Flaps Used for Reconstruction After Resection of Oral and Pharyngeal Cancers

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Abstract:
Several techniques have been developed to reconstruct oral and pharyngeal defects following surgery, in order to restore function and cosmesis. These are primary closure, skin grafts, local transposition of skin, mucosa and/or muscle, regional flaps and free vascularized flaps. Because of the 'bulky', pedicled nature and problems with the donor area of locoregional flaps, and consequently frequently unsatisfactory functional results, free vascularized flaps have gained popularity during the last decade. The authors review the current options available to give physicians, who are not experienced in the field of reconstruction in the head and neck, an impression of the range of techniques available for reconstruction of oral and pharyngeal defects following tumor resection. For reconstruction of oral cavity and pharyngeal defects, fasciocutaneous (e.g. radial forearm and anterolateral thigh flaps) and myocutaneous free flaps (e.g. rectus abdominis and latissimus dorsi) have proven to be very reliable. Free vascularized osteocutaneous flaps (e.g. fibula and iliac crest) permit reconstructive options for bony defects of the mandible or maxilla that can be adapted to a variety of defects. Depending on the site, size and involved tissues of the surgical defect and patient factors, a variety of reconstructive options are available. For both soft tissue and bony defects of the upper aerodigestive tract, microvascular free flaps provide good functional outcomes.
Keywords: Reconstruction, Flaps, Oral and Pharyngeal cancer.

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Introduction:

One of the most common cancers of the head and neck region is the oral cavity cancer. Globally, over 300,000 people are diagnosed with oral cancer each year, being the eight most common cause of malignancy. In early stages, a cure is possible with minimum morbidity; unfortunately, such disease is not usually diagnosed until it has set to an advanced stage impacting survival, including in that stage morbidity due to tumor

invasion or tissue devastation, and its consequent treatment negatively impacts the quality of life **(1)**.

With that in mind, every effort must be done to reconstruct the defect of the primary

resective procedure in order to restore swallowing, speech, esthetics, and color match, among others. A complete evaluation must be done to define the optimal reconstruction without compromising the oncological resection and first of all evaluating each patient in terms of age, functional capacity, adjuvant therapies, airway protection, survival, etc. **(2)**.

There are many options to reconstruct the defect, so a comprehensive approach should be planned, principally considering its location in the oral cavity, the size of the anatomical structure resected, as well as the consequence of the defect that may affect a complex functional unit that could include the mucosa, muscle, bone, skin, or a combination of them, which additionally may develop a continuity solution that creates a communication between the oral cavity with the neck and its subsequent salivary fistula, infection, risk of a major vessel blood bleeding or carotid blowout, and death. The reconstruction might be done just with a primary closure and skin graft or may be left to heal by second intention with no closure; some cases will need a pediculate, local, or regional flap, and in complex and huge defects, a microvascular free flap might be needed **(3)**.

Currently there is a trend to perform a microvascular reconstruction for most of the defects, but even in a two-team approach, the microvascular reconstruction increases the cost and duration time of the surgery; furthermore, some health centers lack surgeons with the necessary skills to perform a microvascular surgery **(4)**.

I. Anatomic landmark

The oral cavity begins at the lips and ends at the anterior surface of the faucial arch. It is lined by squamous epithelium with interspersed minor salivary glands. It contains the lips, buccal mucosa, mandibular and maxillary alveolar ridge, retromolar trigone, hard palate, floor of the mouth, and anterior oral tongue. Motor innervation of intrinsic musculature is supplied by the hypoglossal nerve and sensation is provided by trigeminal nerve V2 and V3 branches. The sensation of the anterior two-thirds of the tongue is provided by the lingual nerve (CN V3), and its taste comes via the chorda tympani (CN VII) **(5)**.

II. Defect characteristics

Assessing the characteristics of the defect is the first step to decide which is the best option to reconstruct. The size and specific subsite of the primary resection including its function will determine the need for subsequent reconstruction. Small or medium defects may not disturb function, so minimal intervention to reconstruct is necessary; on the other hand, composite defects that include several units and structures like the muscle, mucosa, bone, or even skin can affect the function in many ways, so in order to restore it, a specific composite tissue is needed, which is also a technique to avoid scars, nonfunctional tissue, or retractions with its subsequent unit dysfunction. Previous treatment like chemotherapy and especially radiation will also entail special needs in terms of reconstruction since providing a new normal tissue is essential to prevent local

complications like fistula, dehiscence, infection, or a permanent scar **(6)**.

III. Specific subsites

With the aim to choose correctly from a range of different technics, although it is frequent to face a combination of subsites and structures after surgical resection, each subsite must be considered independently to assist the decision **(7)**:

A. Floor of mouth

The subsite floor of mouth (FOM) is limited anteriorly by the inferior alveolar ridge, posteriorly by the ventral surface of the lingual tongue, and laterally by the anterior tonsil pillar. The FOM avoids the spillage of saliva to the neck and is also necessary to support the tongue in speech and deglutition as well as to maintain the humidity of the mouth due to the big amount of minor salivary glands and to the outlet of the submandibular gland duct. The resection may result in a small or big defect that could or could not include the mucosa, bone and skin **(8)**.

The main goal of reconstruction is to restore the anatomic limits of the sulcus to avoid communication with the neck with the corresponding spillage of saliva and food, and to avoid retraction or fixation of the tongue then maintaining the adequate tongue mobility to support articulation and speech as well as allowing the tongue to move freely to push the food bolus back **(9)**.

- **Small defects**

A very small deformity could be let alone without closure and permit healing by second intention with a granulation tissue. A facial artery myomucosal flap (FAMM), which blood supply is provided by the facial artery, could similarly be used for a defect limited up to a width of 2 cm and permit the primary closure of the donor site. A split-thickness skin graft (STSG) or a full-thickness skin graft (FTSG) could be used for a defect smaller than 3–4 cm that does not spare the suprahyoid musculature or expose the bone. The graft is usually secured with a pad dressing, which is removed 6–7 days after surgery. Usually re-mucosalization can be expected, and complete healing is obtained in about 4 weeks. The restriction to the skin graft is related to the difficulty to maintained it insetted due to its exposition to swallowing movements **(10)**.

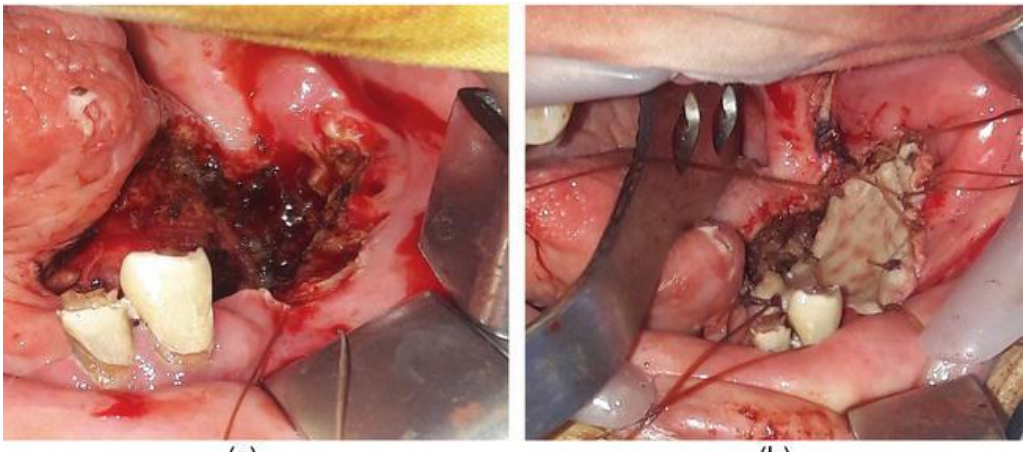

Figure 1: (a) FOM resection and (b) skin graft (11)

The advantage to let the defect to granulate by itself is the shortest time of the procedure; however, it usually takes up to 3 weeks to obtain a complete healing, implying some minor disturbances for the patient including pain and difficulty to swallow. The disadvantage of the graft is the secondary scar of the donor site but is off-setted by the result in the zone of resection and a shortened time of recovery **(12)**.

- **Medium defects**

For FOM defects up to 6 cm which may include a limited bone exposure, a regional pediculate flap can be employed to reconstruct; the most used are the submental (SMF) and the supraclavicular flap (SCF). Additionally, in that kind of defects, especially when postoperative radiotherapy is projected, a pediculate flap must be planned if possible **(13)**.

- **The submental pediculate flap**

The submental pediculate flap is vascularized by the submental artery, a branch of facial artery. It must include a segment of the anterior belly of digastric to perfuse the overlying skin through perforants. The amount of tissue available to harvest depends on the pitching test that predicts the possibility of primary closure of the donor site. This flap entails to avoid sacrifice of its vascular pedicle so the clue is that it should be planned and harvested at the beginning of neck dissection **(14)**.

Sometimes nodal disease levels Ia and Ib limit the ability to harvest the submental flap without impairing the oncological resection. The main advantage of this flap is the proximity between the donor site and the floor of the mouth so it can be insetted easily; the main problem is that if it is harvested with a big amount of muscle, the result once insetted may be a bulky flap resulting on swallowing and speaking problems **(15)**.

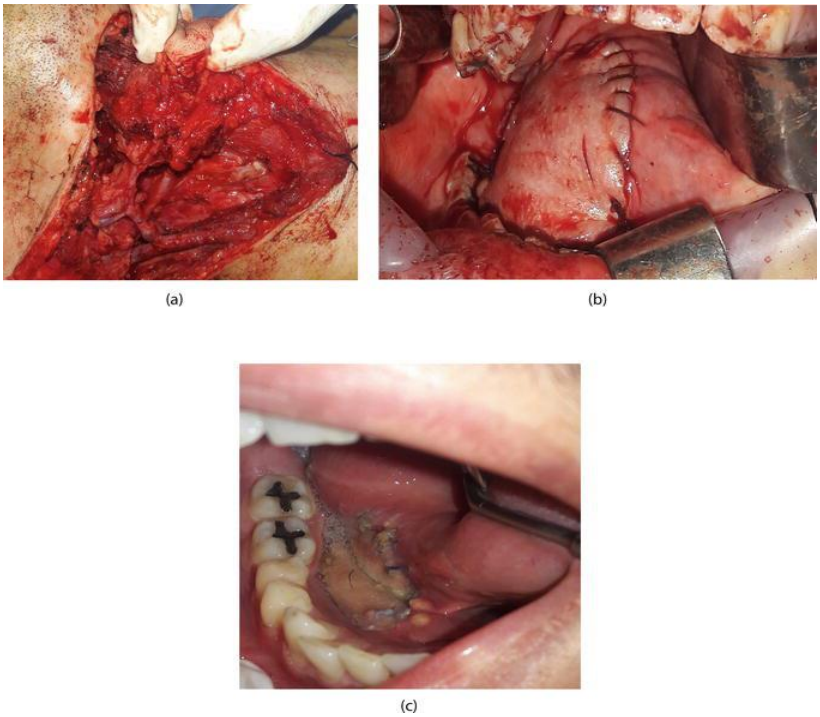

Figure 2: (a) Submandibular flap harvest, (b) submandibular flap insetting, and (c) final result (11)

- **The supraclavicular pediculate flap**

The supraclavicular pediculate flap is an alternative to the submental flap particularly when a larger amount of skin is needed and in cases of huge nodal disease in level I. The flap can be raised if there are no bulky nodes in the neck in the level IV. The SCF is based on axial circulation from the supraclavicular artery which arises from the transverse cervical artery and in a small percentage of cases from the suprascapular artery. It can be used to reconstruct soft tissue defects measuring up to 20 cm in size after tumor excision, being an advantage over the SMF in FOM defects. As well as the submandibular flap, usually there is low donor site morbidity permitting its primary closure, and of course the main restriction is related to neck dissection in level IV due to the possibility to injure the cervical transverse pedicle impairing its vascularization **(16)**.

Another advantage is that it can be raised at the end of the surgery after neck dissection or in cases when you do not plan to dissect level IV or there is no doubt about the probability to alter its vascularization; it can be harvested at the beginning of neck dissection once you have defined the size of the defect you need to reconstruct **(Figure 3) (16)**.

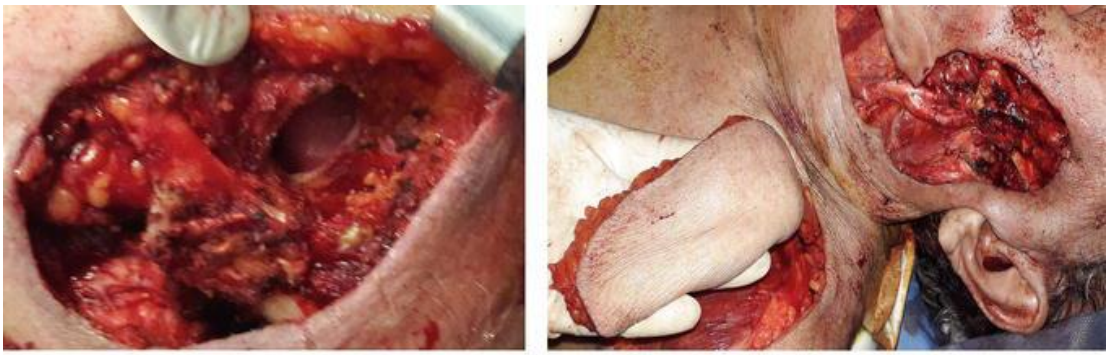

Figure 3: (a) Yugal mucosa resection and (b) supraclavicular flap harvest (11)

The main complication for both flaps is the loss of the flap due to arterial or venous ischemia. To prevent that fatal complication, a meticulous dissection is needed to preserve its vascularization during harvesting and trying to avoid tension during insetting. When only venous congestion is present, the flap may recover without additional intervention, but if ischemia is established, the lost flap must be retired to avoid infection and systemic complication, and if possible, a new way of reconstruction must be considered **(17)**.

- **Large defects**

In a bigger or composite defect of FOM, the reconstruction can be a challenge, especially when the bone, tongue, and skin are involved. It is important to assess preoperatively the degree of bone invasion to suitably plan possible mandibulectomy requiring additional bone tissue for reconstruction. If only soft tissue is required,

a radial forearm free flap (RFFF) or an anterolateral free flap (ALT) can be harvested, but if the bone required a fibula free flap (OCFF), the iliac crest flap (VICF) or the scapula free flap (SFF) are the main options **(18)**.

- **The radial forearm free flap**

The radial forearm free flap based on the radial artery provides a pliable and thin skin that makes the RFFF an ideal choice for reconstruction of the floor of the mouth; in few cases if a small marginal segment of the bone is required, a composite radial free flap including a limited segment of radial bone can be obtained; if furthermore the tongue is compromised, the RFFF can be insetted with a bilobed design allowing one lobe to restore the volume of the tongue and the second one to resurfaces the FOM **(19)**.

The RFFF is considered the battle horse in microvascular reconstruction due to the skin quality, the length of the pedicle, the size of the vessels, and the easy preoperative assessing since it does not require vascular images just the Allen test to evaluate distal perfusion of the hand provided by palmar arch, and additionally, it is easily harvested. Its limit is usually referred to the size in cm that can be harvested (up to 20 × 12 cm), but it almost never applies as an exception in oral cavity reconstruction. The principal risk and disadvantage of the osteocutaneous radial free flap is the risk of fracture when a segment of the bone is included in the RFFF, so prophylactic fixation of the radius with the appropriately sized 2.4-mm locking reconstruction plate is performed to avoid fracture of the donor site **(20)**.

The disadvantages of this flap are the hairy non-mucosalizing skin paddle, the cosmetic deformity of the donor site due to skin grafting that sometimes let an ugly scar and, in some cases, a bulky dysfunctional flap. The hairy skin can atrophy after radiation, or it can be treated with laser peeling, so in most of the cases, the final reconstruction result is excellent. To improve the cosmetic result of the donor site, any effort must be done to preserve the paratenon over the flexor tendons; setting a 4 mm better than a 2 mm skin graft over the donor site with an appropriate plaster bandage for temporal immobilization is also suggested. This usually ends in a better cosmetic result. Finally, to avoid a bulky dysfunctional flap, planning an adequate design of the size and form of the flap before harvesting is advisable **(21)**.

- **The ALT flap**

The ALT flap is also proposed as an excellent recourse when only the skin and soft tissue are required, especially in thin patients; it is advocated by many as a first choice to avoid the donor site morbidity. This flap pending on a septocutaneous branch coming from the lateral circumflex femoral artery involves a more difficult dissection due to the smaller diameter of the vessels **(22)**.

It can be harvested thinner (supra fascial) or thicker (subfascial) depending on specific needs of skin and soft tissue. One important advantage is that can be raised even bigger allowing primary closure. The disadvantage of a hairy non-mucosalizing skin paddle is like the RFFF, and in an obese patient the flap is unacceptably bulky. Another disadvantage occurs when the nerve branch to the vastus lateralis muscle is cut unnoticed causing knee instability. In rare occasions the donor site needs to be skin grafted **(23)**.

- **The osteocutaneous fibula free flap**

The osteocutaneous fibula free flap is considered by many, the gold standard when oncological resection includes a large segmental mandibular defect that may or no include skin and is generally the first choice and the iliac crest and scapula are alternatives chiefly in segmental small defects. The osteocutaneous fibula free flap (OCFF) based on peroneal artery is a reliable, and versatile flap for mandibular reconstruction and is considered the gold standard in mandibular reconstruction. It usually offers enough length of bone and skin to reconstruct a partial or complete mandibular resection and allows to place bone-integrated implants **(24)**.

It is essential to plan its harvesting and design from the beginning at the outpatient clinic, since it is mandatory to perform limb vascular imaging studies to assess the normal vascular anatomy and avoid fatal vascular morbidity or ischemia of the donor limb after bone resection. It does not need to plate the remaining fibula that remains attached to the tibia, and if harvesting in the right way, it does not cause limb instability. As a norm, it is easy to harvest, and one-stage reconstruction can be performed **(25)**.

There are some downsides to it; first the size of the skin paddle is limited just to permit primary closure of skin donor site; but if needed it also can be skin grafted. Second the hairy and non-mucosalizing skin paddle that is placed intraorally could end in an disturbing sensation, usually temporally if radiation is added to the treatment, and third in cases of arterial or venous disease in the lower extremities or previous surgery, there is a formal contraindication for flap harvesting **(26)**.

- **The scapula free flap (SFF)**

The scapula free flap (SFF) based on the circumflex artery arising from the subscapular artery, which is a branch of the axillary artery in the upper thorax, similarly provides acceptable bone length while supplying significantly larger skin and soft tissue paddles (up to double in overall area). It is an excellent alternative to small and wide to medium defects when wide bone is necessary. The main disadvantage of this flap is the need of repositioning during the surgical procedure restraining a double team approach **(27)**.

- **The vascularized iliac crest bone flap (VICF)**

The vascularized iliac crest bone flap (VICF) has also been proposed as a new approach to reconstruct a mandibular deformity, especially in lateral mandibular defects. This flap is based on the deep circumflex iliac vessels and usually harbors consistent anatomy; the length of the vessel averages 8–10 cm, and its diameter averages 2–3 mm. Pending on specific reconstruction needs may be harvested as a full thickness bicortical or as a partial thickness unicortical bone, and its main advantage is the natural curved contour of the bone that is ideal for lateral mandibular reconstruction. It can be raised with skin or muscle when needed. The donor site morbidity is related to the local appearance deformity and the probability to develop a future hernia **(28)**.

B. Tongue

In the oral cavity the more common defects requiring reconstruction are those from glossectomies. The three-dimensional oncological resection needs adequate margins up to 1 cm, so the size of the defect may be variable, a quarter, half, near total, or

total and can be simultaneously related or not with other structures like the floor of the mouth, cheek, skin, or bone. Based on that, reconstruction may be just a primary closure, a local or a pediculate flap, or a simple or composite free flap **(29)**.

- **Small defects**

In cases of small defects up to one-third of the tongue, primary closure could be done **(Figure 4)**, and if needed, due to a small floor of mouth resection, a skin graft is added in order to avoid a scar combined with tongue fixation. Usually the functional results are optimal, but sometimes skin graft contraction and hyperpigmentation can result, or graft fixation may be inadequate leading to shearing and wound dehiscence **(30)**.

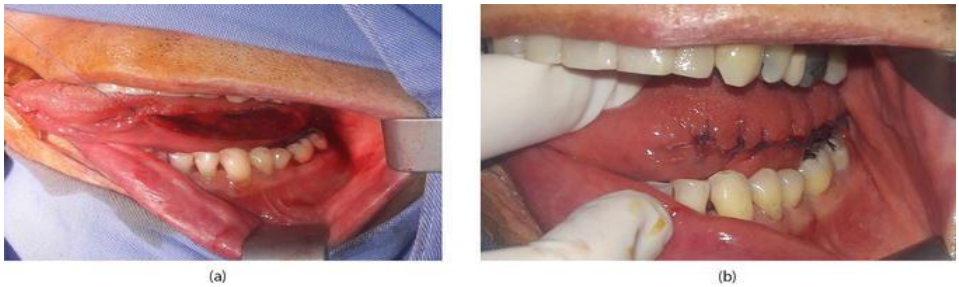

Figure 4: (a) Primary closure and (b) primary closure outcome (11)

- **Larger defects**
  - **Pediculate flaps**

In a bigger defect up to half of the tongue or particularly in a huge composite defect that may include the floor of the mouth, cheek, or both, a pediculate and free flap are the alternatives preferred. In a defect up to 6 or 7 cm, the pediculate submandibular flap can be harvested and is my first choice as long as the neck is N0 or N+ with no fixed nodes and small metastatic nodes **(Figure 5)**. It usually provides a non-bulky flap that can be harvested to cover the defect and can be tied to the tongue to allow mobility for swallowing and speech **(31)**.

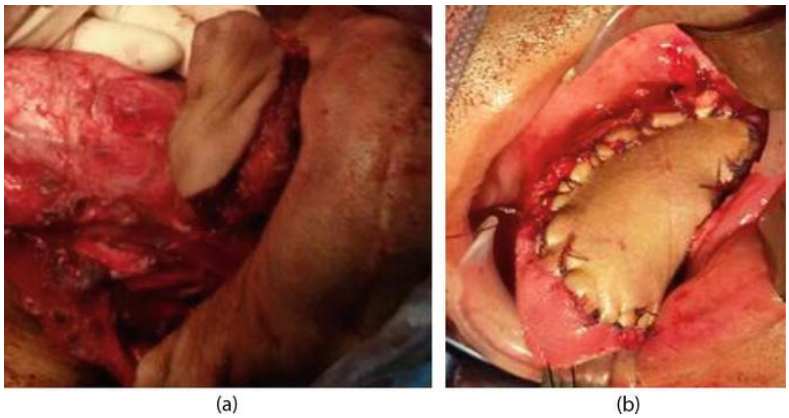

Figure 5: (a) Submandibular flap harvest and (b) submandibular flap insetting (11)

- **Free flaps**

In cases of a near total or total glossectomy that frequently is associated with composite resections of the floor of the mouth, cheek, skin, or mandible, a free flap is required **(Figure6)**. Speech and swallowing functions after reconstruction for those defects remain disappointing due to the reduced mobility of the flap and the poor functional muscle quality, therefore, the more tongue musculature left, the better rehabilitation of speaking and swallowing will be achieved, and of course, a better functional outcome. The reason for that is that the coordinate movement of the tongue cannot be replaced, and the new tissue attached to the rest of the tongue relies on its mobility and just leaves a bulk (**32)**.

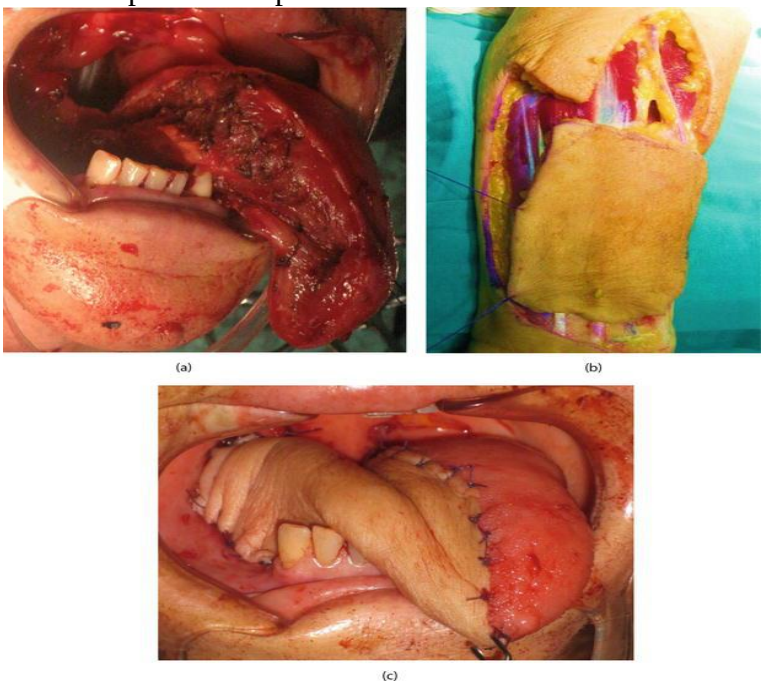

Figure 6: (a) Tongue defect after resection, (b) RFFF harvest and (c) RFFF insetting (11)

Figure 7: (a) ALT flap design and (b) ALT flap harvest (11)

- **Alternative options**

For selected patients in whom free tissue transfer is not an option, the pectoralis major myocutaneous flap offers a reliable reconstructive procedure following both primary and salvage surgery **(Figure** 81**8)**. This flap based on the thoracoacromial artery can be raised as a myocutaneous or fasciocutaneous flap. It is reliable, robust, and easily harvested in terms to tongue reconstruction and can provide muscle and skin to fulfill the tongue and floor of the mouth and effectively separate the oral cavity from the neck. It must be suspended across the mandibular arch by either suturing to the pterygoid musculature or securing to the mandible using drill holes to avoid and prevent the flap from falling **(33)**.

This flap is considered a horse battle in rescue setting when a free flap fails. When the defect includes mandible, during the reconstruction it must have keep in mind that mandible contributes to airway stability, oral competence, speech, deglutition and mastication, so the goal of this reconstruction must include the preservation of the ability to open the mouth, occlusion, and the restoration of the inter arch continuity solutions to promote dental implants and restore chewing as mentioned in floor of mouth defects extended to mandibula **(34)**.

Options in reconstruction include metal plates, non-vascularized bone grafts, osteomyocutaneous pedicled flaps, and osteocutaneous free flaps. Fixing soft tissues just with plates was widely used in the past and usually results in extrusion intraorally, external exposure or fracture of the plate up to 60% of the cases with a worst defect and a very poor functional outcome. Autogenous bone grafts from iliac crest, scapula, or calvarium usually end in no vascularization of the new bone and its atrophy even more if radiation is added to the treatment, and finally similar results as the plating alone are obtained, so similarly they are no more used **(35)**.

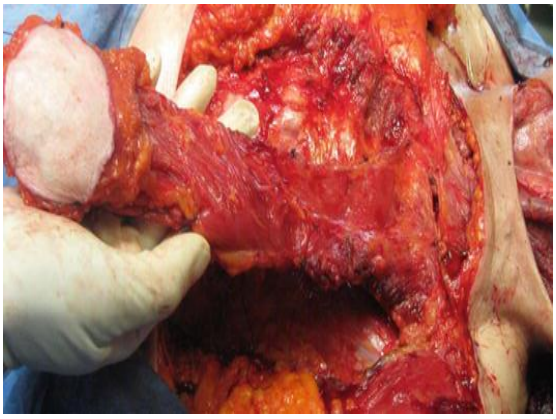

Figure 81: Major pectoral flap harvest (11)

Currently the gold standard in mandible reconstruction is the osteocutaneous free flaps and carries the same consideration as mentioned in floor of mouth reconstruction with a trend to perform a first time micro vascularized bone reconstruction with dental implants mainly in a previous dentulous young patient **(Figure 9) (36)**.

In an aged edentulous patient in the reconstruction setting, there is most likely no need to be aware for dental implants unlike dentulous young patient. Again, in selected patients with poor clinical condition and not suitable for a long procedure, a osteocutaneous pediculate flap such as a osteomyocutaneous trapezius flap or a bicortical parietal osteofascial pedicled flap can be perform providing a better functional result compared with just soft tissue coverage. Both flaps require experience, skills, and anatomic knowledge to harvest them in a short period of time but are an excellent alternative when needed **(37)**.

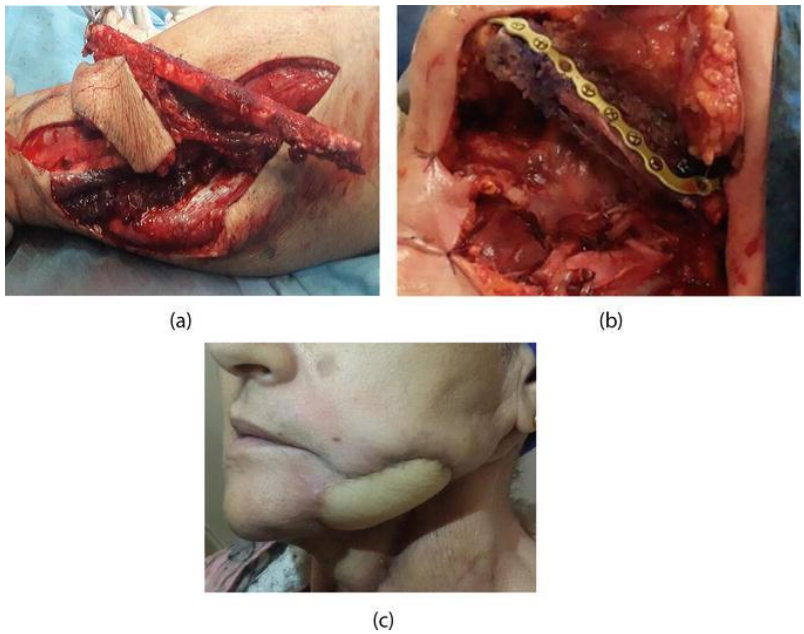

Figure 9: (a) FFF harvest, (b) FFF insetting and (c) FFF early postoperative outcome (11)

C. Cheek

The cheek resection is done less frequently except in some countries like India, where cheek cancer is frequent and as a consequence of chewing tobacco; usually its oncological resections leave a complex defect that includes skin and mucosa in an area where a functional lip is required to avoid food spillage. The consequent defect may be small or big and simple or composite associated to another oral cavity subsite resection. Small lesions of the cheek could be let alone to epithelize, but a bigger one will end in a scar and retraction, so a reconstruction must be done **(38)**.

In most of the cases a facial artery mucomucosal flap (FAMM) could be used. This flap based on a branch of the facial artery is elevated in the layer underneath the facial artery including the overlying buccinators muscle and a small portion of orbicularis oris muscle close to the oral commissure; it is rotated to cover the defect commonly restoring it, and the donor site could be primary closed or let it to heal secondarily without impairing its final functional result **(39)**.

A huge defect might need a pediculate flap such as submandibular or supraclavicular flap or even a microvascular free flap. Some encourage for the supraclavicular pediculate flap as the first option in this scenery, which usually provides a good amount of a non-bulky tissue without affecting oncological resection of node neck dissection in level Ia and Ib, and adducing that submandibular flap is too bulky to be placed it in this specific region **(40)**.

D. Hard palate

The extent of resection of hard palate is crucial to define the type and modality of reconstruction. The defect may be small and involve any portion of the hard palate, the premaxilla, or any portion of the maxillary alveolus with or without tooth-bearing or may be as huge as more than 50% of the hard palate. Many of the times, it is associated with partial or total maxillectomy so ending

in a complex defect. Small defects can be let just to re-epithelize with excellent results **(41)**.

For a bigger one, a skin graft can be used; the problem is to support it long enough to achieve its integration to the hard palate; sometimes, the flap is detached and lost in which case healing by second intention is required. Small to medium defects may demand to harvest a palatal mucoperiosteal flap (PMPF). This flap is based on the greater palatine artery; preserving this vascular pedicle allows to rotate it to resurface the mucosal defect **(42)**.

Its limit is related to the amount of tissue needed, and up to 3 cm can be covered with this flap. In a bigger 3–5 cm hole, also a submandibular pediculate flap could be used to cover it. In as much as in this location, there are no specific needs for muscle or for a thicker, soft tissue; any attempt should be done to assemble it with just enough muscle behind that guarantees skin perfusion by perforants preventing necrosis and providing a flat new tissue. A composite defect that includes the maxillary alveolus with tooth-bearing or partial to total maxillectomy will end in oroantral communication **(Figure 20) (43)**.

This type of reconstruction needs special considerations that are not the subject of this chapter and are best described in midface reconstruction; in general terms the main goal of the reconstruction is to restore chewing and solve the oroantral communication, so options for small include lesions and the use of an obturator that covers the opening avoiding leaks through the paranasal sinus and improving chew. As the aperture gets bigger, soft tissue flaps like a radial forearm free flap or an anterolateral thigh free flap are needed, and if dental implants are planned, microvascular osteocutaneous flaps obtained from fibula free flap or iliac crest free flap must be designed **(9)**.

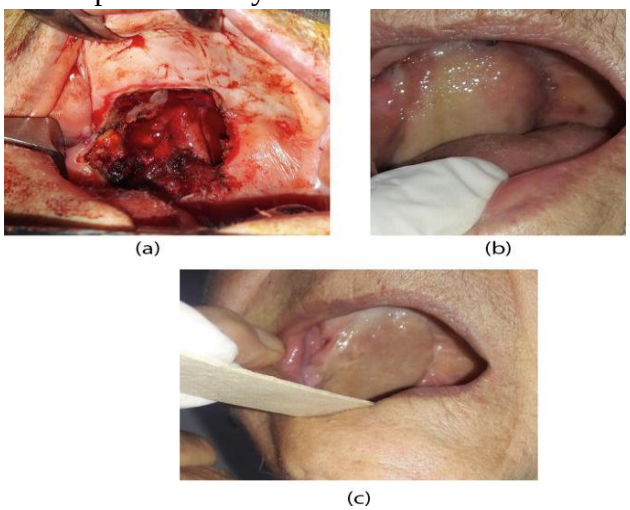

Figure 20: (a) Hard palate defect after resection, (b) hard palate outcome after 1 month reconstruction and (c) hard palate outcome after 2 years of reconstruction (11)

Reconstruction of pharyngeal defects

Oncologic management of the pharynx presents complex challenges for both ablative and reconstructive surgeons. The move away from surgical management of both laryngeal (VA study) and pharyngeal malignancy has meant that many patients eventually presenting to surgery do so in a salvage setting. With the advent of transoral robotic surgery (TORS), a reframing of the role of surgery in the management of pharyngeal malignancy is underway **(44)**.

The 5-year survival rate of pharyngeal squamous cell carcinoma (SCC) depends on tumor stage and human papillomavirus (HPV) status. Up to 60% of patients die within three years. However, beyond oncologic outcomes, functionality and quality of survival is an important determinant of therapy. The physiologic cost of surgery needs to be balanced against the well-known long-term effects of nonsurgical therapies. The role of the reconstructive surgeon is to manage short term perioperative problems and long-term functional outcomes to achieve the optimal quality of life result for the patient **(45)**.

The extent of defect determines the extent of reconstruction required. For small pharyngeal defects, primary closure or healing by secondary intention with the acceptance of some distortion of the local pharyngeal contour might be acceptable in the non-salvage setting. Post radiation granulation or primary repair, regardless of the defect size, is an unpredictable clinical scenario which should be avoided. Rates of pharyngocutaneous fistula (PCF) are related to the size and complexity of the defect and prior (chemo) radiation. The incidence of PCF range from 9–23% depending on the clinical context **(46)**.

- **Pre-operative considerations: goals and planning**

All forms of treatment for these pharyngeal/pharygolaryngeal malignancies carry considerable toxicity, particularly to deglutition. Surgery, which is increasingly used to salvage failures of organ-preservation therapy, has considerable morbidity and mortality more so than for any other type of head and neck cancer. The complexity of care in the salvage setting is difficult to overstate **(47, 48)**.

Primary goals of reconstruction of pharyngeal defects are maintenance of integrity, restoration of function and form, minimizing morbidity, and improving quality of life. The reconstruction needs to be able to withstand adjuvant radiotherapy but be compliant enough to restore a range of three-dimensional defects.The gold standard of reconstruction should be a one-stage procedure with the lowest morbidity, a short hospital stay, early recovery of swallowing, and the restoration of a socially acceptable appearance. Given the aim of getting the patient to adjuvant therapy, achieving the seal of the pharynx to allow for the restoration of enteral feeding and avoidance of neck sepsis is crucial **(49)**.

- **Intra-operative considerations**
  - **Pharyngeal defect**

The extent of pharyngeal defect after resection can range from a small tonsillar or sidewall defect to a circumferential defect resulting from laryngopharyngectomy. Smaller defects in the primary setting can be managed by secondary intention without any sophisticated reconstruction. Larger defects or those in the post-radiation setting are more likely to benefit from active efforts to re-establish the pharynx **(50)**.

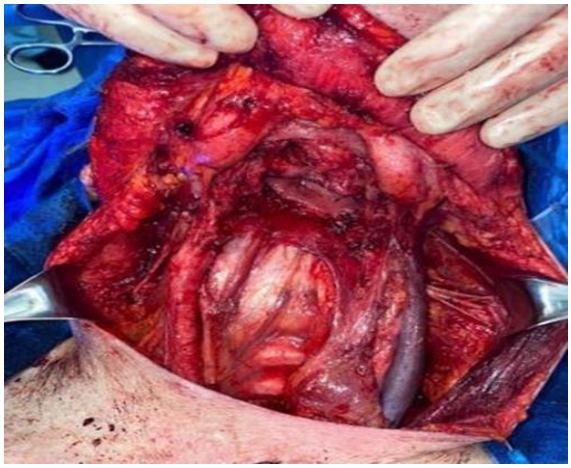

Figure 31: Defect following salvage total pharyngolaryngectomy (44).

Flap choices

Most soft tissue flaps are designed to be 10 to 20% larger than the defect itself to accommodate for tissue shrinkage. They can be pedicled or microvascular free flaps depending on the nativity of their blood supply **(49)**.

1. **Pectoralis major myocutaneous flap**

In the setting of pharyngeal defects, it can be grafted to a defect with or without a cutaneous component. Inset of an area of skin into a pharyngeal defect allows for a more robust seal to be achieved early. Without skin, the muscle flap can be used to seal a defect or to onlay over a primary pharyngeal closure. Using the PM pedicled flap as an onlay flap has been shown to decrease the rate of pharyngocutaneous fistula when compared to primary closure alone **(51)**.

2. **Supraclavicular artery island flap (SCAIF)**

The SCAIF is a pedicled fasciocutaneous flap based on the supraclavicular artery and vein. These vessels arise from the transverse cervical vessels and this flap can be used for a multitude of head and neck reconstructions where a thin and pliable replacement is indicated. Up to 20% of patients will not have the branch of the transverse cervical artery (TCA) and preoperative audible doppler will allow for assessment of this vessel as it runs over the lateral clavicle into the deltoid region **(52)**. **Emerick et al.** reported their experience using the SCAIF in reconstruction following total laryngectomy. A benefit of the SCAIF is its ability to reconstruct the anterior neck skin, which may be necessary in the setting of salvage laryngectomy **(53)**.

3. **Internal mammary artery perforator flap (IMAP)**

The IMAP is supplied by the first 3 or 4 branches of the internal mammary artery. It is raised in a subfascial plane to within 2–3 cm of the sternal margin. The flap is raised as an island to allow for rotation on a relatively short pedicle. It was suggested that it is a reliable and suitable option for lower anterior neck defect including for revision of tracheostomes **(54)**.

4. **Thoracoacrominal artery perforator flap (TAAP)**

The thoracoacrominal artery perforator (TAAP) flap is a local alternative solution for reconstruction of complex circumferential hypopharyngeal defects when free tissue transfer is contraindicated, or neck vessels are depleted. It can be harvested as a chimeric flap including both muscle and skin components to cover defects in pharynx as well as skin **(55)**.

5. **Radial forearm free flap**

The radial forearm free flap (RFFF) is easy to harvest, has a long pedicle with excellent vessel caliber, and is made up of a thin, pliable skin paddle of variable size and

form that allow a great deal of latitude in pharyngeal reconstruction. Its long pedicle provides an option for vascular anastomosis to be performed on the contralateral neck. One of the major advantages of this is that its inherently thin and pliable skin paddle matches the thickness of the pharyngoesophageal wall. If there is sufficient mucosa to close the pharynx primarily, the RFFF can be harvested without a skin paddle as a fascia-only flap to reinforce the pharyngeal suture line **(56)**.

6. Anterolateral thigh free flap

The anterolateral thigh free flap (ALT) can be used as an onlay, a patch, or a tubed flap. It has more considerable vascular variability when compared to the RFFF. Its thickness also varies significantly depending on a patient's body habitus. The excess adipose tissue can be removed to within 2 cm of the perforating vessel to limit the flap thickness. The ALT can be raised as a chimeric flap with muscle (usually vastus lateralis). The muscle can serve to provide coverage of the great vessels in the case of concurrent radical neck dissections, to fill in neck contour defects, or as a vascularized bed to facilitate skin grafting for the external neck. A distal or a second skin paddle can be brought out to external skin and utilized as a monitoring paddle **(57)**.

7. Gastro-omental free flap

The gastro-omental flap is typically raised via laparotomy although it can be harvested laparoscopically. The flap provides a tubed segment of the greater curve of the stomach which is nourished by the right gastroepiploic artery and vein, which also supply an apron of omentum. The advantage of the gastro-omental flap is its unique wound-healing properties provided by the rich omental source of fibroblasts and other progenitor cells. The omentum also serves as a malleable vascularized layer over the microvascular anastomoses and protects the great vessels from contamination by salivary egress **(58)**.

Figure 42: Gastro-omental flap inset (44)

8. Jejunal free flap

The jejunal flap provides a hollow viscus which can replace a circumferential pharyngeal defect. It has a relatively shorter pedicle than the other free flaps herein described. A perioperative mortality rate was 3.8% in a series of 368 patients who had jejunal free flap for circumferential laryngopharyngectomy defects. The potential morbidity of abdominal surgery such as postoperative ileus, wound infection, bowel obstruction, superior mesenteric syndrome, intra-abdominal bleeding, and delayed enteric feeding are significant complications in an already medically compromised population. The jejunal flap is less tolerant of ischemia and has a shorter pedicle than other flaps such as the ALT or gastro-omental flaps **(59)**.

9. Temporoparietal fascial free flap

Temporoparietal fascial free flap (TPFF) is thin and pliable and can be used as a PIG to reinforce pharyngeal closures after salvage laryngectomy. **Higgins et al.** demonstrated comparable wound outcomes to the pectoralis major myofascial flap without the associated shoulder and arm dysfunction. This flap has minimal donor site morbidity other than a 25% rate of local alopecia. The pedicle is short and with small caliber. It is still possible to undertake a two-team approach if harvest commences after ipsilateral dissection is complete **(60)**.

10. Serratus anterior free flap

Khan et al. published the first series utilizing the serratus anterior free flap (SAFF) as an onlay to reinforce primary closure. Authors cite the ease of harvest, low donor site morbidity, and the pliability of the flap as significant advantages over other free flaps used for similar purposes. The shapes and sizes of all flaps depends upon the shape and size of the defect the surgeon is repairing **(61)**.

Predictors of flap failure

Several variables have been found to be associated with flap failure in the literature, including intraoperative fluid administration, medical comorbidities, history of radiation and/or chemotherapy, age, smoking status, and total operative time. Although these aforementioned variables have been found to be correlated to free flap failure, ischemia time is seldom reported in the literature **(62)**.

Alcohol use, alcohol withdrawal, prolonged ischemia time, intraoperative pedicle revision, and laryngeal reconstruction are associated with free flap failure. Possible causes for increased failure in the laryngeal reconstruction group could be due to lack of external monitoring of the skin paddle and salivary leak. Alcohol use and withdrawal have been reported to be associated with increased complications of head and neck surgeries **(63)**.

Free flap failure has been found to be increased in patients who experience alcohol withdrawal in the postoperative period. A study reported free flap success rate in those without alcohol withdrawal was 97.8% vs 87% in those who did have alcohol withdrawal. The etiology of this failure rate is unclear **(64)**.

Malnutrition leads to impaired wound healing, which could explain an increase in complications and flap failure. Alternatively, the increased physiologic stresses, including blood pressure changes or even physical thrashing during delirium tremens, could contribute to failure. Preoperative identification, treatment, and nutritional intervention of patients at risk for alcohol withdrawal are of utmost importance to prevent free flap complications and failure **(65)**.

Preoperative identification of at-risk patients can be completed using the Prediction of Alcohol Withdrawal Severity Scale, a validated tool for predicting alcohol withdrawal syndrome in hospitalized patients **(66)**. A strategy for targeting this population of patients is to have them abstain from

alcohol use for at least week prior to surgery and close follow-up with a physician during this time to observe for withdrawal complications. If this is not feasible, pedicle flap reconstruction such as a pectoralis flap could be considered instead of free flap reconstruction in a subset of these patients **(67)**.

A concern for microvascular reconstruction surgeons is ischemic reperfusion injury to the flap, leading to no-flow phenomenon. The risk of this has been shown to be related to the duration of ischemia time. Implications for prolonged ischemia time affecting free flap success rates include the decision to complete the inset prior to reanastomosis vs partial inset with completion after reanastomosis. An argument for completing at least part of the inset after reanastomosis is the opportunity to observe the pedicle **(68)**.

It was found that by performing the inset after reanastomosis and directly observing the pedicle for a period of 30 to 45 minutes, they were able to detect vascular complications intraoperatively and salvage a portion of free flaps. In some cases, the edema of the soft tissue after the anastomosis can obstruct or complicate the inset, such as complex oropharyngeal or pharyngeal reconstructions. In those cases, the decision may be made to complete the more difficult portion of the inset prior to performing the anastomosis. It may be that prolonged ischemia time is merely a marker for a difficult dissection, inset, or anastomosis. These situations are noted in the operative report dictations and were included in our analysis **(69)**.

There was no correlation of difficulty noted in the operative report and the length of ischemia time per our analysis. Prior chemoradiation therapy was not associated with increased ischemia time. **Kass et al.** identified hypotension as a significant risk factor for free flap failure in 445 free flaps. Interestingly, hypertension was found to be protective in our osteocutaneous free flap analysis. Although we do not have intraoperative blood pressure data, these patients may have been less likely to have intraoperative hypotension and thus have higher success. In conclusion, flap reconstructions that have prolonged ischemia time or require revision of the pedicle at the initial surgery require careful postoperative surveillance and a low threshold for investigation if there is a question of failure **(70)**.

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