattern flap receiving blood supply from the skin pedicle, only the skin and superficial adipofascial layer, not including the platysma muscle, may be elevated. From the viewpoint of circulation, a cervical island flap can be concomitantly used with neck dissection. A cervical island flap, in combination with a sternocleidomastoid muscle flap by separate elevation, can also be used for reconstruction after subtotal glossectomy. By including the deep adipofascial layer and the submental branch of the facial artery in a cervical island flap, similar to those in a platysma flap, both axial and random circulatory patterns can be constructed, facilitating the preparation of a skin flap with more favorable circulation (Fig. 9.21).

With regard to the surgical procedure, a platysma flap may be more difficult to prepare because it requires conservation of the long branch in the deep adipofascial layer. Since the pivot point of a platysma flap is located around the center of the submandibular gland in which the submandibular branch bifurcates from the facial artery, the arc of rotation is limited. Therefore, to reconstruct the tongue is very challenging with the use of the lingual side of the mandible as the route for the flap to reach the target. In a systematic review of cases between 1982 and 2002 (Szudek et al. [53]), the platysma flap has been applied to the mobile tongue and the base of the tongue in 37 % of 190 cases, but these include cases treated with a cervical island flap that is actually a random-pattern skin flap just including the platysma and is termed a platysma myocutaneous flap.

An 80-year-old woman (Patient 1) underwent tumor resection of squamous cell carcinoma of the right buccal mucosa (T2N0M0, WHO grade I, INFa). The region down to the subcutaneous fat layer, including the buccinator muscle, was the vertical resection range. A 5×4 cm platysma flap was elevated. The buccinator muscle was reconstructed by filling the platysma muscle sheet. Reconstruction while maintaining flexibility was possible by applying the deep adipofascial layer to the fat layer and the skin flap region (skin and superficial adipofascial layer) to the buccal mucosal defect. Since the cervical branch of the facial artery was conserved due to its distribution in the deep adipofascial layer, the platysma muscle has been maintained without fatty change for 8 years after surgery. No disturbance of mouth opening attributed to scar contracture in the reconstructed region has been noted, and favorable functioning of the oral cavity prevails (Fig. 9.22).

A 68-year-old woman (Patient 2) underwent reconstruction with a PMMC flap after resection of squamous cell

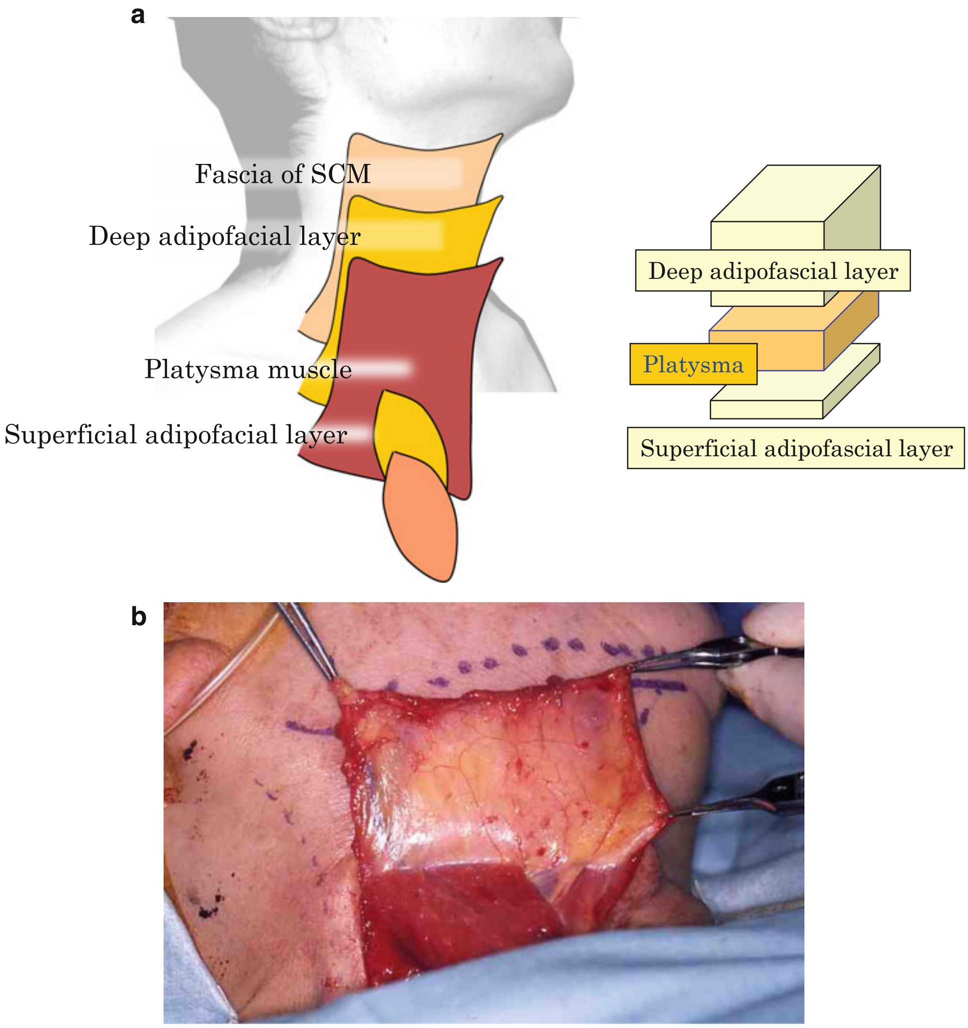


Fig. 9.19 The platysma adipofasciomusculocutaneous flap. The submental branch of the facial artery and its arborization are distributed in the deep adipofascial layer and extend perforators to the platysma and skin (**a**). Thus, no axial-pattern circulation is obtainable unless this layer is conserved. The dominant pedicle extends a long branch to the deep adipofascial layer and forms a vascular plexus, but extends only a small vessel to the platysma, and no vascular plexus is formed between the platysma and skin (**b**). Thus, elevating a platysma flap as a musculocutaneous flap is risky; it should be elevated as an adipofasciomusculocutaneous flap

carcinoma of the oral floor, but an orocervical fistula formed because of poor blood circulation. A moderate tissue defect after fistula resection was reconstructed with a platysma flap prepared from the collateral nonsurgical side. Having an appropriate volume, the platysma flap was very useful in closing the fistula (Fig. 9.23).

In a 60-year-old woman (Patient 3) with disturbed mouth opening (7 mm) resulting from scar contracture after resection of carcinoma of buccal mucosa, the contracture was eliminated by cicatrectomy wherewith mouth opening increased to about 30 mm. As in Patient 1, the buccinator muscle region was reconstructed with a platysma muscle sheet, the fat layer with the deep adipofascial layer, and the buccal mucosal defect with the skin flap region. Since the cervical branch of the facial artery was conserved, the platysma muscle has been maintained for 4 years after surgery, sustaining flexibility of the buccal mucosal region. Mouth opening has increased to 35 mm (Fig. 9.24).

An 80-year-old woman (Patient 4) underwent modified radical neck dissection and resection of squamous cell carcinoma of the left oral floor (T2N1M0, WHO grade I, INFb). The patient's condition was complicated by cardiovascular disease, necessitating cutting operating time short. Therefore, the floor of the mouth was reconstructed with a cervical island flap. Submandibular reconstruction

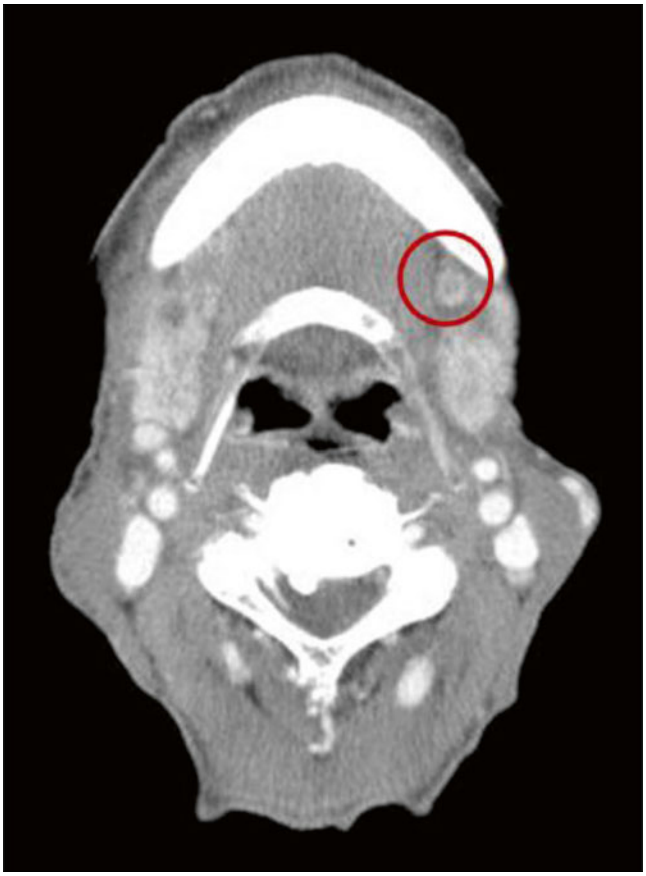


Fig. 9.20 Late cervical metastasis after reconstruction with platysma flap (squamous cell carcinoma of buccal mucosa). From the viewpoint of cervical lymph flow, a platysma flap destroys the structure of the cervical fascia. Moreover, since the deep adipofascial layer is present in the superficial space, the platysma flap includes the superficial cervical lymph node. Taken together, these conditions may induce a late neck lymph node metastasis-like abnormality. Nonetheless, we have not encountered any late metastatic case assumed to have induced an abnormality in cervical lymph flow

was carried out while preventing formation of dead space in this region by plication of the mylohyoid muscle and the digastric muscle and by inserting the cervical island flap through the submandibular region. The postoperative result was good (Fig. 9.25).

An 85-year-old woman (Patient 5) underwent elective supraomohyoid neck dissection and subtotal glossectomy for squamous cell carcinoma of the left tongue; the carcinoma was suspected of having infiltrated the mylohyoid muscle and was by histopathology diagnosed as infiltration factor (INF) type C (T4aN0M0, WHO grade II). Since the patient's age and cardiovascular disease necessitated cutting operating time short, the submandibular defect was reconstructed with a sternocleidomastoid muscle flap and the tongue with a cervical island flap. The postoperative result was good (Fig. 9.26).

9.2.5 Functional and Aesthetic Reconstruction of Full-Thickness Cheek, Oral Commissure, and Vermilion Defects

Full-thickness cheek defects arise as a result of resecting buccomucosal squamous cell carcinomas. In terms of direct tumor invasion or safety margins, even the vermilion including the oral commissure has to be resected in some cases where patients demonstrate massive defects involving the cheek, oral commissure, and vermilion. Various vascularized free flaps have previously been reported for reconstructing the cheek [60–67]. The vermilion was reconstructed by tissue-expanding vermilion musculocutaneous flaps (vermilion advancement flaps) as described by Goldstein [68]. Both functional and aesthetic problems can be resolved by using both procedures in combination.

A tumor resection team resected the cheek, oral commissure, and vermilion (Fig. 9.27a). Neck dissection was carried out according to the status of each case. A reconstruction team raised a flap (radial forearm flap or rectus abdominis musculocutaneous flap) commensurate with the size of the defect. Microvascular anastomoses were carried out with arterial branches from the external carotid system and venous branches from the external or internal jugular system. After vascular anastomosis, the flap was transplanted into the oral cavity (Fig. 9.27b), and the distal portion of the flap was sutured to the oral mucosa. When the suture advanced to the vicinity of the oral commissure, the flap was folded to the facial side. Subsequently, repair of the cheek-skin defect was carried out. Then a portion of the folded flap was deepithelialized, corresponding to the neovermilion (Fig. 9.27c). Rectus abdominis musculocutaneous flaps were used for larger defects than radial forearm flaps. When reconstruction was carried out with a rectus abdominis musculocutaneous flap, the contour of the cheek was reconstructed with the muscle portion and the oral cavity and the cheek skin were lined with the cutaneous portion. A cutaneous portion elevated was twice as large as the muscle portion, because the folding was done in the cutaneous portion alone (Fig. 9.27d). Mucosal lining of the vermilion and the oral commissure was carried out with vermilion advancement flaps raised by incising the residual vermilion along the white roll up to the contralateral oral commissure including the labial artery and orbicularis oris muscle (Fig. 9.27e). The upper and lower vermilion advancement flaps were advanced to the point of the putative new oral commissure. The flap ends were then sutured to the deepithelialized skin flap to form both the vermilion and the neocommissure (Fig. 9.27f).

Vermilion reconstruction is considered successful only when both sphincteric and sensory functions are reestablished. Full-thickness cheek defects have been repaired with various vascularized free flaps without eliminating postoperative

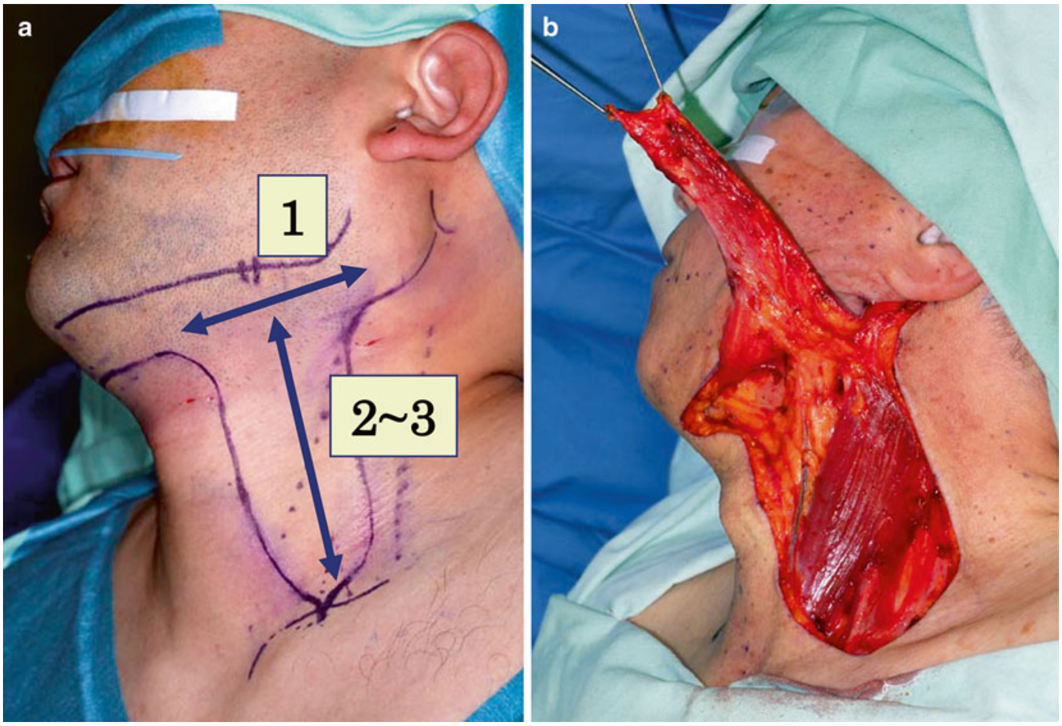


Fig. 9.21 Design and elevation of cervical island flap. A peninsula design is prepared in anticipation of a random pattern in the cervical region for the cervical island flap. The rule of cervical skin flap preparation (width/length = 1:2–3) is observed. The main platysma-feeding artery is the submental branch of the facial artery, and its branch is distributed in the deep adipofascial layer. Thus, no axial-pattern circulation of the platysma flap can be obtained unless this layer is conserved and unless there is a marked difference in the circulation system and flap stability from those of a cervical island flap dissected and elevated in this layer. Furthermore, since a cervical island flap is a random-pattern flap receiving blood supply from the skin pedicle, only the skin and superficial adipofascial layer, not including the platysma muscle, may be elevated. From the viewpoint of circulation, a cervical island flap can be concomitantly used with neck dissection

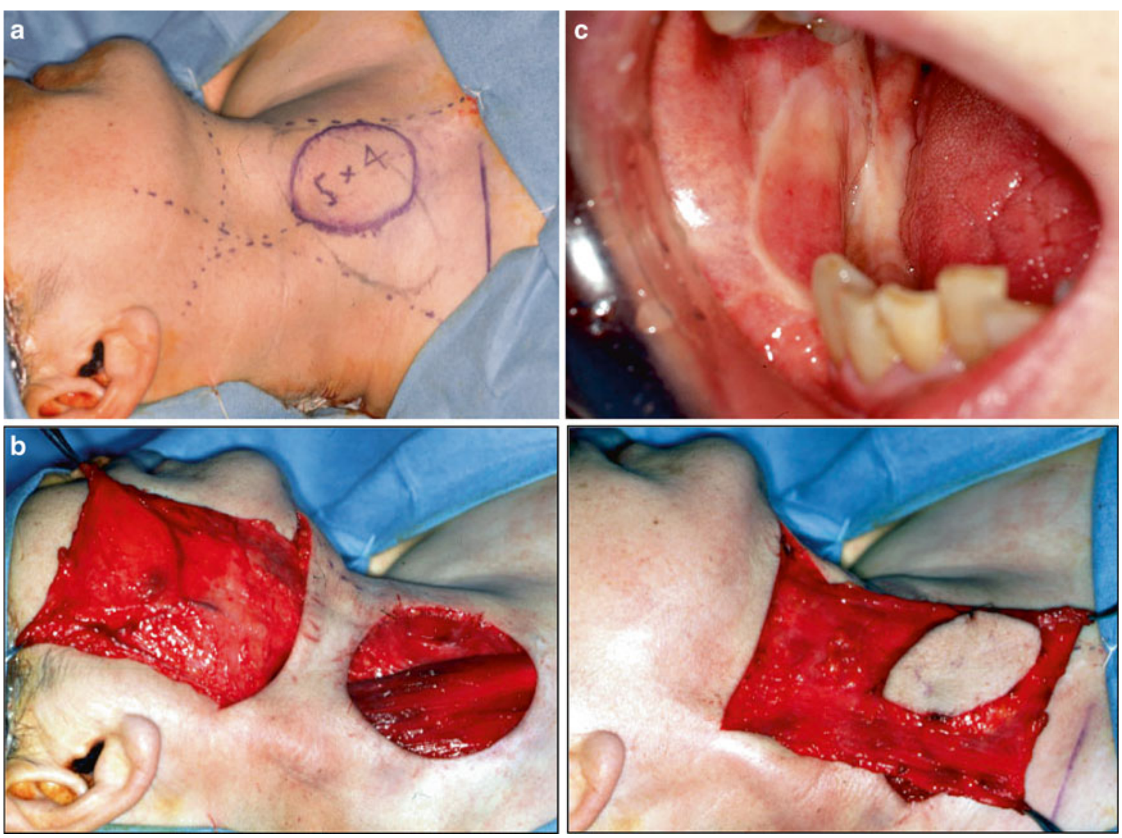


Fig. 9.22 Patient 1: platysma flap reconstruction after resection of squamous cell carcinoma of buccal mucosa. (**a**) Design of platysma flap, (**b**) elevation of flap, (**c**) 8 years after surgery

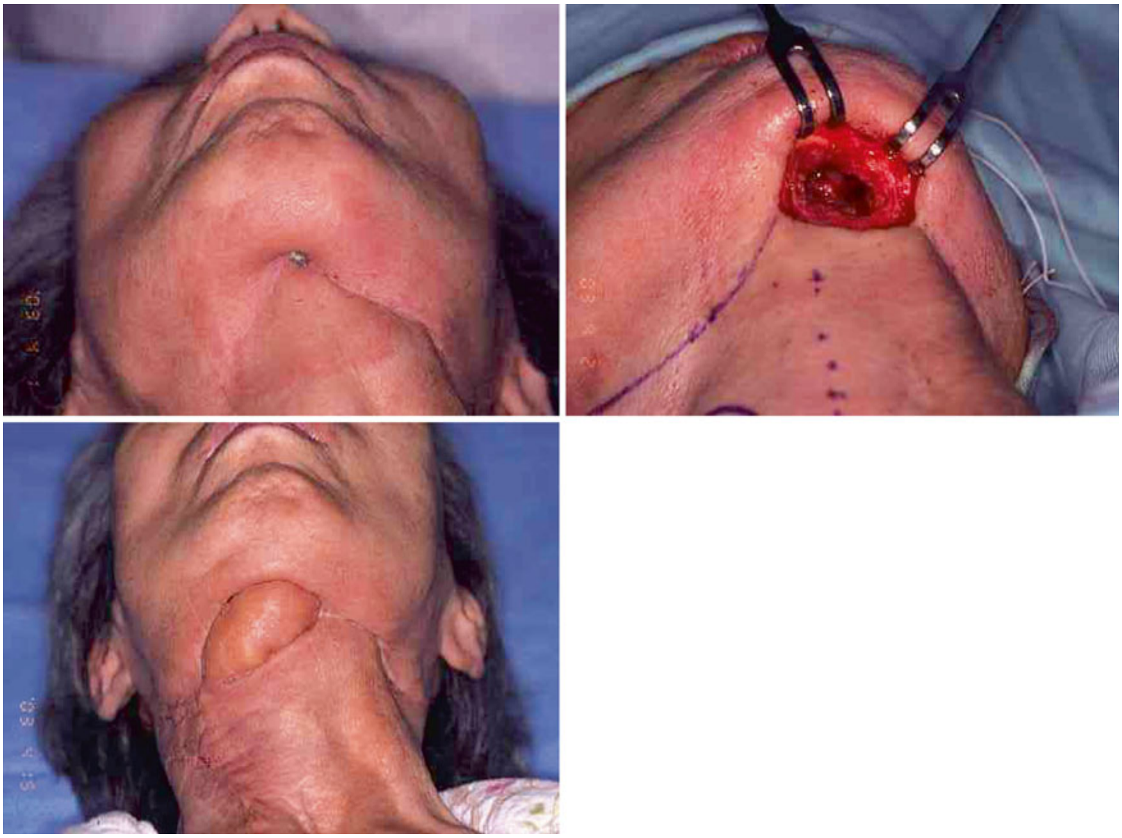


Fig. 9.23 Platysma flap reconstruction of cervical fistula. (**a**) Orocervical fistula after reconstruction with PMMC flap, (**b**) moderate defect after fistula resection, (**c**) closing the fistula

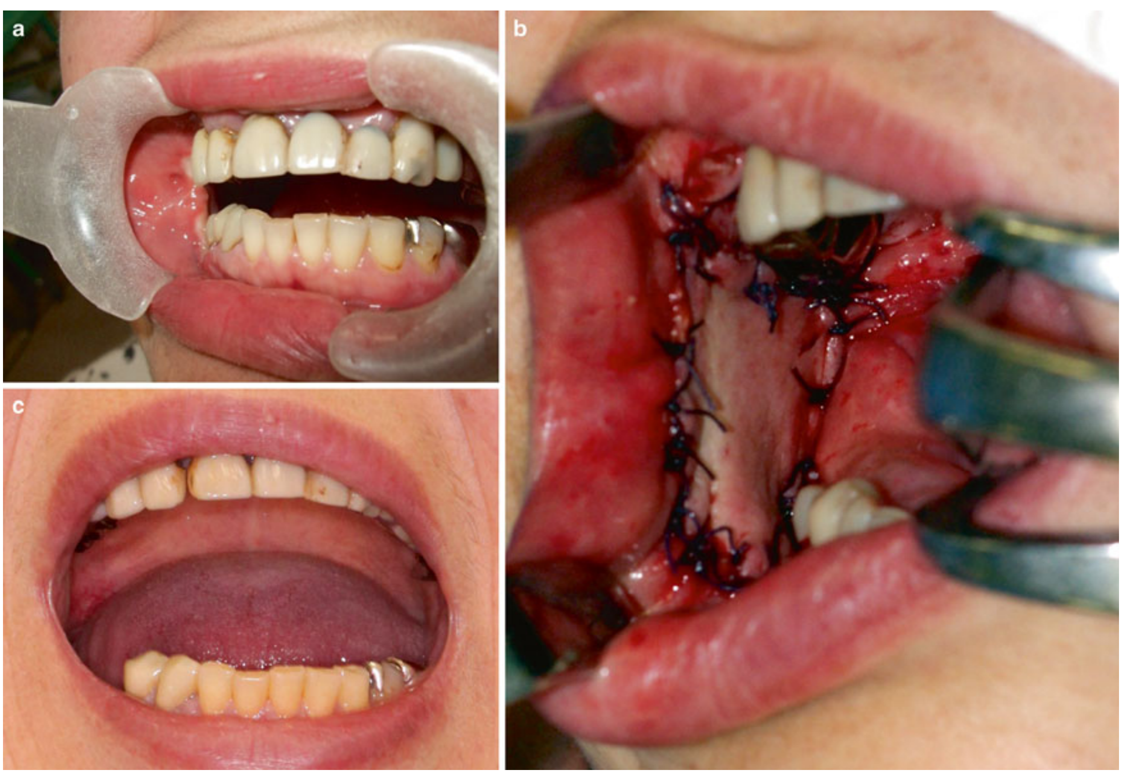


Fig. 9.24 Platysma flap reconstruction after cicatrectomy. (**a**) 7 mm mouth opening before surgery, (**b**) platysma flap reconstruction after cicatrectomy, (**c**) 35 mm mouth opening 1 year after surgery

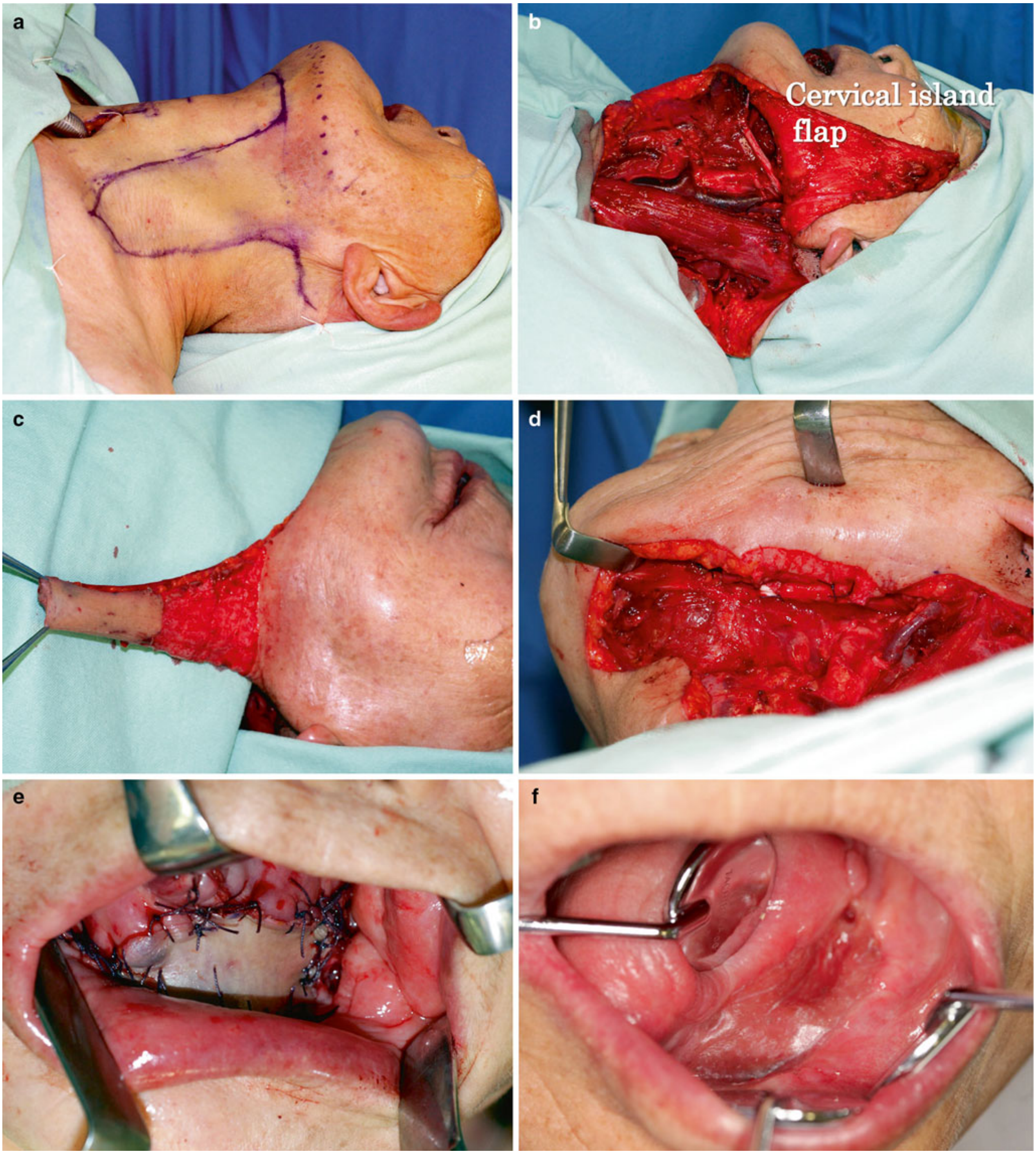


Fig. 9.25 Cervical island flap reconstruction after resection of squamous cell carcinoma of the floor of the mouth. (**a**) Design, (**b**) cervical island flap elevation and supraomohyoid neck dissection, (**c**) deepithelization of flap, (**d**) reconstruction of submandibular region (formation of mylohyoid structure), (**e**) reconstruction of the floor of the mouth, (**f**) 4 years after surgery

functional disorders such as trismus due to scar contracture [60–67].

In our procedure in this presentation, the reconstructed cheek was soft and supple, demonstrating no scar contracture, because a radial forearm flap or a rectus abdominis musculocutaneous flap of good blood supply was used. Since continuity of the orbicularis oris muscle ring and configuration of the vermilion were reconstructed using a combination of these soft and supple skin flaps and a vermilion advancement flap as described by Goldstein [68], sphincteric function was

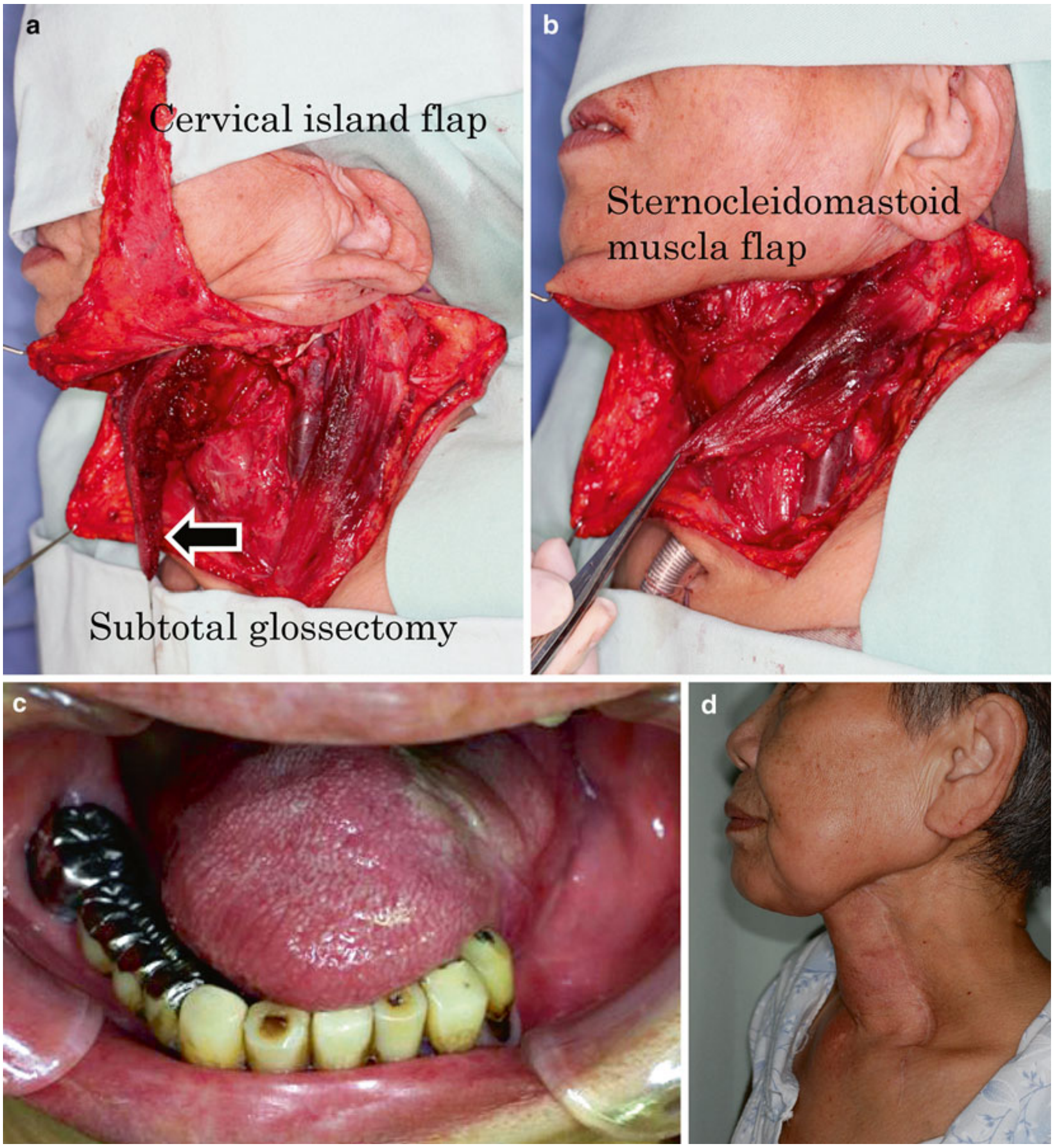


Fig. 9.26 Reconstruction after subtotal glossectomy with combination with cervical island flap and sternocleidomastoid muscle flap. (**a**) Cervical island flap elevation and modified radical neck dissection, (**b**) reconstruction of the floor of the mouth and submandibular dead space with sternocleidomastoid muscle flap, (**c**) reconstruction of the floor of the mouth, and (**d**) condition of submandibular and cervical region

restored. It is particularly essential to retain or restore sensory function in lip reconstruction in order to avoid insufficient lip closure and drooling. As suggested by Goldstein [68], the sensory function of the vermilion can be retained because the musculocutaneous flap (vermilion advancement flap) is innervated. Corderio and Santamaria [69] have reported that in large defects of the midface, orbit, and maxilla that include the upper lip and oral commissure, the midface is reconstructed and sphincteric function and sensory function of the lip and oral commissure are reestablished with a combination of a rectus abdominis musculocutaneous flap and a lip switch flap. The same concept was applied in our patients for the reconstruction of the oral commissure and lips (Fig. 9.28).

9.2.6 Maxillomandibular Reconstruction

9.2.6.1 Introduction

Among osseous reconstruction materials for mandibular and maxillary defects, vascularized free bone is highly resistant to infection because it is a living bone—an advantage when blood supply to the recipient site is poor due to radiotherapy and when the bone defect is large [70]. Fibular and scapular

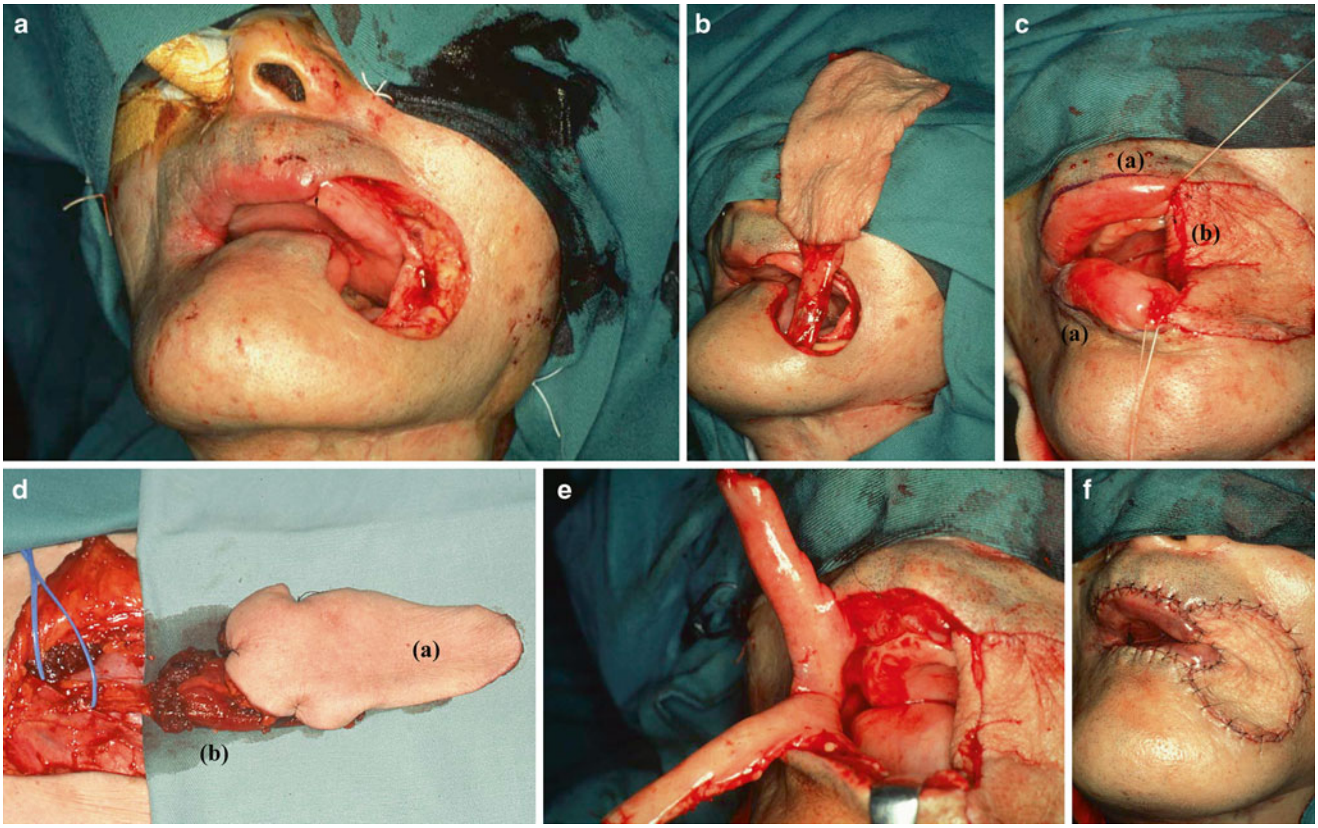
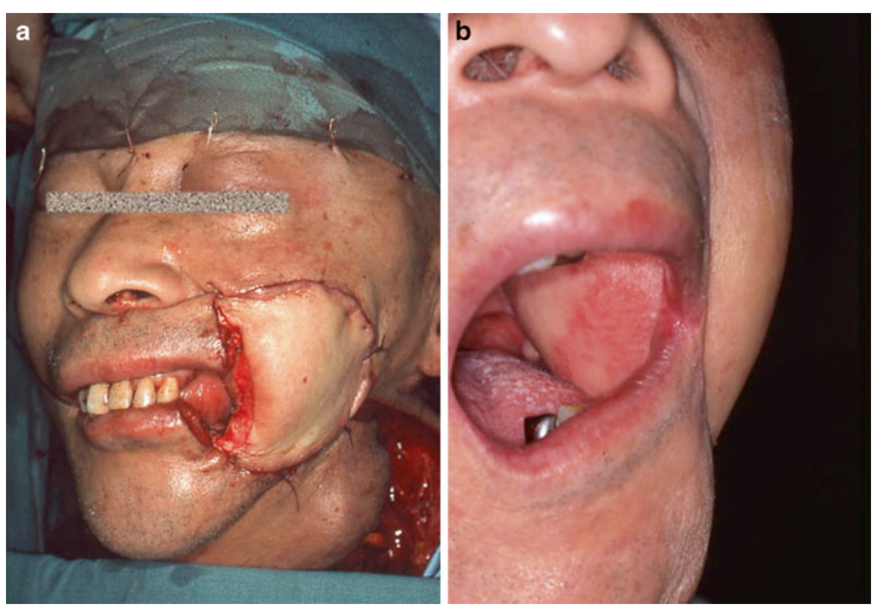


Fig. 9.27 Operative procedure. (**a**) The full-thickness cheek including the upper and lower lips and the oral commissure were resected. (**b**) A free radial forearm flap was grafted for repair of the cheek defect. (**c**) (*a*) Design of the vermilion advancement flap. (*b*) The free radial forearm flap deepithelialized at the folded portion and formation of the neovermilion and neocommissure. (**d**) Rectus abdominis musculocutaneous flaps were used for larger defects than radial forearm flaps. When reconstruction was carried out with a rectus abdominis musculocutaneous flap, the contour of the cheek was reconstructed with the muscle portion, and the oral cavity and the cheek skin were lined with the cutaneous portion. The elevated cutaneous portion was twice as large as the muscle portion because the folding was done in the cutaneous portion alone. (*a*) Cutaneous portion. (*b*) Muscular portion. (**e**) Raising the vermilion advancement flap. (**f**) Completed reconstruction

Fig. 9.28 Vermilion advancement flap and rectus abdominis musculocutaneous flap. (**a**) The full-thickness cheek including 10 % of the lower lip and the oral commissure were resected. The contour of the cheek was reconstructed with the muscle portion, and the oral cavity and the cheek skin were lined with the cutaneous portion of the rectus abdominis musculocutaneous flap. Vermilion advancement flap repaired for the lower lip alone. (**b**) One year postoperatively: good form of the oral commissure was reestablished



bones are frequently used for maxillomandibular reconstruction, and while there are no clear criteria for choosing grafts, it is essential that the selection be based on a full understanding of the characteristics of the kind of bone [71–73]. In surgery for oral cancer, soft tissue is often widely resected with the maxilla and the mandible, and bone is transplanted as a complex tissue graft, such as fibular and scapular flaps and vascularized LD musculocutaneous flaps with scapular bone (scapular tip flap) (Fig. 9.29).

Iliac bone bloc and PCBM are used for shaping autologous bone grafts that are collected from anterior and posterior iliac crests. A titanium mesh (metal) and poly-L-lactic acid (PLLA) mesh (artificial biomaterial) are used as scaffolding for PCBM. A titanium plate is used as temporary reconstruction material until bone grafting, but may sometimes be placed for a long time [74, 75].

For mandibular reconstruction, alveolar ridge plasty combined with secondary bone grafting and distraction osteogenesis may be applied at final occlusal reconstruction with dental implants and resection dentures after marginal mandibular resection [76]. Since the continuity of the mandible is lost after segmental mandibular resection, masticatory disturbance and facial deformity occur because of mandibular deviation. Currently, vascularized free bone flap grafts are widely used for primary reconstruction of the mandible; also used is the combined graft of a reconstruction plate and soft tissue (skin and musculocutaneous flaps) or one of soft tissue alone (skin or musculocutaneous flap) [1, 77–81]. Since reliable closure of the oral mucosal side is an essential prerequisite to a successful autologous bone graft, the risk of infection is high in immediate reconstruction. An autologous bone or a vascularized free bone graft is mainly used for secondary reconstruction. Although primary operative time can be shortened, multiple surgeries may be requisite, and positioning and morphological restoration of the mandible may become difficult due to scar contracture. Moreover, reconstruction with a vascularized free bone graft may not be possible when no blood vessel is available for anastomosis at the recipient site, a crucial issue to be investigated for secondary reconstruction. The level of functional recovery after

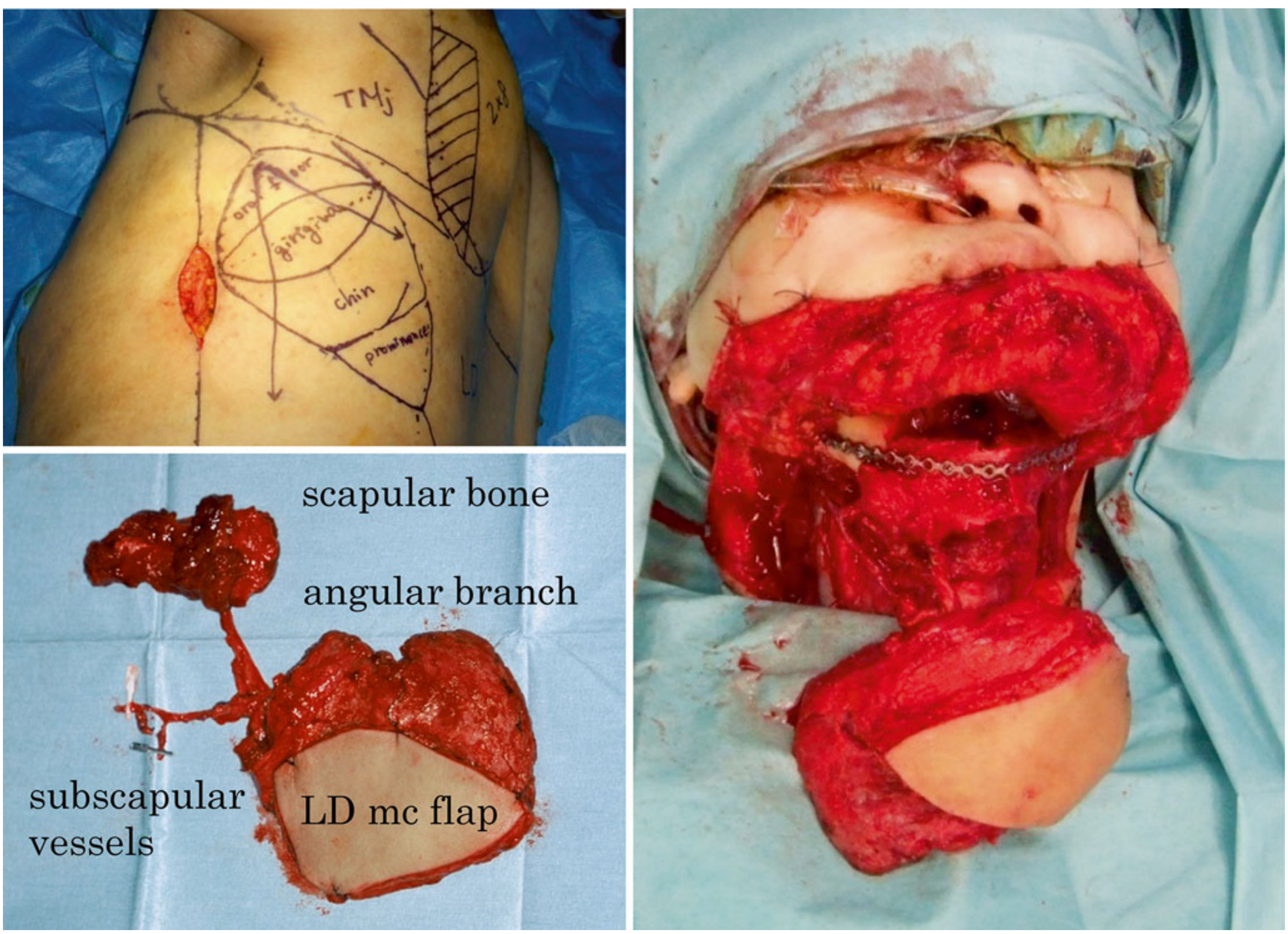


Fig. 9.29 Vascularized LD musculocutaneous flap with scapular bone (scapular tip flap)

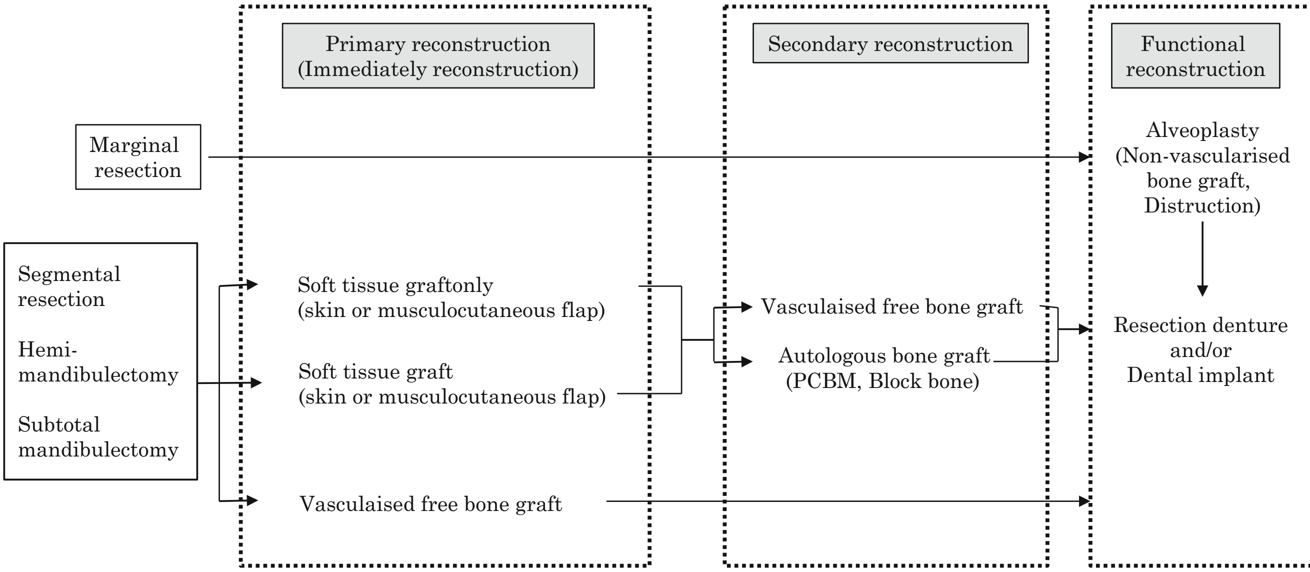


Fig. 9.30 Algorithm of mandibular reconstruction

mandibular reconstruction, and when mandibular continuity is restored, varies, because the occlusal relation among the upper and lower dentitions, the mobility of surrounding soft tissue, and the number of residual teeth are strongly reflected (Fig. 9.30).

For maxillary reconstruction, when the defect was large, instability of resection dentures due to sagging or an excessive volume of a musculocutaneous flap in cases with soft tissue reconstruction alone was an issue [82, 83]. Therefore, osseous reconstruction with a vascularized free bone flap has been introduced, which, with dental implants, markedly increases the stability of resection dentures. After subtotal or less extensive maxillectomy producing a hard palate/unilateral alveolar defect or a smaller defect with residual teeth, resection dentures may be more effective than closure with flaps (Figs. 9.31, 9.32, and 9.33) [82, 84–88].

9.2.6.2 Strategy of Mandibular Reconstruction

In our department, a 5 cm or smaller segmental defect is treated with a graft comprising a combination of a non-vascularized free iliac bone block and PCBM (Strategy 1) (Fig. 9.34). For segmental defects larger than 5 cm, a vascularized free bone graft (Strategy 2) with fibular or scapular bone (Figs. 9.29 and 9.35) is applied, or, more recently, regenerative mandibular reconstruction is carried out, in which a wrap-around procedure with a reconstruction plate and musculocutaneous flap is used before secondary reconstruction with a PCBM graft (Strategy 3). For hemi- and posterior mandibular defects, basically the methods of Kroll et al. [80] and Bulter et al. [89] are used. Instead of a free-end saddle reconstruction with a bone flap or a reconstruction plate, aesthetic contour reconstruction with a musculocutaneous flap alone is carried out (Strategy 4).

Strategy 2: Vascularized Osteocutaneous Flap (Scapular Osteocutaneous Flap)

A 47-year-old man with mandibular invasion of the right oral floor by squamous cell carcinoma (T4N1M0) underwent tumor excision involving left radical neck dissection, resection of the right oral floor tumor, subtotal glossectomy of the mobile tongue, and right segmental mandibular resection (from the right mandibular ramus to the right lower canine region), before oromandibular reconstruction with a free scapular osteocutaneous flap. For vascular anastomosis, the right subscapular and suprathyroid arteries were anastomosed end to end with the right subscapular and external jugular veins, respectively, and the scapular bone was fixed with mini plates. The oral floor and the tongue were reconstructed with a scapular flap (Fig. 9.35).

Strategy 3: Regenerative Mandibular Reconstruction

A 54-year-old woman with left squamous cell carcinoma of the lower gingiva (T2N2bM0) underwent primary tumor excision involving left modified radical neck dissection and segmental mandibular resection. In the primary reconstruction after resection, a titanium reconstruction plate was wrapped with a vascularized free rectus abdominis musculocutaneous flap to reproduce mandibular morphology. In the secondary reconstruction 6 months thereafter, regenerative mandibular reconstruction of the defective

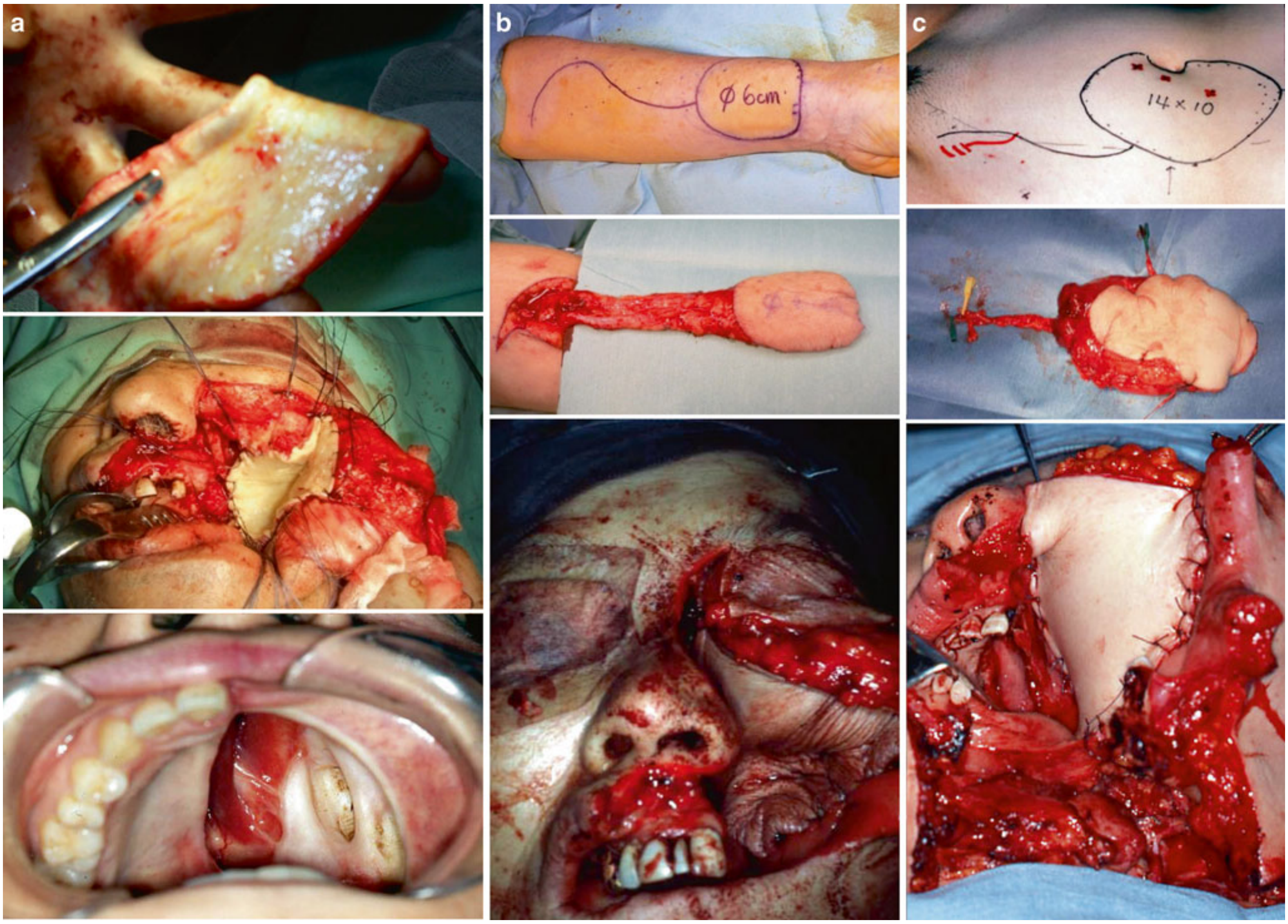


Fig. 9.31 Soft tissue reconstruction of maxilla. (**a**) Skin graft. (**b**) Vascularized free forearm flap. (**c**) Vascularized free rectus abdominis musculocutaneous flap

region was carried out with a titanium mesh and PCBM. A 3D model was constructed from CT images, and the mandibular morphology on the healthy side was reproduced with a titanium mesh on the defective side. With the titanium mesh as a scaffold, PCBM collected from the posterior iliac crest was buried in the muscular portion of abdominis musculocutaneous flap. New bone formation was confirmed after 3 months, and regenerative mandibular reconstruction was completed 6 months postoperatively. An aesthetically and functionally favorable outcome was attained (Fig. 9.36).

Strategy 4: Reconstruction After Hemimandibulectomy: A Strategy Not Necessarily Requiring Osseous or Plate Reconstruction

Viewpoints on osseous reconstruction or free-end saddle reconstruction with a plate after hemimandibulectomy vary markedly among institutions, and no conclusion has been reached: some institutions report no functional improvement after surgery, while others describe improvement of postoperative QOL and facial appearance [89–91]. Basically, we use the reconstruction method established by the MD Anderson Cancer Center for hemimandibular and posterior defects [80, 89]. Instead of free-end saddle reconstruction with a bone flap or reconstruction plate, the contour is reconstructed with a musculocutaneous flap alone (Fig. 9.37). The most important aspect of this procedure is maintenance of the facial contour, i.e., preventing reduction of the volume of the musculocutaneous flap and facial asymmetry over time. Rectus abdominis musculocutaneous flaps are advantageous in that (1) reduction of whole total tissue volume is small because atrophy of subcutaneous fat and muscle with fatty change is mild due to the good blood supply, (2) muscular atrophy is delayed by reformation of the intercostal nerve to nerve suturing, and (3) modification can be carried out with the use of an anterior sheath of the abdominis muscle to prevent gravity-induced sinking of the musculocutaneous flap. Thus, a vascularized free rectus abdominis musculocutaneous flap is the specified standard flap for this reconstruction

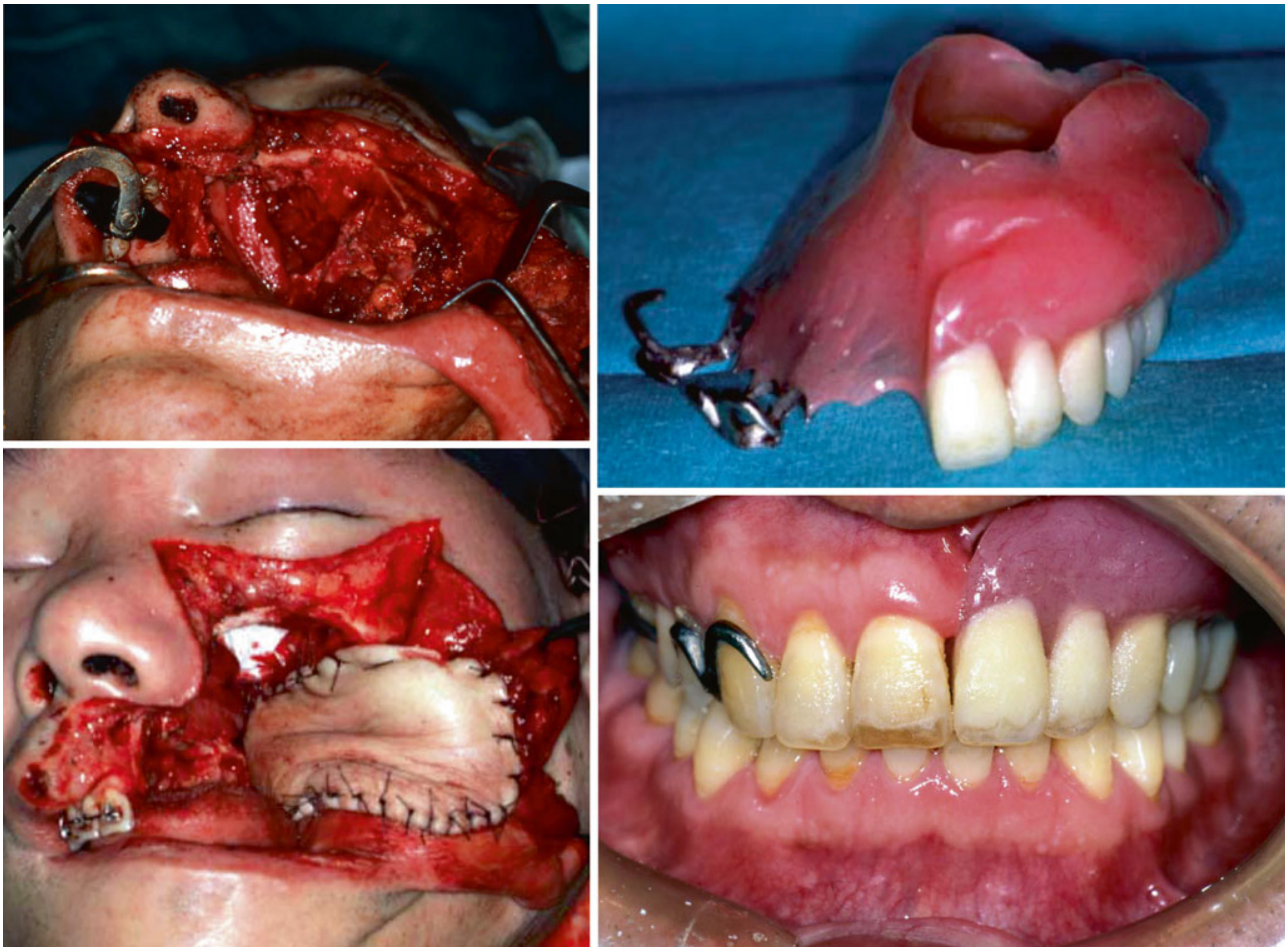


Fig. 9.32 Reconstruction with free forearm flap and resection denture after subtotal maxillectomy

(Figs. 9.37 and 9.38) [1]. When an abdominis musculocutaneous flap cannot be used, a pectoralis major musculocutaneous flap is selected (Figs. 9.39 and 9.40), for which conservation or reformation of a motor nerve, the medial pectoral nerve, is essential. This reconstruction also requires strict body weight management to maintain the overall volume of tissue (Figs. 9.38 and 9.40). MaCraw [92] reported that, when muscle is cut at its origin or end together with the dominant nerve, the muscle volume decreases to 50 % and fatty change occurs rapidly. Poor blood supply is also a major cause of fatty change in the muscle. Therefore, clinical and histopathological analyses are used in our institution to ascertain that early volume reduction of a musculocutaneous flap is prevented and a favorable facial contour is attained and maintained over a long period of time. A rectus abdominis musculocutaneous flap or a pectoralis major musculocutaneous flap incorporates an abundant blood supply; thus, subcutaneous fat does not markedly change over time, and the motor nerve can be reformed. Moreover, fixation of musculocutaneous flaps, particularly the muscle portion, is crucial for maintaining the motor function of the muscle and preventing its atrophy.

Trismus, which occurs in many cases of mandibular free-end saddle reconstruction when using a plate with an artificial condylar head, was not observed in cases treated with aesthetic contour reconstruction incorporating a musculocutaneous flap, and no major difference was noted in the eating function. Interestingly, some patients from whom a reconstruction plate with an artificial condylar head was removed on a patient's request, the patients' satisfactions with the function increased, indicating that the functions of the masticatory muscles, mandibular ligament, and temporomandibular joint structures, such as the articular disk and capsule, were not reconstructed after mandibular resection, and the simple insertion of a free bone flap and plate did not reconstruct functionally. Moreover, it is possible that trismus, which frequently develops in cases treated with free-end saddle reconstruction, is a functional disorder due to scar

Fig. 9.33 Reconstruction with dental implants and resection denture after subtotal maxillectomy

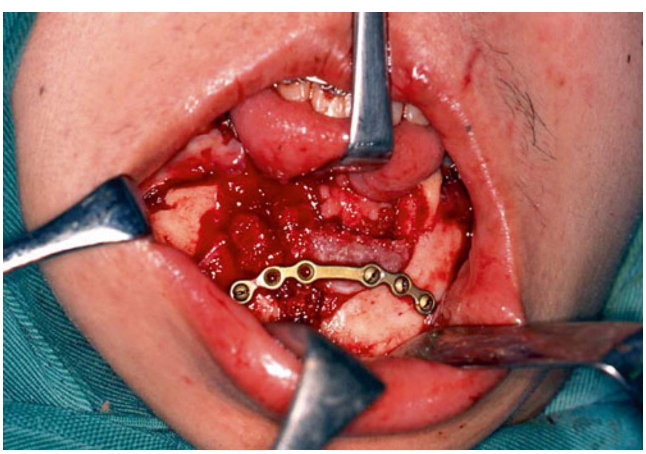


Fig. 9.34 Strategy 1 for mandibular reconstruction: reconstruction of 5 cm or smaller segmental mandibular defect with non-vascularized free iliac bone block and PCBM

contracture on the reconstructed side and fatigue caused by overstress of the temporomandibular joint on the non-reconstructed side.

In aesthetic contour reconstruction with a musculocutaneous flap, marked deviation of the residual mandible toward the resected side is problematic for occlusal reconstitution, and a jaw that is nearly or completely edentulous makes it more difficult. To overcome this, we regard postoperative modification of the prosthesis as essential and requisite for maintaining mandibular function with a musculocutaneous flap alone. Ten patients with osseous or plate reconstruction after hemimandibulectomy and eleven with only soft tissue reconstruction, evaluated with the use of the performance status scale (PSS), functional assessment of cancer treatment in general (FACT-G), and disease-specific questions, have demonstrated that osseous reconstruction or free-end saddle

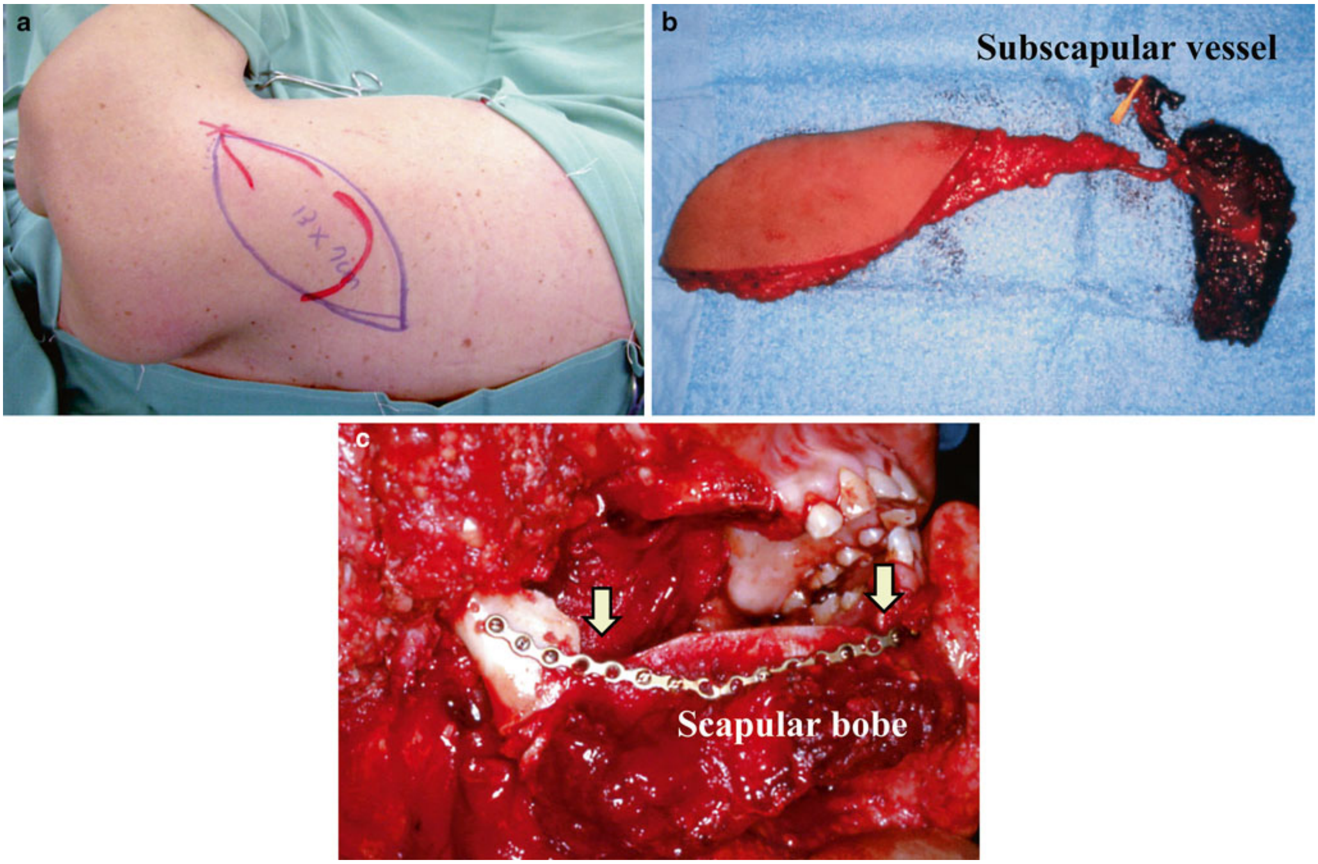


Fig. 9.35 Strategy 2 for mandibular reconstruction: vascularized osteocutaneous flap (scapular osteocutaneous flap)

reconstruction with a plate improves patient QOL [93]. No description of postoperative prosthetic treatment of the soft tissue reconstruction has been mentioned, however. We consider that aesthetic hemimandibular reconstruction with a musculocutaneous flap alone is effective only when modifications of the prosthesis, such as the application of dental implants to the residual bone and prosthetic appliances with palatal lump, and strict management of occlusion, are carried out (Fig. 9.41).

Dental implant placement in reconstructed bone improves the masticatory function, and some oral and maxillofacial surgeons consider that free-end saddle reconstruction of the mandible with a bone flap is a prerequisite to dental implant placement. On the other hand, the sensory perception of peri-implant soft tissue is crucial for dental implants to improve masticatory function [94]. In our experience, if the reconstructed region does not sense stimuli, dental implants, although placed into the grafted bone, do not improve masticatory function.

9.2.6.3 Maxillomandibular Reconstruction and Functional Unit Reconstruction

When maxillomandibular reconstruction, particularly reconstruction of the masticatory function, is considered, many oral and maxillofacial surgeons, plastic surgeons, and oral and maxillofacial prosthodontists carry it out with the percept that occlusion = mastication. Mastication is a collective term comprising three functions: manipulation, trituration, and consolidation. The role of occlusion is only trituration; the others are effected by tongue movement. Occlusion is just one of the functional units of the masticatory system, along with the tongue, mouth floor, and buccal mucosal movements; that is why the reconstruction of occlusion alone does not restore the masticatory function. Occlusal reconstruction causes swallowing disorders, and the resection of the tongue alone sometimes leads to the inability of chewing. Based on the principle of functional unit reconstruction, it is not possible to effectively reconstruct the oral function by reconstructing individual units,

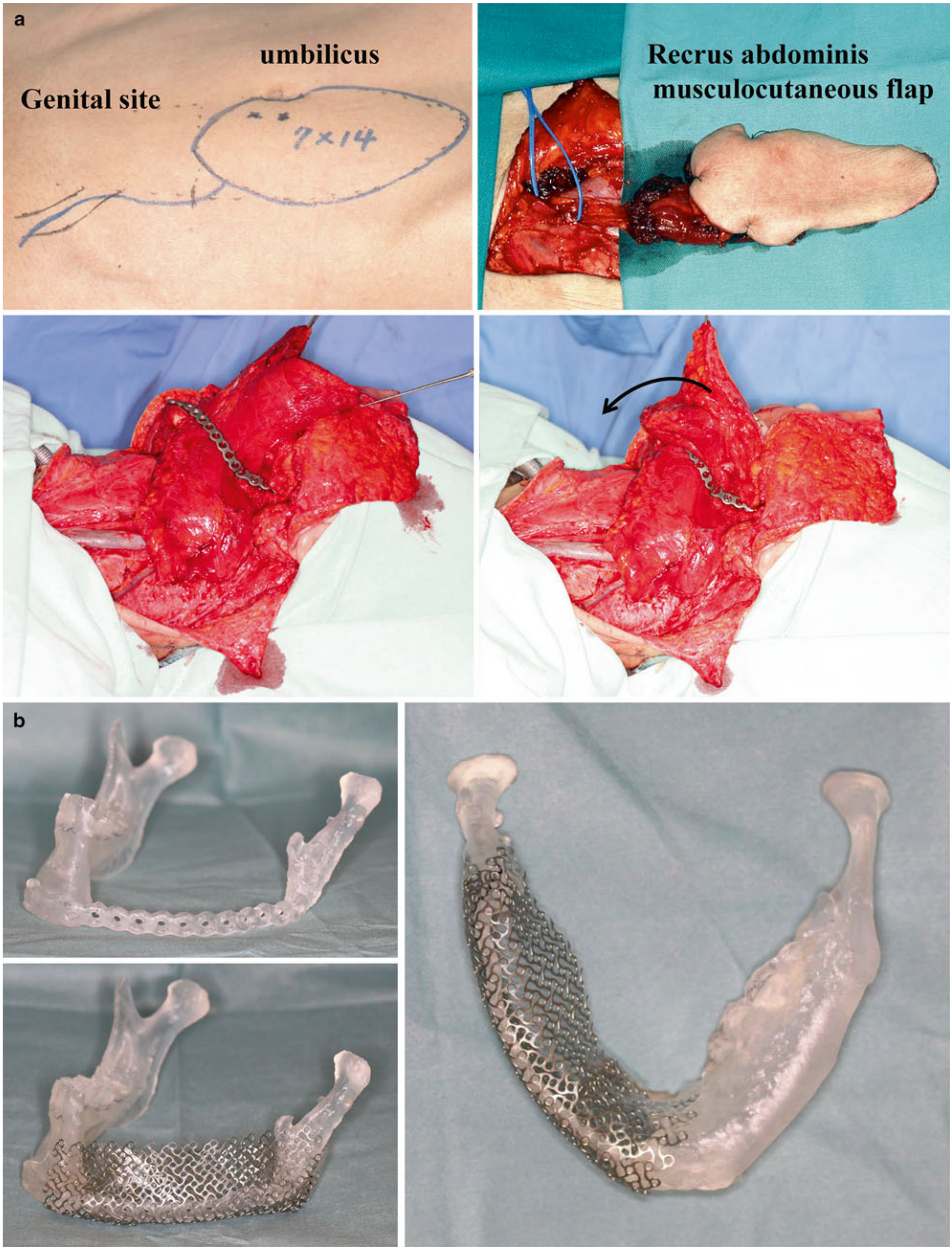


Fig. 9.36 Strategy 3 for mandibular reconstruction: regenerative mandibular reconstruction. (**a**) The primary reconstruction, so-called wrap-around procedure, in which a titanium reconstruction plate was wrapped with a muscular portion of the vascularized free rectus abdominis musculocutaneous flap, was carried out to restore the contour of the lower face. (**b**) A 3D model was constructed from CT images, and the mandibular morphology on the healthy side was reproduced with a titanium mesh on the defective side. (**c**) Six months thereafter, secondary regenerative mandibular reconstruction was carried out with PCBM and titanium mesh as a scaffold. PCMB collected from the posterior iliac crest was then buried in the rectus abdominis muscle of the flap. (**d**) Regenerative mandibular reconstruction was completed in the next 6 months

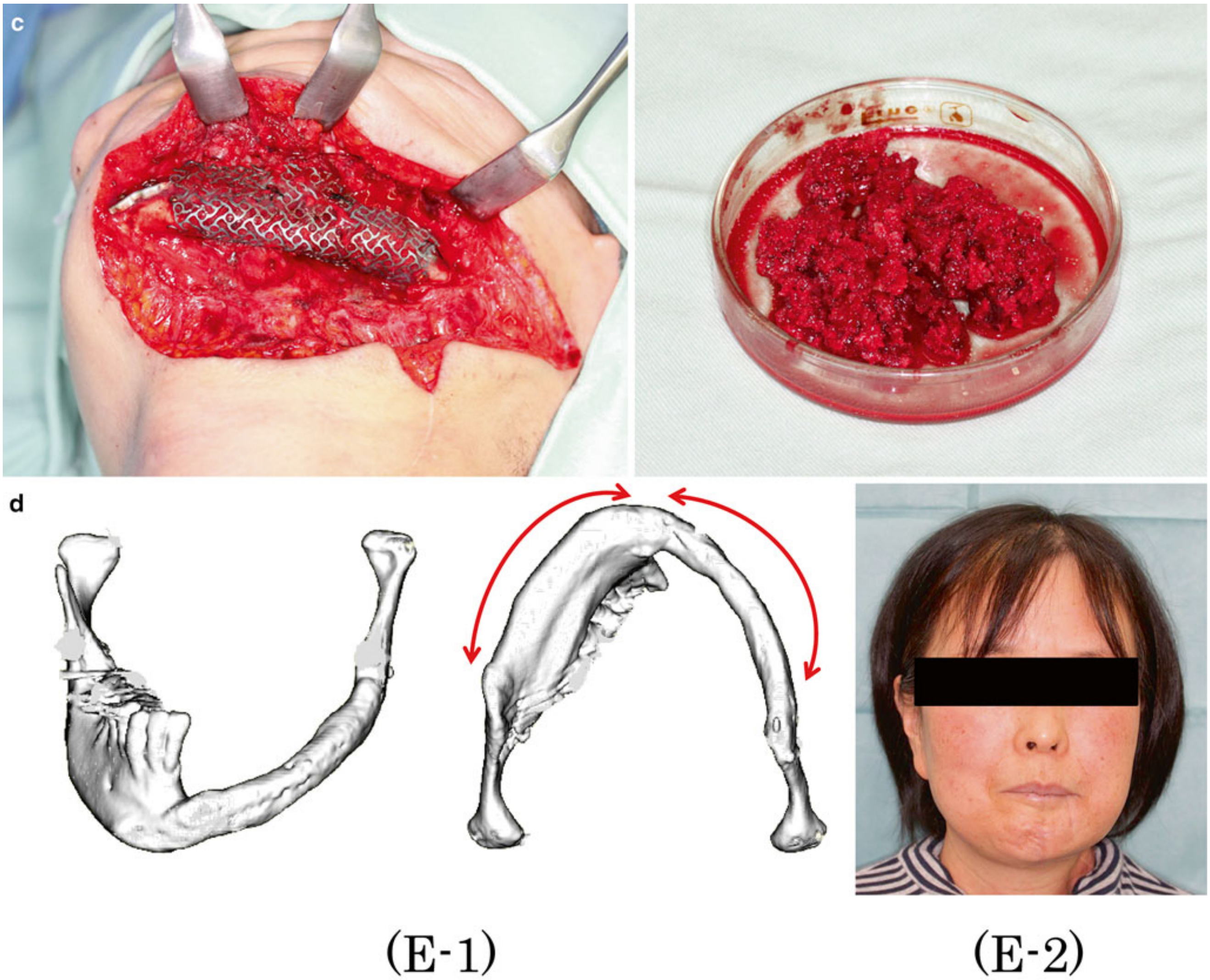


Fig. 9.36 (continued)

such as the tongue, oral floor, buccal mucosa, and mandible. The goal of functional reconstruction comprises diverse elements: not only the extent of resection (residual function) and the reconstruction method, but also the patient's potential (laryngeal function and residual teeth) and motivation (positive attitude toward rehabilitation). The consistency of postoperative meals desired by patients also varies. Since easily ingestible therapeutic diets are better than normal diets that sometimes cause distress, it is important to set an optimal method and goal based on each patient's potential and residual function. Moreover, it is difficult to evaluate functions after reconstruction. Evaluation of the movement of individual units, such as the tongue and mandible, is often not reflected in postoperative meal consistency, which is not directly linked to the degree of satisfaction. To make eating an enjoyable activity, not just to maintain life, it is necessary to evaluate the ease of eating and the savoring of food. Functional oral and oropharyngeal reconstruction including maxillomandibular reconstruction is a challenge toward answering the crucial question: What is eating?

9.2.6.4 Mandibular Reconstruction with a Prefabricated Osseous Free Flap Using a Three-Dimensional Digital Model

For successful mandibular reconstruction, it is important that the continuity lost in the mandibular bone due to mandibulectomy be restored precisely and for donor bone shaping to complement the mandibular defect. The vascularized fibula first reported by Hidalgo [95] has been a preferred donor site because of its length and versatility, and many hospitals and medical centers mainly use vascularized fibular osteocutaneous flaps for mandibular reconstruction.

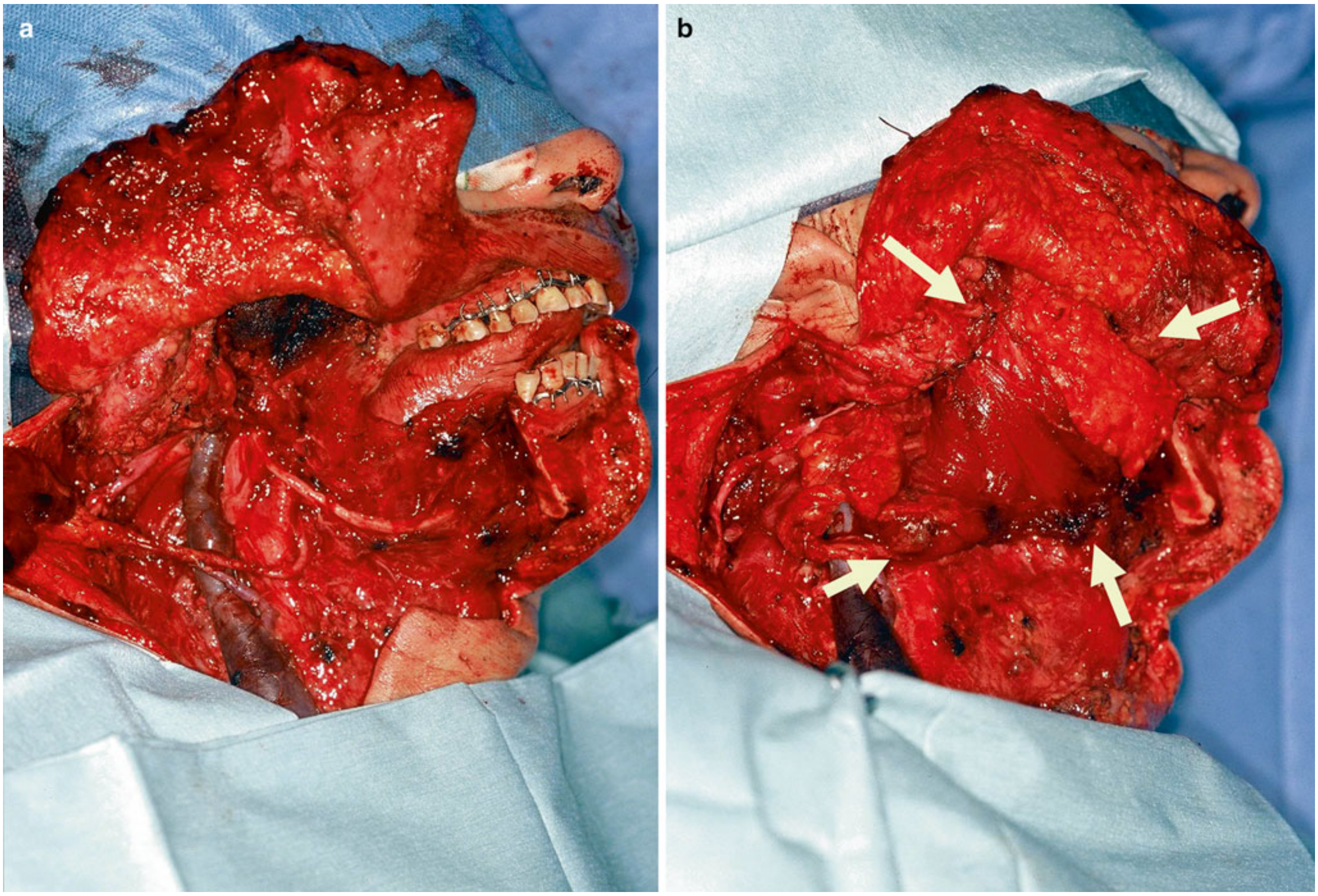


Fig. 9.37 Strategy 4 for mandibular reconstruction: reconstruction after hemimandibulectomy. (**a**) Hemimandibulectomy. (**b**) Aesthetic facial contour reconstruction with a rectus abdominis musculocutaneous flap alone

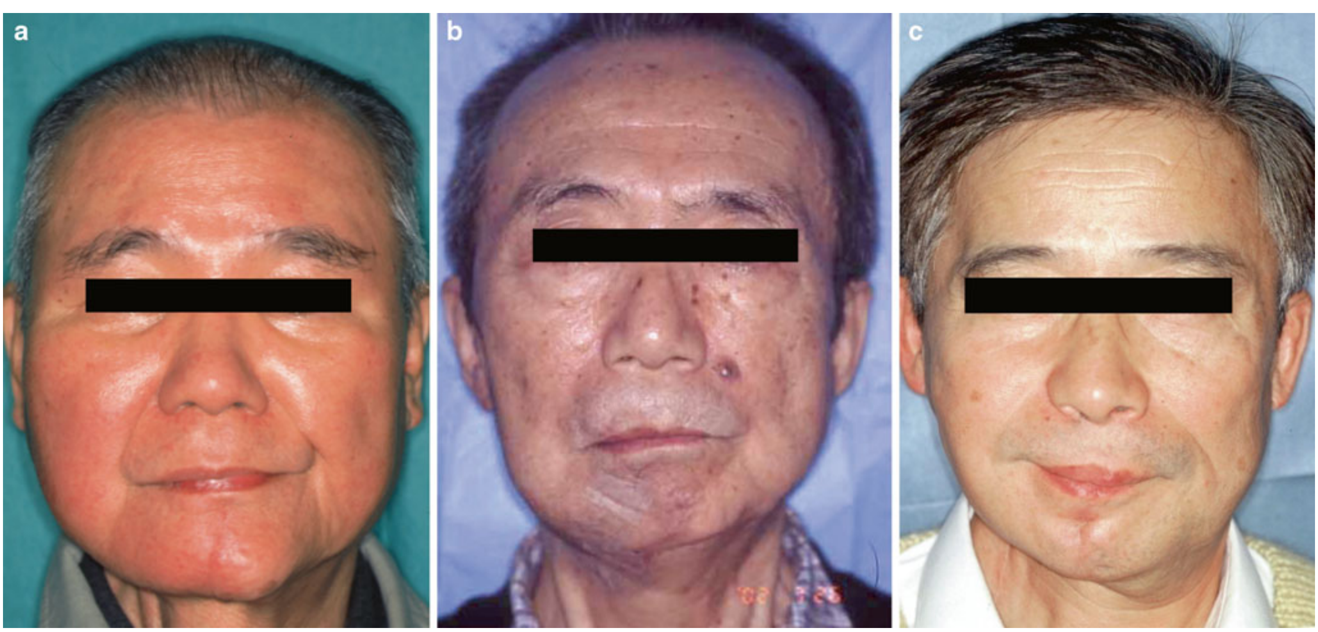


Fig. 9.38 Results of aesthetic facial contour reconstruction after hemimandibulectomy with a rectus abdominis musculocutaneous flap. (**a**) Seven years postoperative. (**b**) One year postoperative. (**c**) One year postoperative

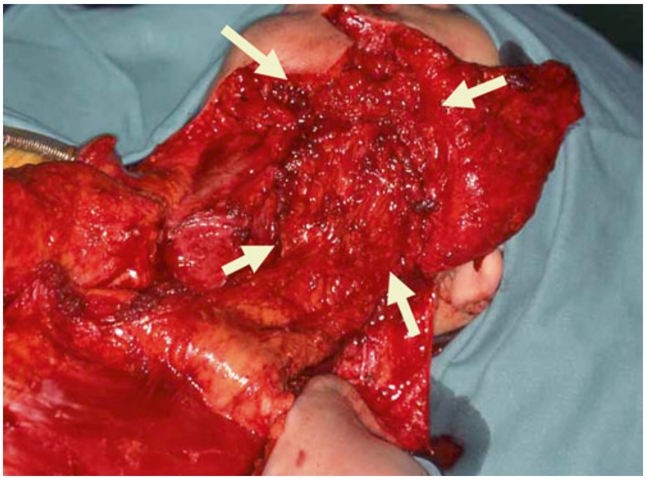


Fig. 9.39 Aesthetic facial contour reconstruction with a pectoralis major musculocutaneous flap alone

Unlike reconstruction of some other defects, mandibular reconstruction demands a high degree of precision because of the spatial and functional constraints of the mandible. When fibular osteotomies are required for a mandibular defect, mandibular reproduction at the time of reconstruction is difficult, the operation time is long, and the manipulation requires high-level proficiency. In an attempt to overcome these problems, preoperative surgical planning (model-based surgery) using a prefabricated stereolithographic mandibular model (SLMM) is a useful technique. Furthermore, computer-aided design software can be used to not only maximize the precision of bony osteotomies, which helps to recreate the shape of the mandibular arch, but also improve the overall efficiency of the reconstructive process (Fig. 9.42a, b). The prefabricated model clarifies the form and state of the diseases, shortens the operation time, and reduces operative blood loss [96–99].

In the preoperative state, a prefabricated SLMM constructed preoperatively by three-dimensional (3D)-CT and computer-aided virtual preplanning is used to accurately and promptly perform mandibulectomy and fibular osteotomies. Replicas of the mandible and fibula (acrylic plastic or plaster of Paris) are also made preoperatively using a 3D printer for model-based surgery (Fig. 9.43). Surgical guides are also prefabricated to decide on the line of mandibular resection (Fig. 9.44). A precisely simulated, postreconstructive mandibular model with fibular replacement is also made using model-based surgery (Fig. 9.45), and the number and lengths of harvested fibula can be planned.

During the operation, in order to avoid malocclusion and displacement of the condylar head after mandibulectomy, a 3D adjustable fixation device is applied to fix the parts of the mandible to be preserved, and, then, the surgical guide is matched to the mandibular bone by setting it preoperatively (Fig. 9.44). Segmental mandibulectomy is performed according to the planned line of resection with the surgical guide. Segmental mandibulectomy and fibular harvesting are performed simultaneously by maxillofacial and orthopedic or plastic microsurgical teams. After mandibulectomy, the harvested fibula is shaped with several osteotomies to fit the mandibular defect using a prefabricated reconstruction model

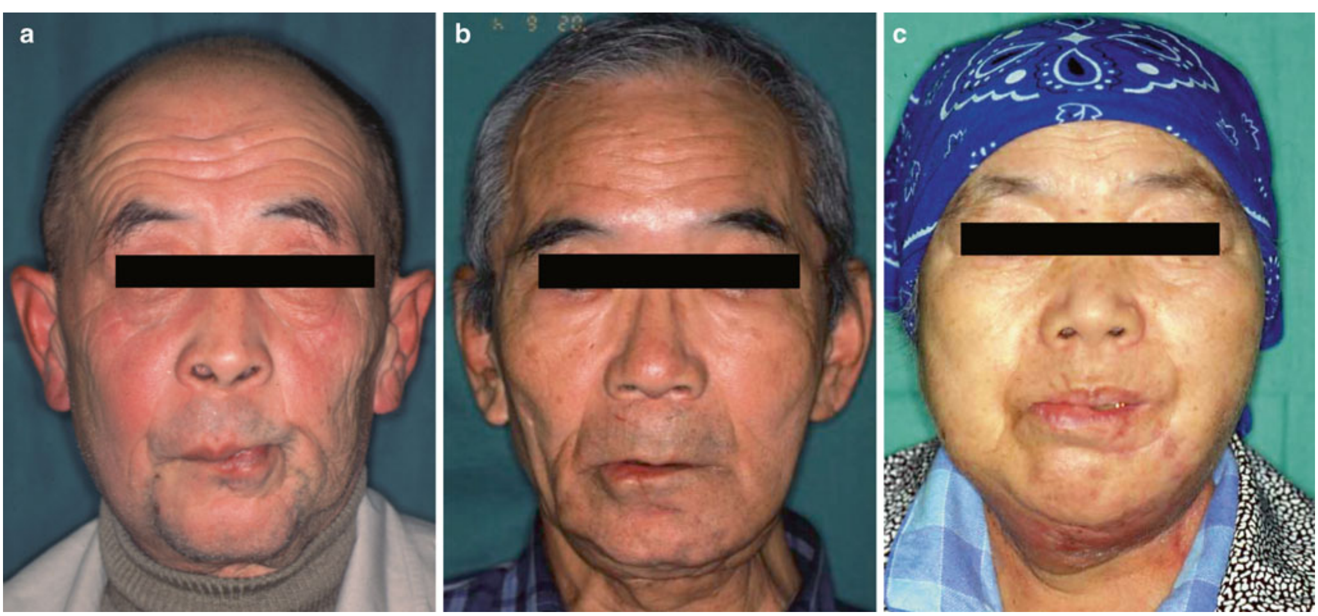


Fig. 9.40 Results of aesthetic facial contour reconstruction after hemimandibulectomy with a pectoralis major musculocutaneous flap. (**a**) Six years postoperative. (**b**) Five years postoperative. (**c**) One year postoperative

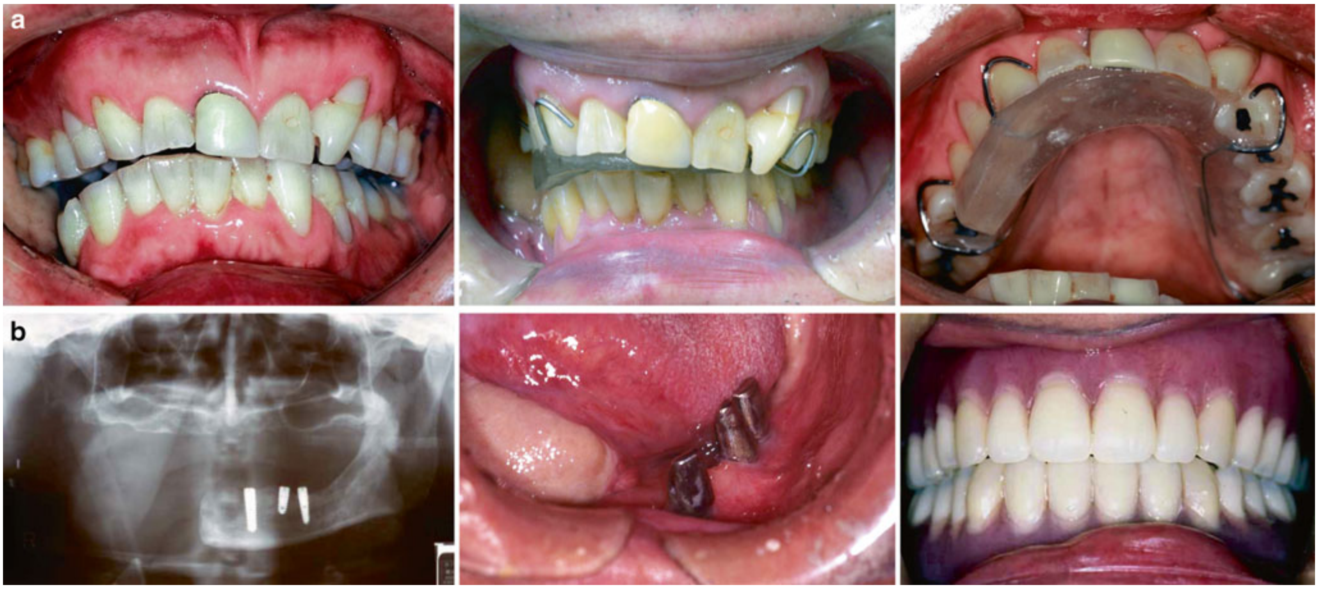


Fig. 9.41 Application of dental implants or palatal lump. (**a**) Palatal lump. (b) Dental implants

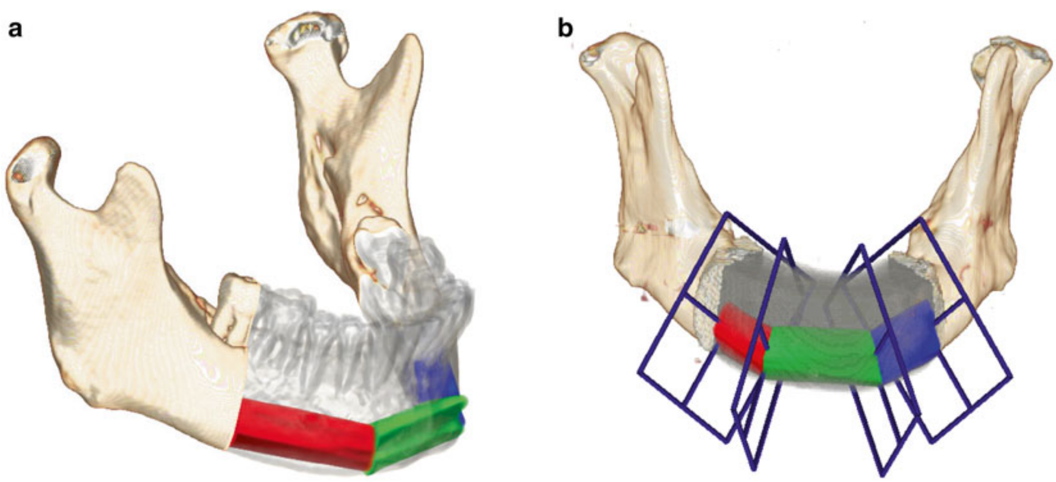


Fig. 9.42 (**a**) Computer-aided virtual surgical planning. (**b**) Planned resection margin with surgical guides

and fibular osteotomy guide template (Fig. 9.46a, b), and it is fixed to the remaining mandibular bone with a titanium mini plate (Fig. 9.47). Next, the graft is anastomosed to the recipient site vessels after fixing the grafted bone (Fig. 9.48).

The SLMM technique has been reported to be useful [97–99]. Using it, we can perform model-based surgery to simulate the resection range and fibular osteotomies and facilitate accurate and prompt mandibulectomy and fibular osteotomy during the operation. In addition, the prefabricated reconstructed model is helpful for recreating the symmetry of the mandible postoperatively.

The mandibulectomy is performed according to the planned line of resection with a surgical guide, and the mandible is reconstructed with more accurate shaping of the harvested fibula, in accordance with the configuration of the virtual graft in the prefabricated SLMM.

This procedure using a SLMM can effectively facilitate mandibular reconstruction surgery, and it is useful to increase the accuracy and shorten the operation time, achieving satisfactory aesthetic results. This technique is simple, effective, and helpful for surgeons performing not only mandibular but also maxillofacial reconstructions [100].

Fig. 9.43 Craniofacial skeleton and fibula models (acrylic plastic or plaster of Paris) were made preoperatively based on 3D-CT

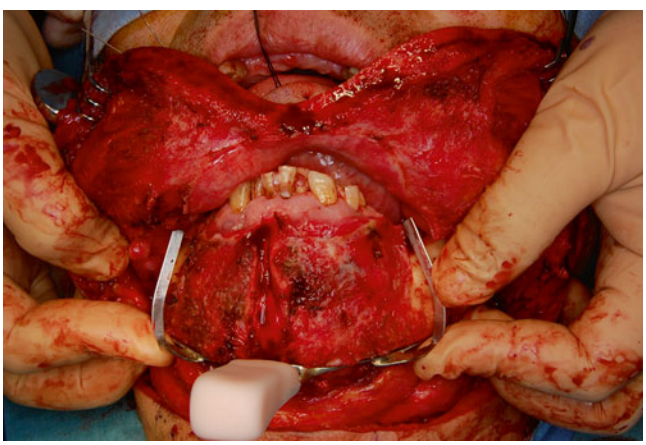


Fig. 9.44 A surgical guide was also prefabricated to decide on the line of mandibular resection

9.2.6.5 Double-Barreled Vascularized Fibula Graft for Mandibular Reconstruction

The vascularized fibula flap is ideal for mandibular reconstruction and has become the most popular reconstruction method after mandibular resection, because it generally provides adequate bone graft length and can be easily contoured by multiple osteotomies to recreate the proper mandibular curvature and osseointegrated implant insertion is easy.

However, the main disadvantage of the fibula is its limited width, which is not suitable for patients with a large difference in height between the neomandible and the dentulous or nonatrophic mandible [101, 102]. Using the single fibula bone may produce a height discrepancy between the native mandible and the grafted fibula that results in subsequent difficulty in wearing conventional dentures or osseointegrated implants [103]. Because the low height of the reconstructed segment creates a large distance to the occlusal plane and a large vertical dimension for the prosthetic device, this evokes high leverage forces, which can be detrimental to the implants in cases of solely implant-borne superstructures, as well as to supporting teeth in free-end hybrid situations, especially if the crown/fixture ratio is greater than 1:1 [104]. Moreover, patients are not satisfied with the postoperative facial appearance after reconstruction of the symphysis because of the collapse of the cheilion and lower lip [105].

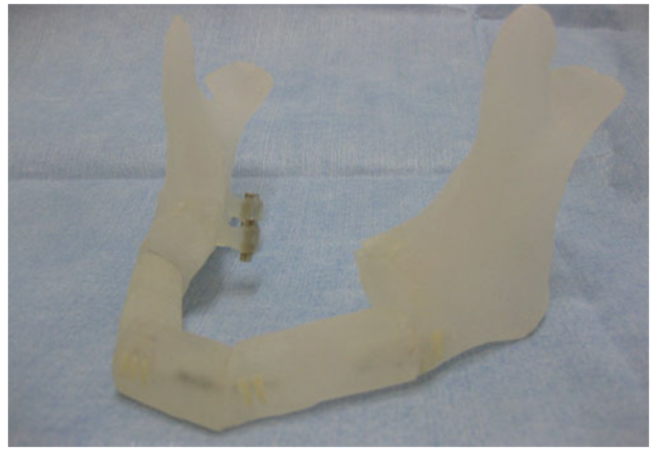


Fig. 9.45 A precisely simulated postreconstructive mandibular model with fibular replacement was also made employing model-based surgery

Then, to avoid a large vertical dimension of the prosthetic superstructure, it is good to use a long fibula graft that is halved and folded onto itself to increase the height of the neomandible [106]. The basis for the use of the double-barreled graft is that the height of the mandible is at least twice the diameter of the fibula; otherwise, the reconstructed segment would be too high. If the mandible is within twice the diameter of the fibula, the fibula will be segmented and used as a one-and-a-half fibula. The average thickness of the fibular diaphysis is about 10 mm, and the height of the segment is established from the panoramic radiograph and 3D-CT scans of the head and neck.

Surgical Planning

Preoperatively, a prefabricated stereolithographic or plaster of Paris mandibular model (replica) of the mirror images of the contralateral unaffected mandible is prepared using CT data and computer-aided design/computer-aided manufacturing technology. The extent of the mandibulectomy, the length of fibula required, the osteotomy sites of the fibula,

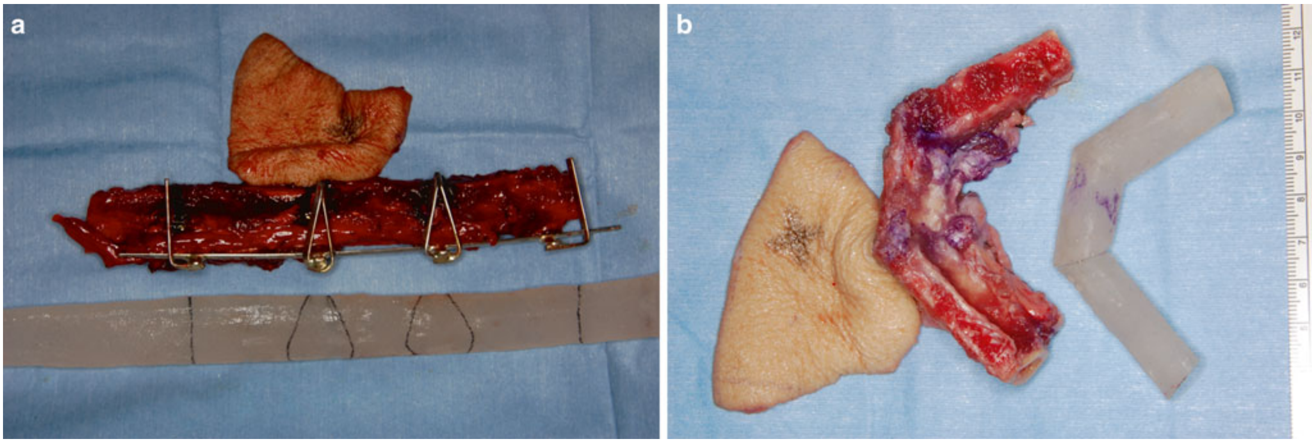


Fig. 9.46 After mandibulectomy, the harvested fibula was shaped with several osteotomies to fit the mandibular defect using a prefabricated reconstruction model and fibular osteotomy guide template (**a**, **b**)

Fig. 9.47 Shaped harvested fibula was fixed to the remaining mandibular bone with a titanium mini plate

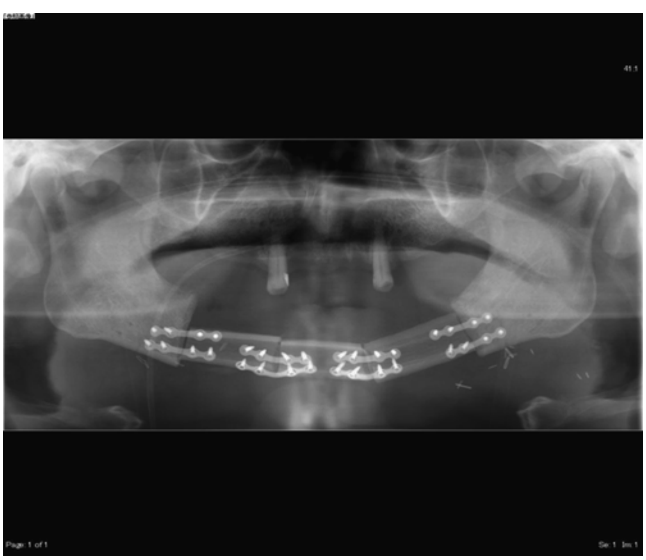


Fig. 9.48 Panoramic radiograph of the reconstructed mandible at 12 months postoperatively

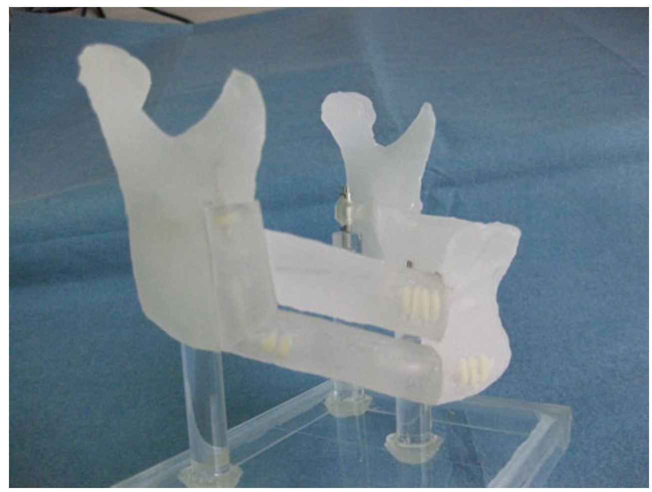


Fig. 9.49 A prefabricated stereolithographic or plaster of Paris mandibular model (replicas) is prepared preoperatively by use of the CT data and computer-aided design/computer-aided manufacturing technology. Postreconstructive mandibular model with fibular replacement was also made

and the site of double barreling are determined with these replicas (Fig. 9.49).

Operative Procedure

Segmental mandibulectomy, harvesting of the fibula osteocutaneous flap, and mandibular reconstruction are performed according to the presurgical planning. In cases in which the soft tissue defect is in the intra- or extraoral region and requires reconstruction at the same time, a fibula flap is harvested including the skin paddle in the distal third of the lower limb with careful protection of the perforators. The harvested fibula is formed with some osteotomies to fit the mandibular defect without damaging the vascular bundle, using the prefabricated reconstruction model. The anterolateral

Fig. 9.50 The double-barrel fibula graft was shaped with several osteotomies to fit the mandibular defect using a prefabricated reconstruction model and fibular osteotomy guide template

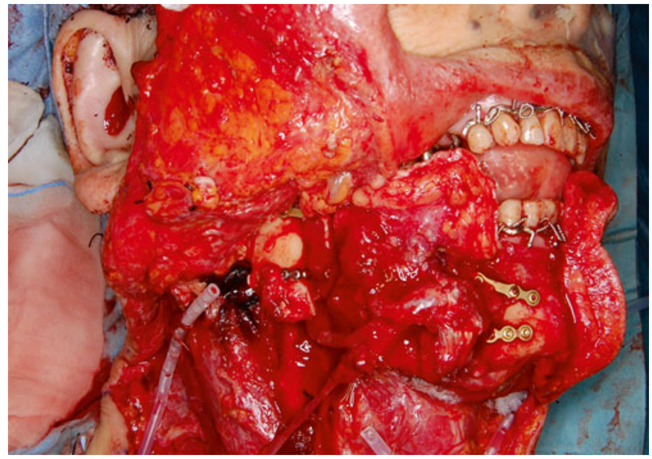


Fig. 9.51 The lower barrel of the osteotomized fibula is partially fixed into the defect with mini plates so that the locations of osseointegrated dental implants can be planned on the upper barrel

surfaces of two osteotomized bones are folded into contact to form the double barrel. At the folding point, an approximately 1 cm portion of the fibula is discarded, and periosteal continuity is maintained to prevent stretching, compressing, kinking, or twisting of the vascular bundle (Fig. 9.50). It is also possible that the segmentalization of the fibula at the folding point by using a single vertical osteotomy and reflection of about 2 cm of periosteum at this point without the removal of any bony segment will reduce the operative time and the risk of injury to the vascular pedicle with no loss of bone stock. At the curving point, the fibula is contoured by wedge osteotomies and fit to the mandibular defect using a prefabricated reconstruction model. The lower barrel of the osteotomized fibula is then partially fixed into the defect with mini plates so that the locations of osseointegrated dental implants can be planned on the upper barrel [102, 105]. At that time, the upper barrel is located slightly more lingually than the lower barrel to avoid a crossbite. After the neomandible is created, anastomoses are performed between recipient and peroneal vessels (Figs. 9.51 and 9.52).

Microsurgically anastomosed bone grafts can develop a solid union by 4 weeks after transfer so that functional loading of implants is possible 4–6 weeks postoperatively [107]. The fibula is a long bone, with a thick cortex. It has a denser structure than the scapula, radius, or iliac bone, and it is therefore more suitable for supporting dental implants [108]. The implant-bearing bone of the double-barreled graft is a more suitable distance to the occlusal plane of the adjacent dentate mandible than the bone of the conventional single fibula graft (Fig. 9.53). This reduces the height of the prosthetic superstructure and diminishes unfavorable lever arm forces on the implants in cases of solely implant-borne superstructures, as well as to the supporting teeth in free-end hybrid situations [106].

Fig. 9.52 Panoramic radiograph of the reconstructed mandible with double-barrel fibula graft at 6 months postoperatively

In the case of a mandibular defect larger than 10 cm, the double-barreled technique is not suitable, because the fibula length usually required during bone harvest is 24 cm, which would result in higher risk of donor site morbidity. In the case of a larger defect, as for reconstruction of the mandibular body and ramus, the partial double-barreled fibula graft can be applied. The mandibular body and ramus are reconstructed with a medial fibular fragment, and the remaining fibula is halved and folded into part of the medial fibula to increase the vertical height [109]. In the symphysis, the partial double-barreled fibula graft is performed to support the lower lip and cheilion (Fig. 9.54). For patients with

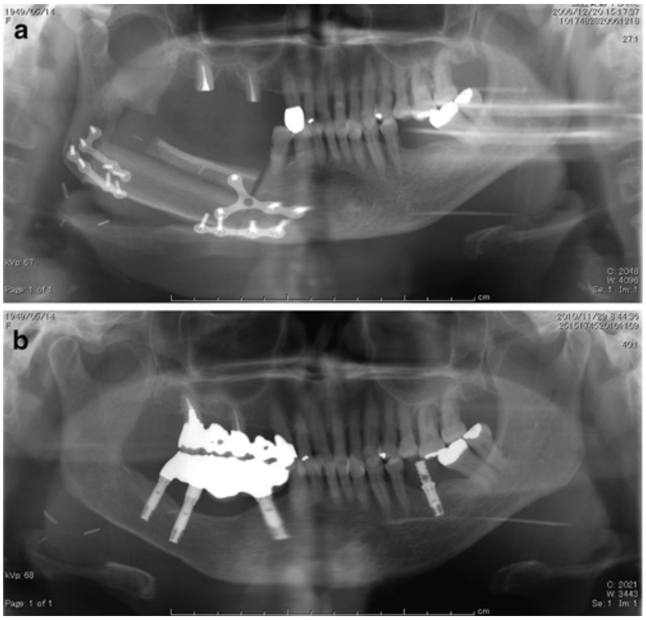


Fig. 9.53 Panoramic radiograph reveals the bone union of the native mandible and the double-barrel fibula graft 6 months after surgery (**a**) and positive osseointegration between the dental implants and fibula 12 months after initial surgery (**b**)

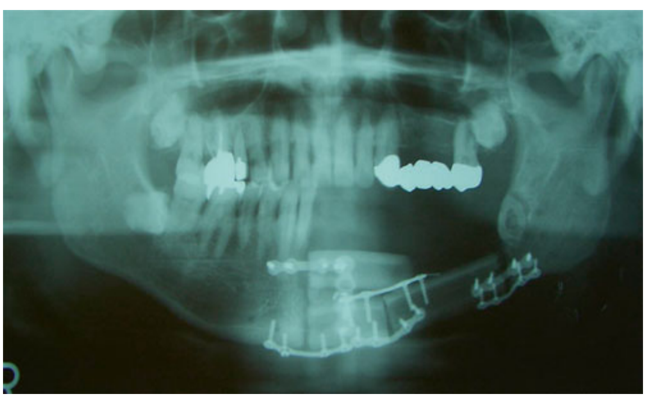


Fig. 9.54 In the symphysis, the partial double-barrel fibula graft is performed to support the lower lip and cheilion

preservation of the mandibular lower border, a double-barreled fibula graft is used as an onlay graft instead, with enough vertical allowance for dental rehabilitation.

The advantages of using the double-barreled fibula graft in mandibular reconstruction can be summarized as follows: (1) the greatest bone length to fold in the double barrel; (2) no delayed operation compared with the onlay bone graft and distraction of the fibula for achieving the height of the native mandible; (3) greater suitability for osseointegrated implantation than the iliac bone graft; (4) a unique blood supply that allows folding of bone struts and does not affect blood flow through the supplying vessels and the medullary cavity; and (5) low donor site morbidity and the possibility of using a skin paddle in the reconstruction of a composite defect [103, 110].

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