11 Surgical Approaches to the Maxilla, Maxillary Sinus, Pterygopalatine Fossa, and Infratemporal Fossa for Malignant Tumors

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11.1 Introduction

The maxillary sinus is the site of the sinonasal tract most frequently affected by cancer (60% of cases), followed by nasal cavity (20%) and ethmoid sinus (15%). Tumors in sphenoid and frontal sinuses are extremely rare [1]. The reason why the maxillary sinus is the most affected by neoplasm has several explanations. First of all, since its big size, it has a larger surface for contact with inhalant carcinogens. Then, its position, more accessible by inhalant pollutants, and associated with a slower clearance of mucus compared to other sinuses, allows a prolonged contact between mucosa and carcinogenic agents, easing mutagenesis and tumor development. Also, pathologic conditions, such as complete or partial obstruction of the ostium, such as in case of chronic rhinosinusitis, or alterations in the ventilation pattern (e.g., in case of septal deviation, often associated with contralateral inferior turbinate hypertrophy) further prolong the contact time between the carcinogenic agents and the mucosa [2, 3].

Sinonasal cancers are generally slow growing and tend to remain asymptomatic till advanced stages. Their presentation is commonly with unilateral nasal respiratory obstruction, epistaxis, and nasal drip.

Squamous cell carcinomas (SCCs) constitute the majority of the maxillary sinus cancer followed by malignancies of salivary gland origin (adenoid cystic carcinomas first, adenocarcinomas and mucoepidermoid carcinomas second). Very rare are midline (NUT) carcinoma, neuroendocrine carcinoma, teratocarcinosarcoma, extranodal NK/T cell lymphoma (midline malignant granuloma), extraosseous plasmacytoma, and neuroectodermal and melanocytic tumors.

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The maxillary sinus offers several ways of neoplastic spread:

- The medial wall and the floor are the most fragile areas and, once these have been passed, the mass infiltrates the ipsilateral nasal cavity, the nasopharynx, and the hard palate.
- The lateral wall, so the cancer may emerge on the skin of the cheek.
- The posterior wall is very thick, so tumors that manage to overcome it typically show a very aggressive growth pattern: in this case, the tumor could invade infratemporal and pterygopalatine fossa and could infiltrate sphenopalatine ganglion and maxillary nerve. If V2 trigeminal branch has been involved, the mass may spread through it to the middle cranial fossa.
- The roof, through which the cancer reaches the orbit and may spread through its vascular and nervous structures.

Regional nodal and distant metastases are uncommon, occurring in less than 20% of patients, higher in advanced-stage tumors. In maxillary sinus non-squamous cell carcinomas, the rate of neck metastases at diagnosis is very low (6%) and metachronous nodal metastases are rare, whereas in squamous cell carcinomas the rate of neck metastases at presentation is 10.3% [3].

Nodal metastases worsen patient's prognosis, going from a 2-year survival of 70.3% for N0 patients to a survival of 48.5% for N+ patients with maxillary cancer [3].

Metastatic spread by blood has been documented in 1.5–18% of cases and usually occurs in very advanced stages of the disease [2, 3]. The diagnostic process of sinonasal malignant tumors consists of anamnesis, physical examination, videorhinoscopy, imaging, CT and MRI, and endoscopically guided biopsy. CT is superior to MR imaging for identifying bone erosion and for identifying involvement of the hard palate. MR imaging, especially with T2-weighted images, is helpful for tumor mapping and for distinguishing between tumor extension and obstructed secretions.

Staging of malignant sinonasal cancers, with the exception of lymphoma and sarcoma, is based on the 8th edition of TNM [4]. This new classification introduces the important prognostic role of location of the tumor inside maxillary sinus: cancers that arise below Ohngren's line (in the anteroinferior portion of the maxillary sinus) are associated with a good prognosis, while cancers that arise above that line (in the posterosuperior part) show a poorer prognosis due to early invasion of critical structures, including the orbit, skull base, pterygoid plates, and infratemporal fossa. Another important clinical factor introduced by the 8th edition of TNM [4] is the extranodal extension: tumor metastases invading beyond the lymph node capsule into the surrounding connective tissue, with or without associated stromal reaction.

Management of sinonasal cancers involving the maxillary sinus depends on the histology and tumor size as well as location in relation to the adjacent critical structures. The typical up-front locoregional treatment includes transfacial, transoral, or endoscopic maxillectomy, with or without neck dissection, followed by reconstruction and adjuvant radiation therapy, to optimize local control [2]. The use of postoperative RT and concomitant chemotherapy should be considered in patients with positive lymph nodes, particularly in cases of multiple metastatic lymph nodes or nodes with extracapsular spread [2]. The overall 5-year survival rates range from 30% to 60% [2, 3, 5].

11.2 Anatomical Landmarks

Before starting a surgical dissection of the maxillary region, it is necessary to deeply understand the complex morphology of this area. The maxillary bone forms most of the skeletal support of the midface, and part of the nasal cavities, by outlining the inferior border of the pyriform aperture and the inferior third of the lateral nasal wall. This bone has a main body, which contains the maxillary sinus (also called Highmore's antrum), whose superior and anterior plates, respectively, form the orbital floor and the infraorbital region and join each other at the level of the inferior orbital rim.

The infraorbital nerve (derived from V2 trigeminal branch) emerges from the infraorbital foramen, located within the canine fossa, a niche

on the anterior maxillary wall, just above and laterally to the prominence of the superior canine tooth root. The anterior maxillary wall articulates with the body of the zygomatic bone, and it is also in continuity with the posterolateral or infratemporal surface, which articulates with the pterygoid process of the sphenoid and forms, joining the medial endonasal maxillary wall, the apex of the maxillary sinus [6].

The frontal process of the maxillary bone stretches upwards to join the lacrimal bone at the level of the medial portion of the orbital rim, the nasal bones, and the frontal bone. The alveolar process of the maxilla extends inferiorly and forms half of the superior dentary arch. The palatine process, in continuity with the alveolar one, extends medially to form the anterior part of the hard palate and posteriorly joins the palatine bone. The pyramidal process of the palatine bone presents a groove, which articulates with the greater palatine groove of the maxilla, forming a canal for the descending palatine vessels and the palatine major nerve. The nasal crest arises in the suture between these two processes and articulates with the vomer. Anteriorly, the septal cartilage attaches to a thick protrusion called the anterior nasal spine. Behind the palatine process lies the horizontal process of the palatine bone (lamina horizontalis), completing the floor of the nasal cavity.

The medial endonasal maxillary face forms the lateral wall of the inferior meatus and gives insertion to the inferior turbinate. Anteriorly, it continues upward as the medial face of the frontal process, which articulates with the lacrimal bone and contributes to form the anterolateral half of the bony canal hosting the nasolacrimal duct. The frontal process also articulates with the middle turbinate in the ethmoidal crest and with the inferior turbinate in the conchal crest in the medial face. The maxillary sinus is usually the largest of all paranasal sinuses, with an average volume of 15 mL, and dimensions of about 34 × 23 × 33 mm in length, width, and height, respectively. It consists of a pyramid-shaped cavity, whose apex may also extend laterally into the zygomatic process of the maxilla or into the zygomatic bone itself.

Its boundaries are the anterior (facial) wall of the maxilla anteriorly, the infratemporal fossa posterolaterally, the pterygopalatine space postero-medially, the lateral wall of the nasal cavity medially, and the orbital floor superiorly. The maxillary sinus also gives origin to several niches, including the zygomatic and the alveolar recesses. The infraorbital nerve and vessels form a longitudinal prominence on the maxillary sinus roof, but they may also be dehiscent. The maxillary sinus may be partially divided by Schaeffer's septa, which may affect mucous drainage. In adults, the floor of the maxillary sinus may extend up to 5 mm below the level of the nasal cavity, whereas in children, with the sinus not completely developed, it is usually located above the nasal cavity floor.

The maxillary ostium (hiatus maxillaris), tough wide in the disarticulated maxilla, is greatly reduced in size in anatomical conditions, due to several complex spatial interactions with other bony and mucous structures. In particular, the uncinate process of the ethmoid diagonally crosses the ostium region to articulate with the ethmoidal process of the inferior turbinate, whose maxillary process covers the inferior margin of the maxillary hiatus itself. The vertical part (lamina perpendicularis) of the palatine bone hides the posterior notch of the maxillary, and a small portion of the lacrimal bone covers its anterosuperior angle. The remaining gap in the maxillary ostium is closed by connective tissue and mucosa, forming the *fontanelle*, which is divided into anterior and posterior *fontanelle* by the uncinate process. The natural ostium of the maxillary sinus is located in the anteroinferior angle of the fontanelle and constitutes the connection of the maxillary infundibulum with the ethmoidal infundibulum. It is hidden medially by the concave portion of the uncinate process [7].

Accessory ostia may be often seen as round holes in the region of the *fontanelle*. During endoscopy, they can be easily distinguished from the natural ostium, since they are round and can be visualized with a 0° endoscope, while the latter is oval shaped and cannot be seen unless an angled scope is employed or the uncinate has been removed or anteriorized. Posterior-superior and anterior-superior vessels and nerves, as well as infraorbital ones, provide innervation and blood

supply for the maxillary sinus. Small vessels from the inferior turbinate enter the maxillary sinus via the ostium region. Just postero-medially to the maxillary sinus lies the pterygopalatine fossa. It is a pyramid-shaped space, located medially to the pterygomaxillary fissure, and below the orbital apex. It is bounded by the posterior wall of the maxilla laterally, the base of the pterygoid process and the grater wing of the sphenoid posteriorly, and the perpendicular plate of the palatine bone medially. The latter shows the sphenopalatine foramen in its superior aspect.

The pterygopalatine fossa communicates with the surrounding regions via eight openings that give way to several neurovascular structures:

- Inferior orbital fissure (in which pass infraorbital, zygomatic nerve, infraorbital vessels, veins to pterygoid plexus, ophthalmic vein)
- Pterygomaxillary fissure (which connects pterygomaxillary and infratemporal fossae and is crossed by the internal maxillary vessels)
- Sphenopalatine foramen (located in the posterior part of the lateral nasal wall, just posteriorly to the end of the middle turbinate, and crossed by sphenopalatine artery)
- Foramen rotundum (which contains V2 branch)
- Pterygoid or vidian canal (located inferomedially to the foramen rotundum, and crossed by the vidian nerve in its route to the sphenopalatine ganglion)
- Pharyngeal canal (which opens into the lateral aspect of the roof of the choanae, and transmits pharyngeal branches of the sphenopalatine ganglion and of the internal maxillary artery)
- Greater pterygopalatine canal (crossed by the greater palatine vessels and nerves)
- Lesser pterygopalatine canal (crossed by the lesser palatine vessels and nerves)

The pterygopalatine fossa contains the third portion of the internal maxillary artery with its branches (posterosuperior alveolar artery, infraorbital artery, descending palatine artery, artery of the pterygoid canal, palatovaginal artery, sphenopalatine artery), pterygoid venous plexus, V2 nerve with its branches (zygomatic nerve, ganglionic branches, posterior-superior alveolar nerves, infraorbital nerve), vidian nerve, and sphenopalatine ganglion.

In relationship with the maxillary bone and the pterygopalatine fossa lies the infratemporal region. It is an anatomic space with irregular boundaries, encompassing the masticator and upper parapharyngeal spaces and located below the floor of the middle cranial fossa. In turn, the masticator space includes the medial and lateral pterygoid muscles, tendon of the temporalis muscle, internal maxillary artery, maxillary (V2) and mandibular (V3) branches of the trigeminal nerve, tensor and levator veli palatini muscles, and Eustachian tube. The styloid diaphragm, formed by the styloid aponeurosis, divides the UPPS into pre- and poststyloid compartments [6].

According to Li [8], the infratemporal region may be divided into five compartments in relationship with the endoscopic anatomy of the axillary sinus.

- Zone 1 (retromaxillary space) is defined as the space lying between the posterolateral wall of maxillary sinus and the complex of temporalis and pterygoid muscles. It may be accessed by removing the posterolateral wall of the maxillary sinus and its periosteum lateral to the infraorbital nerve down to the level of the floor of the maxillary sinus, to expose the buccal fat pad, beneath which the branches of the internal maxillary artery lie. Laterally to such vascular branches, the temporalis and pterygoid muscles can be observed.
- Zone 2 (superior interpterygoid space) is located at the superior part of the ITF and comprises the superior head of the lateral pterygoid muscle, V3, and foramen ovale. In anatomical dissection, approaching from the pterygopalatine fossa and using the maxillary nerve as a landmark to identify the pterygoid base and greater wing of the sphenoid bone, V3 and foramen ovale may be identified posterior to the origin of the lateral pterygoid plate, once the superior head of the lateral pterygoid muscle is elevated.
- Zone 3 (inferior interpterygoid space) includes the inferior head of the lateral pterygoid muscle, medial pterygoid, and temporalis muscles. The deep temporal nerve, located at the medial

border of the temporalis muscle, serves as a landmark to identify such region. Along the virtual space enclosed by the temporalis muscle and the medial and lateral pterygoid muscles in a posterolateral direction, the lingual and inferior alveolar nerves lie on the superior border of the medial pterygoid muscle, and the internal maxillary artery is detected to enter the posterior aspect of the infratemporal fossa. Additionally, the medial aspect of mandible ramus and the fascia of the deep head of masseter muscle could be through this corridor.

- Zone 4 (temporo-masseteric space) is defined as the space lateral to the temporalis muscle, and mainly contains fat, that leads to the medial aspect of the zygomatic arch and the superficial head of masseter muscle.
- Zone 5 (tubopharyngeal space) includes the Eustachian tube, the tensor and levator veli palatini muscles, and the structures within the upper parapharyngeal space. These structures may be exposed after elevation of the lateral pterygoid muscle off the lateral pterygoid plate and drilling of the pterygoid process, and lateral pterygoid plate. Along the superior border of the medial pterygoid muscle, in a posterior direction, the tensor veli palatini muscle at the anterolateral aspect of cartilaginous Eustachian tube and the levator veli palatini muscle at its anteroinferior aspect can be found. Behind these structures, the fat in the prestyloid compartment envelops the deep lobe of the parotid gland. Removal of the styloid aponeurosis leads to the exposure of the parapharyngeal internal carotid artery, the mixed cranial nerves (IX–XI), and the internal jugular vein. The hypoglossal nerve (XII) is placed posteriorly to the parapharyngeal internal carotid artery.

11.3 Background

The idea of maxillectomy was first described in 1826 by Lazars, whereas its first successful execution dates back to 1828 [9]. First pioneeristic maxillectomies were characterized by a high morbidity rate mostly due to important blood loss. This drawback led to the spread of radiation therapy for the treatment of maxillary tumors. After the Second World War, the innovations introduced in the fields of anesthesia, antibiotic therapy, and blood replacement contributed to a wider adoption of maxillectomy. Traditional approaches included transfacial incisions such as in the lateral rhinotomy or Weber-Ferguson technique [10, 11]. Modifications or additional procedures were subsequently added to maxillectomy, in order to better fulfill the needs of patients. Maxillectomies were performed together with resections of the pterygoid plates, the anterior skull base, or the nasopharynx, even including approaches through the infratemporal fossa [12]. In this way, lesions previously deemed as unresectable became eligible for surgical treatment aiming for a radical asportation. In the 1970s, the midfacial degloving approach affirmed itself as an alternative to the traditional transfacial incisions avoiding external scarring [13]. Endoscopic sinus surgery then affirmed itself progressively as the technique of choice for the treatment of lateral nasal wall tumors and as an extremely effective tool in combination with transfacial approaches for the control of the margins of resection due to the superior visualization [14].

11.4 Patient's Preparation

Maxillectomy is generally performed under general anesthesia. Orotracheal intubation is normally preferred, with the tube being secured to the opposite side of the lesion on the lower lip. In case orotracheal intubation is not deemed possible or in patients with particularly difficult airways, nasal fiber-optic intubation or even a tracheostomy may be taken into consideration. Broad-spectrum antibiotic prophylaxis is given at least 60 min before surgery. Clindamycin or ampicillin/sulbactam cover skin and oral cavity bacteria and are therefore good options. In case a skull base resection is performed, a third-generation cephalosporin is used because of its capability to penetrate the blood-brain barrier [15]. Massive hemorrhage is uncommon; however, appropriate measures should be taken into account in case excessive blood loss occurs so as to maintain adequate blood volume. The pivotal point for hemorrhage in the maxilla region is the

course of the internal maxillary artery in the infratemporal or pterygopalatine fossae.

11.5 Equipment

Regular otolaryngology and maxillofacial surgery instrumentation is normally proper to perform a resection of the maxilla. Standard endoscopic sinus surgery instruments are required in case an endoscopic maxillectomy is performed. Osteotomies may be done by means of reciprocating saws, oscillating saws, or piezoelectric devices. Bone chisels or rongeurs might be required as well.

11.6 Positioning

The patient is in supine position on the operating room table, with the head slightly rotated towards the side of the lesion. In case the eye is spared, a protective tarsorrhaphy or a corneal shield is used.

11.7 Preoperative Evaluation

Before surgery, it is mandatory to investigate the intranasal anatomy with nasal endoscopy. Physical examination of the oral cavity, the orbit, and the cranial nerves is also paramount. As far as radiological examinations are concerned, patients should undergo a CT scan, MRI, or even both. CT scans with contrast provide excellent information on the bony anatomy and the vascular architecture of the lesion. On the other hand, MRI provides better details on soft tissues, especially in those cases in which the lesion is in contiguity with the retained secretions [16]. Histological assessment is also mandatory prior to surgical procedure; sampling may be performed transnasally, transorally, or more seldom through an anterior antrostomy.

11.8 Infrastructure Maxillectomy

In an infrastructure maxillectomy, the hard palate and inferior part of the maxilla are removed, along with some of the teeth, but the orbital floor is preserved. As previously reported, the procedure is performed under general anesthesia with orotracheal or nasotracheal intubation, with the tube being secured contralateral to the lesion. The oral cavity is exposed with appropriate cheek retractors. The mucosa in the fornix is incised with either scalpel or electrocautery along with that on the hard palate granting safe margins around the lesion. If the patient is dentate, a tooth may be extracted in order to make the osteotomy pass through the post-extractive socket, so as to preserve the integrity of the remaining dentition. The mucosal incision is then deepened to the bony wall of the maxilla on the external aspect and to the bony palate on the internal aspect. All soft-tissue attachments to the aforementioned structures should be separated before osteotomies. Either an oscillating saw, a reciprocating saw, or a piezoelectric device is then used to perform the cuts onto the bony walls following the previously defined mucosal incisions. A chisel might be utilized to refine the osteotomies and most of all to detach the specimen from the pterygoid plates on the posterior aspect of the resection. Particular attention must be given to control hemorrhage from the descending palatine artery so as to prevent postoperative bleeding. After the resection, the maxillary antrum may be exposed. If the sinonasal mucosa is healthy, it can be left in place; on the other hand, in case of sinonasal disease, it is advisable to remove it by means of a curette. The procedure usually continues with the steps in accordance with the reconstructive technique of choice.

11.9 Subtotal Maxillectomy

In a subtotal maxillectomy, the entire maxilla, including the infrastructure and the suprastructure, is removed, sparing only the floor of the orbit. The patient is usually administered, as previously mentioned, general anesthesia by orotracheal intubation, with the tube being secured on the opposite side of the lesion. The most common surgical approach in a subtotal maxillectomy is the Weber-Ferguson approach. First of all, the incision line is drawn through

the vermilion border, along the labial philtrum, proceeding around the base of the nose and along the sulcus between the nose and the cheek. In case a subciliary extension is required, the incision continues in a lateral direction 3–4 mm below the cilium to the lateral canthus; however, it can be prolongated further laterally for a wider exposure. The skin incision is performed by means of a scalpel with the subsequent use of electrocautery to control the hemostasis. The upper lip is cut throughout its entire thickness on the median line, up to the superior fornix. At this stage, the superior labial artery is transected and therefore requires ligation or in any case careful hemostasis control. After that, in order to gain adequate elevation of the cheek flap, the incision continues on the mucosa of the fornix. The mucosa is incised in full thickness remaining just above the periosteal layer and continuing until the posterolateral aspect of the maxilla. The subciliary incision is made through the skin and the orbicularis oculi muscle; the dissection is then carried out on a preseptal plane down to the arcus marginalis above the inferior orbital rim. The cheek flap is progressively elevated until the infraorbital nerve is exposed in correspondence of the foramen and the entry of the nerve into the overlying soft tissues. In case the upper margin of the resection is below the foramen, the nerve might be spared so as to preserve the sensitive innervation of the cheek; however, in most cases, the transection of the nerve is necessary for reasons of oncological radicality or anyway to gain a satisfactory exposure of the specimen. The entry into the nasal cavity is obtained through the alar tissues down to the mucosa on the lateral aspect of the pyriform aperture. The oral cavity, the hard palate, and the maxilla are subsequently widely exposed. The first osteotomy is performed on the anterior aspect of the maxilla with the instrument of choice; the superior and the mesial margins of resection are thus identified. The superior osteotomy runs anteriorly through the maxillo-nasal buttress and posteriorly till the malar bone and the posterolateral aspect of the maxilla. Concerning the anterior osteotomy, if the patient is dentate and a tooth is passed through by the mesial margin of resection, it is advisable to extract the element so that the osteotomy is performed in the post-extractive socket and the remaining dentition is preserved.

After that, the mucosal incision on the hard palate is demarcated and performed by means of a needle-tip electrocautery, obviously keeping adequate distance from the lesion. The incision on the hard palate connects the anterior margin of resection to the previously made mucosal incision on the fornix around the maxillary tuberosity and is deepened till the bony layer on its whole length. The hard palate is then divided through this incision with the instrument of choice. Chisels are then helpful to connect the performed osteotomies on the posterior aspect and in particular to detach the specimen from the pterygoid plates. Once the bone cuts have been made, the remaining soft-tissue attachments, most of all the pterygoid muscles, can be transected so that the specimen may be removed. Following the resection, bleeding might be encountered coming from the sphenopalatine artery and by branches of the internal maxillary artery. While the sphenopalatine artery is usually dominated by electrocoagulation, the internal maxillary artery is better controlled by means of vessel ligation. Alike the infrastructure maxillectomy, the remaining sinusal mucosa may be left in place if presenting with a healthy aspect. Following the hemostasis, sharp bony edges get smoothened, and the procedure continues with the chosen reconstructive technique. In the postoperative care, adequate oral hygiene with chlorhexidine or baking soda solution must be ensured, with accurate detersion of debris, crusts, and clots so as to prevent wound infection and dehiscence. Moderate swelling of the cheek and the eyelids is usually encountered as a consequence of the interruption of lymphatic drainage. Following the fourth day after surgery, warm compresses help in reducing the edema. Nose feeding tubes are usually adopted until the surgical wound is healed and the patient is able to get back to a satisfactory oral intake.

An alternative approach avoiding extraoral incisions in subtotal maxillectomy is the midfacial degloving. This approach uses a bilateral circumvestibular incision together with a bilateral

Fig. 11.1 First step of midfacial degloving. A circumvestibular incision has been made to allow the lower lateral cartilages to be reflected with the nasal skin. The latter is then elevated similarly to a closed rhinoplasty

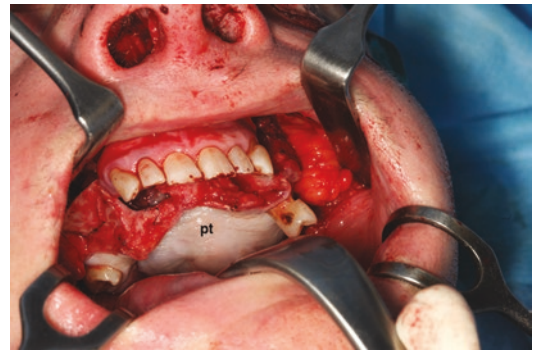


Fig. 11.3 In this image, dissection of the palate has been performed in order to remove the hard palate together with a palate tumor (pt)

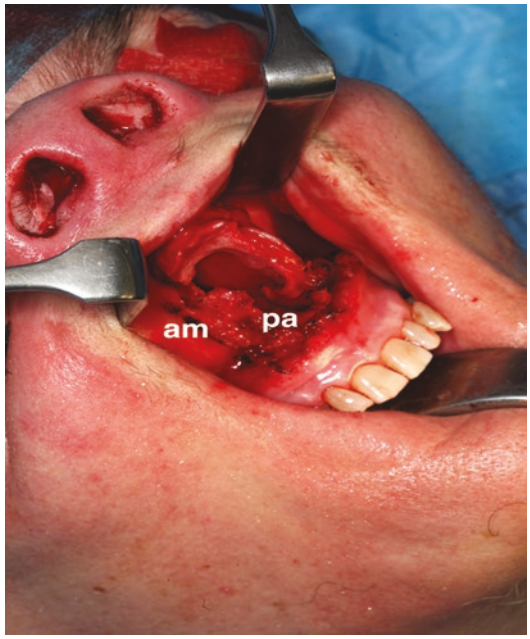


Fig. 11.2 The cheek and nasal skin is elevated in order to expose pyriform aperture (pa) and the anterior maxilla (am). Dissection aims to preserve the inferior orbital nerves

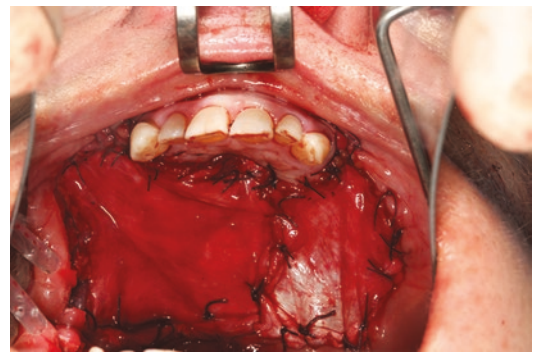


Fig. 11.4 Reconstruction of the palate has been performed with autologous temporoparietal fascia flap, which is adapted and sutured to the resection margins. The skin flap is then replaced and fixed with reabsorbable gum suture under the pyriform aperture

intercartilaginous incision and a transfixion incision, thus enhancing the exposure of the middle third through the exposition of the external nasal skeleton. This approach has the obvious advantage to avoid external scarring but needs wider intraoral incisions to gain adequate exposure (Figs. 11.1, 11.2, 11.3, and 11.4).

11.10 Total Maxillectomy

In a total maxillectomy, the palate, the floor of the orbit, and the whole maxilla are removed. Depending on the extent of tumor invasion and size, this procedure may be associated with an orbital exenteration. The resection of the entire maxilla is indicated when a tumor originating from the sinusal walls ends up filling the entire cavity. This procedure is also indicated in cases of maxillary sarcomas for reasons of oncological radicality. The approach adopted for total maxillectomy does not differ much from that used in subtotal maxillectomy; however, in total

maxillectomy, a larger exposure of the midface is needed. For this reason, the most common access method used in this procedure is the Weber-Ferguson approach with subciliary extension. As previously mentioned, the incision is first demarcated and runs in the midline of the upper lip to the columella. It then proceeds around the ala into the sulcus between the nasal subunit and the cheek up to the medial canthus and, after that, continues with the subciliary extension below the tarsal plate for the entire length of the lower eyelid or further laterally, if needed. The first cut is made into the upper lip, splitting it into two up to the root of the columella and securing the hemostasis of the superior labial artery. The subsequent skin incision around the nose is carried out in depth through the soft-tissue layers of the midface. On the other hand, the first mucosal incision is made along the superior fornix posteriorly till the maxillary tuberosity down to the bone level. The subciliary incision finally elevates a flap on a preseptal plane with a blunt dissection until the arcus marginalis above the inferior orbital rim is reached. Once all the aforementioned incisions have been performed, the resulting cheek flap is lifted till roughly 1 cm laterally of the orbital lateral canthus so as to provide adequate exposure of the region (Figs. 11.5 and 11.6).

Approximately 5.0 mm below the inferior orbital rim, along the midpupillary line, the infraorbitary nerve is encountered and transected. After that, the arcus marginalis is incised either with a scalpel, a Freer periosteal elevator, or electrocautery in order to proceed with a subperiosteal dissection of the orbital floor posteriorly till the orbital process of the palatine bone, which represents the posterosuperior margin of the resection (Fig. 11.7). At this point, a titanium mesh which will be later used for the reconstruction is modeled and bent in order to match the shape of the existing bone and to limit the risk of postoperative enophthalmos (Fig. 11.8).

Fig. 11.5 Elevation of the cheek flap. The cheek flap is retracted laterally

Fig. 11.6 Elevation of the cheek flap. The incision runs in the upper lip until reaching the columella. Then, it goes around the ala up to the medial canthus and follows the lower eyelid. The flap is lifted laterally to the lateral canthus and allows exposure of the entire external surface of the maxilla. *Abbreviations*: ul = upper lip; s = paralateral nasal sulcus; mc = medial canthus; tp = tarsal plate; lc = lateral canthus; cf = cheek flap

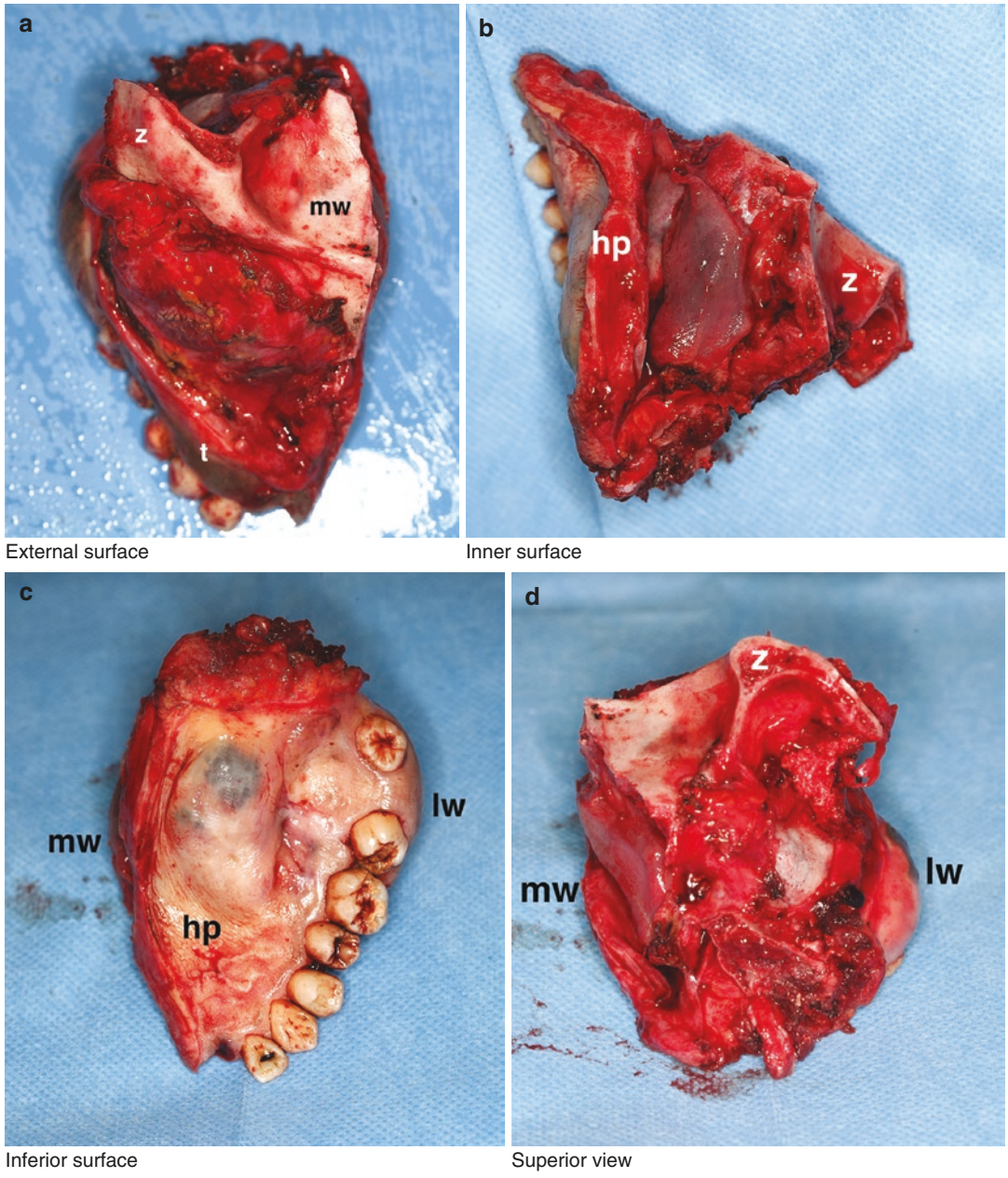
Fig. 11.7 Extension of the maxillectomy as far as the orbital process of the palatine bone (pb). The orbital floor (of) is now uncovered, and the entire maxillary sinus is opened

Fig. 11.8 Positioning of a titanium mesh. The material (white star) is modeled and adapted to the surface of the floor of the orbit. Its purpose will be for reconstruction

Next, the insertion of the masseter muscle to the most anterior and inferior pole of the malar bone is incised and elevated. The following steps take place in the oral cavity, where the demarcation of the resection on the palate and the preparation for the osteotomies occur in a similar fashion to the steps described for the infrastructure maxillectomy and the subtotal maxillectomy. Once all the soft-tissue attachments so far described have been freed, the bone cuts are outlined by means of electrocautery. In the most superior and medial aspect, the maxillo-nasal buttress is cut at the level of the orbital rim, taking care not to damage the lacrimal sac and the medial canthal ligament. Superolaterally, the maxillary bone is divided from the zygoma.

A malleable retractor is then used to retract the orbital content, and the planned osteotomies are continued onto the orbital floor using the landmarks of the inferior orbital fissure and the maxilla-ethmoidal suture. For osteotomies in the orbital floor, the use of a piezoelectric device is highly advisable. Inferiorly, at the level of teeth and hard palate, osteotomies are carried out as previously described. Brisk bleeding is expected to occur from each of the bone cuts. Once the previous steps are completed, osteotomies are connected by means of chisels, leaving the detachment of the pterygoid plates for last given the bleeding associated with branches of the internal maxillary artery and the pterygoid venous plexus. The remaining soft-tissue attachments on the posterior aspect of the resection are freed by means of electrocautery or Mayo scissors. The specimen is then removed, and careful control of the hemostasis takes place, especially focusing on the internal maxillary artery and the related branches (Fig. 11.9a–d).

After that, the procedure can go on with the preferred method for reconstruction. Postoperative indications in a total maxillectomy do not differ much from those observed in a subtotal maxillectomy. Accurate oral hygiene is mandatory, and frequent oral exercise is recommended in order to prevent post-operative trismus. Also in this procedure, a nose feeding tube might facilitate uneventful healing of the intraoral surgical wound. Correct lacrimal drainage should also be monitored, given the risk of epiphora due to cicatricial stenosis of the nasolacrimal duct, with the consequent indication for dacryocystorhinostomy (Figs. 11.10, 11.11, 11.12, 11.13, 11.14, 11.15, 11.16, and 11.17).



External surface

Inner surface

Inferior surface

Superior view

Fig. 11.9 The specimen has been removed after careful hemostasis. Images show the external surface (**a**), the inner aspect (**b**), the inferior aspect (**c**), and a view from above (**d**). *Abbreviations*: z = zygoma; mw = medial wall; t = teeth of the superior arch; hp = hard palate; lw = lateral wall

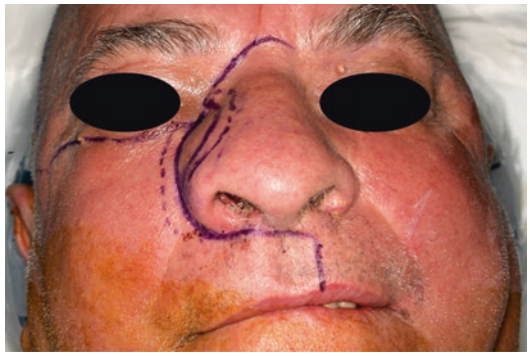


Fig. 11.10 Preoperatively, the patient's head must be slightly rotated towards the side of the lesion to be removed

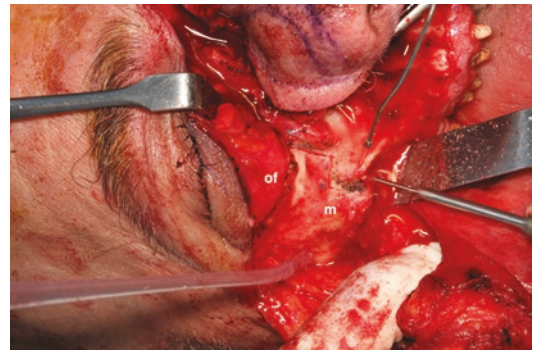


Fig. 11.13 The maxillary bone (m) is drilled in order to be opened and detached, together with the tumor, from the surrounding healthy tissue. In a total maxillectomy, the floor of the orbit (of) is removed

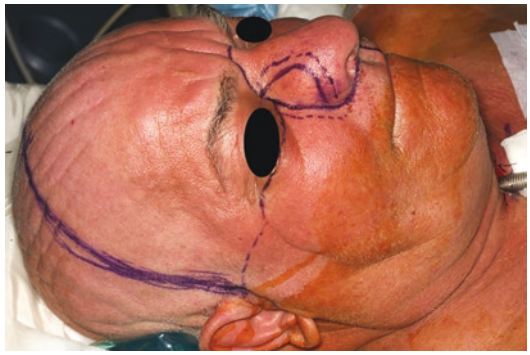


Fig. 11.11 The incision goes through the median line of the superior lip (sl) and proceeds along the sulcus (s) between the nose and the cheek, as far as the medial canthus (mc). Then, it extends laterally to the lateral canthus (lc). The flap is elevated in order to uncover the maxilla (m)

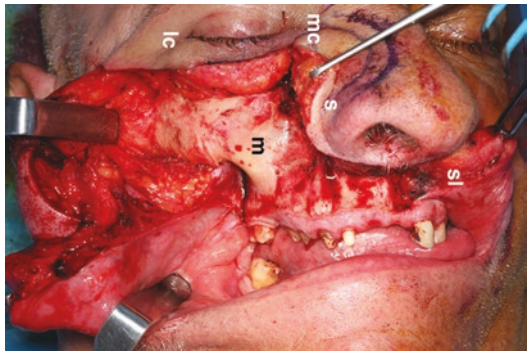


Fig. 11.12 The incision goes through the median line of the superior lip (sl) and proceeds along the sulcus (s) between the nose and the cheek, as far as the medial canthus (mc). Then, it extends laterally to the lateral canthus (lc). The flap is elevated in order to uncover the maxilla (m)

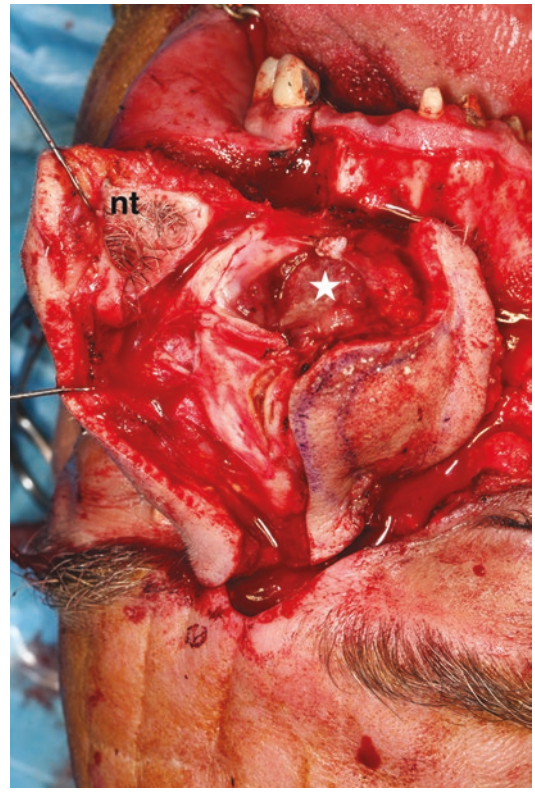


Fig. 11.14 Image showing the intranasal tumor (white star), which requires the maxillectomy. The tip of the nose (nt) is elevated to uncover the nasal cavity

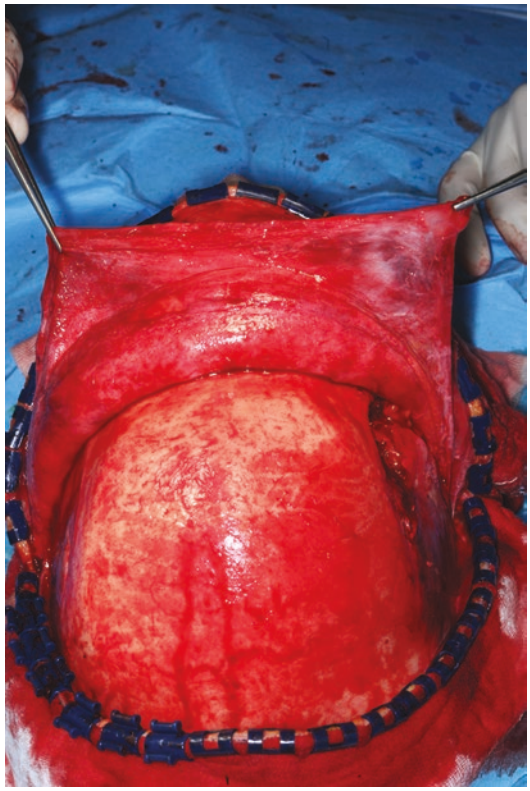


Fig. 11.15 After the radical steps, reconstruction should be performed with proper flaps, according to their extension. In this image, the cranial bones are uncovered with the purpose to collect a galeal flap

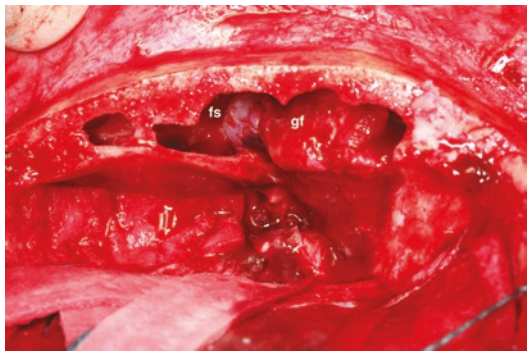


Fig. 11.16 The flap (gf) is made to enter the frontal sinus (fs) to finally reach the maxilla

Fig. 11.17 Final steps consist of adapting the flap (gf) to resection margins. Reabsorbable suture is used to fix the galeal flap into the maxillary area. At last, the cutaneous flap is replaced and sutured

11.11 Transnasal Endoscopic Median Maxillectomies

The increasing interest in reducing surgical morbidity has led to extending of the indication of transnasal surgery to several locally aggressive and malignant tumors of the maxillary sinus [17–22]. At the beginning of the twentieth century, endonasal medial maxillectomies, with lateral nasal wall resection, were first described by Sturmann, Canfield, and Denker [23–25]. Nowadays, partial maxillectomies are routinely performed with video-endoscopy assistance. As a result, endoscopic versions of the traditional interventions have been proposed (endoscopic Sturmann–Canfield or endoscopic endonasal Denker operation) [22].

During the last years, understanding of endoscopic anatomy and familiarity with extended endonasal approaches have improved, leading to a more precise definition of different endoscopic maxillectomy types. Although there is not a universal nomenclature system for endoscopic maxillectomies, modular classifications, based on the anatomic structure progressively removed, have been recently proposed, to allow more precise comparisons between different series and defini-

tion of advantages, limitations, and indications of each maxillectomy type [26–28].

According to Schreiber et al. [27], who proposed a novel modular classification, four types of endoscopic median maxillectomies can be identified. Each of them might be performed via either ipsilateral or contralateral transseptal approach.

The surgical steps, characterizing each endoscopic median maxillectomy type, are the following:

- **Type A**: inferior uncinectomy and removal of the medial maxillary wall to the inferior turbinate insertion (inferiorly), orbital floor (superiorly), palatine canal (posteriorly), and nasolacrimal canal (anteriorly). First of all, a middle meatal antrostomy with removal of the inferior portion of the uncinate process is performed. The natural ostium of the maxillary sinus is identified and posteriorly enlarged by removing the upper portion of the medial maxillary wall, as far as the vertical process of the palatine bone. The exposure obtained with such an approach includes the posterior and superior portions of the maxillary sinus. Via such approach, after drilling out the superior and/or posterior maxillary wall (generally as far as the sagittal plane passing through the infraorbital nerve), a corridor to address adjacent anatomic areas, including the intraorbital compartment, the pterygopalatine fossa, the lateral recess of the sphenoid, or the Meckel's cave, may be obtained.
- **Type B**: After type A maxillectomy, the resection is extended inferiorly by removing the medial maxillary wall together with the inferior turbinate (partially or completely) and connecting the nasal floor with the floor of the maxillary sinus. The anterior limit of the resection is represented by the nasolacrimal duct, which should be identified and preserved. The lacrimal bone and the medial maxillary wall anterior to the nasolacrimal duct are preserved. The anterior part of the inferior turbinate may also be spared [26]. After removing the posterior maxillary wall in a medial-to-lateral direction, deeper regions, such as the pterygopalatine fossa or the pterygoid plates, may be approached. Care should be taken not to injure posteriorly the descending palatine arteries and nerves.
- **Type C**: Type B plus resection of the nasolacrimal duct and removal of the residual anterior portion of the medial maxillary wall: The endoscopic maxillectomy is extended anteriorly by removing the lacrimal bone and transecting the nasolacrimal duct a few millimeters distal to the lacrimal sac. This way, surgical maneuverability inside the maxillary sinus is improved, especially on the lateral and inferior walls, and opportunities for inspection are greater. This procedure is particularly helpful in controlling the retrolacrimal recess, which is crucial in obtaining a radical resection of benign and malignant tumors [26]. This approach may be extended anterolaterally, removing the pyriform aperture transnasally by partially or completely drilling out the ascending branch of the maxillary bone. This offers better control of the anterior half of the maxillary sinus (anterior, lateral, and inferior walls), especially the alveolar recess inferiorly and the zygomatic recess of the sinus laterally. This procedure enables complete control of all maxillary sinus walls and recesses. It is also used extensively to lateralize the surgical fulcrum as far as possible during expanded transnasal-transmaxillary-transpterygoid approaches directed towards the infratemporal fossa, nasopharynx, and upper parapharyngeal space [26].
- **Type D**: Type C plus removal of the anterior wall of the maxillary sinus medial to the infraorbital foramen or more laterally. The nasal vestibule is incised in a vertical, slightly curved fashion. The pyriform crest is identified, and the periosteum and soft tissues enveloping the anterior wall of the maxillary sinus are dissected with an elevator until the infraorbital foramen is reached. The anterior wall of the maxillary sinus can be removed as far as the infraorbital nerve or even more laterally, reaching the zygomatic arch and drilling out the lateral wall of the maxillary sinus as well. Usually, the superior limit of the dissection is

represented by a horizontal plane passing through the infraorbital foramen, in order to preserve the infraorbital nerve and not violate the orbital content. However, in selected cases, this approach may be expanded superiorly by removing the superior wall of the maxillary sinus (orbital floor), preserving the periorbital layer. Whenever feasible, attention should be given to the preservation of the anterior superior alveolar nerve, which branches from the infraorbital nerve at a variable distance from the infraorbital foramen and runs within the bone of the maxilla in an antero-inferomedial direction. This procedure enables the management of pathologies involving the anterior wall of the maxillary sinus. It is also used as a corridor for the transnasal approach to deep lateral tumors of the infratemporal fossa, nasopharynx, and upper parapharyngeal space [26].

The type D maxillectomies may be furtherly divided into five subtypes, according to the extension of the anterior dissection [27, 28]:

- Type D1, extended to two imaginary vertical and horizontal lines tangential to the infraorbital foramen (respectively, lateral and cranial boundary), to the pyriform aperture medially and to a diagonal line from the infraorbital foramen to the point on the pyriform aperture dividing the middle and inferior third of the distance between IOF and nasal floor.
- Type D2, same as D1, but caudally extended to a diagonal line from the infraorbital foramen to the inferolateral corner of the pyriform aperture.
- Type D3, same as D1 and D2, but caudally extended to a horizontal line tangential to the nasal floor.
- Type D4, same as D3, with further inferior extension to reach the caudal portion of the anterior alveolar recess of the maxillary sinus.
- Type D5, same as D3, further extended laterally beyond the infraorbital foramen.

In the transseptal approach to each of the type A to D maxillectomies, a vertical incision of septal mucosa and perichondrium is performed preserving the underlying cartilage just posterior to the anterior margin of the septal cartilage and for 1.5–2.0 cm vertically from the nasal floor. Subperichondral dissection of septal mucosa should be extended backward for approximately 5.0 mm, where a vertical incision of septal cartilage is subsequently performed preserving the contralateral septal mucosa and perichondrium. Subperichondral dissection of the contralateral mucosa is extended backward for approximately 5.0 mm. The muco-cartilaginous flap is harvested with a superior and inferior incision starting from its anterior edge and extending backward to the posterior limit of the septal cartilage at the bony-cartilaginous junction. The posteriorly pedicled muco-cartilaginous flap is then laterally dislocated. The septal window is completed with a vertical incision of the contralateral septal mucosa approximately 5 mm posterior to the cartilage incision and extended from the nasal floor upward for 1.5–2.0 cm [27, 28]. In a surgical setting, this technique allows to harvest a septal window, which can be used to pass through the septum only in one direction.

A possible modification to the type C maxillectomy is the prelacrimal approach [29], in which the inferior turbinate is temporarily displaced medially and then replaced in the original position and fixed with a suture. The nasolacrimal duct is skeletonized and mobilized but preserved.

This kind of modification offers a wide surgical window, similarly to what would be obtained with a type C maxillectomy, while preserving the medial maxillary wall and the nasolacrimal duct. However, in the presence of pathologies eroding or infiltrating the medial wall of the maxillary sinus (e.g., inverted papilloma or malignant tumors), the prelacrimal approach is contraindicated, and the type C maxillectomy endoscopic maxillectomy is generally considered safer and more effective [26].

A modified extended prelacrimal approach [18] may provide a higher oncological radicalness. In this technique, a vertical incision is made in the lateral wall of the nasal cavity along the anterior margin of the inferior turbinate to the nasal floor. The nasal mucosal flap and the medial maxillary wall

bone are removed, as well as the nasolacrimal duct and the bone around it. After osteotomy of the medial maxillary wall, the periosteum and mucosa in the maxillary sinus are completely resected. Resection of the anterior wall of maxillary sinus and the tumor inside maxillary sinus is then performed, after subperiosteal dissection of the anterior wall of the maxilla out to the lateral wall. After medial wall and anterior wall of the maxillary sinus have been resected, the posterior wall, orbital floor, lateral wall, part of the zygoma, and ethmoid sinus are also, respectively, removed. Lastly, the floor of maxillary sinus and horizontal plate of palatine bone are resected.

A possible alternative approach to type D maxillectomy type is the endoscopic endonasal anterior maxillotomy after palpating the edge of the pyriform aperture, just anterior to the head of the inferior turbinate, and the mucosa and periosteum are incised vertically. A subperiosteal dissection of the pyriform aperture and anterior maxilla exposes the infraorbital foramen and neurovascular bundle. The course of the anterosuperior alveolar nerve is then identified, and a window is created in the anterior wall of the maxilla using a high-speed drill, staying inferior to the infraorbital foramen and preserving the anterosuperior alveolar nerve trunk and any major branches. The size of the window may range between 0.5 and 1.0 cm. Such techniques allow to control the entire maxillary sinus, up to its anteroinferior corner and the junction of its anterior and lateral wall [30].

11.12 Transoral-Transnasal Endoscopic Maxillectomy

When a more extensive surgical control of the maxilla, and infratemporal and pterygopalatine fossae, is required, a combined transoral-transnasal approach can allow to achieve clear margins and accurate hemostasis, without external cutaneous scars [31]. After an endoscopic medial maxillectomy has been performed, an incision is placed at the level of the ipsilateral gingivobuccal sulcus, from the contralateral central incisor to the ipsilateral third molar. Blunt subperiosteal dissection of the soft tissues is performed with a Freer dissector along the anterior wall of the maxillary sinus, until reaching the infraorbital nerve superiorly and the zygomaticomaxillary fissure laterally. Vertically oriented osteotomies along the intermaxillary fissure, zygomaticomaxillary fissure, and ascending process of the maxilla, and transversally along the superior or inferior margin of the infraorbital neurovascular bundle, are performed with powered instrumentation to detach the anterior aspect of the maxilla.

An incision is made sagittally along the mucosa of the hard palate, which is raised and reflected with a soft-tissue elevator. A nasal floor/palate osteotomy is performed from posterior to anterior, as close as possible to the medial maxillary wall, in order to preserve more palatal bone to facilitate reconstruction, if oncologically possible. The sphenopalatine artery and foramen are identified at the level of the ethmoidal crest. The sphenopalatine artery is clipped and cauterized, and the foramen is opened. The adjacent posterior wall of the maxillary sinus is also removed in a lateral fashion, thus exposing the pterygopalatine and the infratemporal fossae. The internal maxillary artery is identified and clipped, and the posterior osteotomy is continued as laterally and anteriorly as possible, connecting it to the osteotomy previously performed along the zygomaticomaxillary fissure [31].

11.13 Endoscopic-Assisted Transfacial Maxillectomy

Malignant tumors growing posterolaterally in the maxillary sinus are associated with high recurrence risk and worse survival outcomes compared to tumors with predominant anterior or medial extension [32]. Local recurrence is also most frequently located at the posterior margin of resection and is rarely suitable for salvage surgery [33]. Transnasal endoscopic approach to

maxillectomy could provide some advantages, compared to the traditional open approach, including better visualization of the medial/superomedial component of tumors extended towards the midline, more precise and easy delineation of the posterior resection margin in view of the improved magnification, and possibility to carefully dissect neurovascular and muscular structures with optimal bleeding control [34].

Traditional transfacial maxillectomies are classified as inferior maxillectomy, when the segment of maxilla below the axial plane passing through the infraorbital foramen is removed; subtotal maxillectomy, when the superior osteotomy is made along a plane passing between the infraorbital foramen and orbital floor; total maxillectomy, when resection also includes the orbital floor (also extendable to the periorbital/extraconal fat); or extended maxillectomy, when the orbital content has also been removed [35]. Before proceeding with the transnasal osteotomies, posterior resection is carried on transnasally with endoscopic guidance.

The resection of the posterior peri-maxillary tissues can be modulated according to three types of extension [34]:

- Type 1 posterior resection implies removal of the pterygopalatine fossa content. After debulking the nasal and maxillary portion of the tumor, a type B endoscopic medial maxillectomy is performed. The posterior maxillary wall is partially removed, and the pterygopalatine fossa content is left covered by its periosteum and laterally dissected from the pterygoid plates up to a sagittal plane passing through the infraorbital canal. The pterygoid plates are selectively drilled at the level of the pterygomaxillary junction to detach the maxillary bone from the pterygoid process. For tumors invading the junction between the posterior maxillary wall and orbital floor, the inferior orbital fissure may be included in the dissection.
- Type 2 consists of a type 1 posterior resection, with further partial removal of pterygoid process and muscles. After completing the steps of a type 1 resection, the pterygoid process is sectioned below the vidian canal. For tumors invading the upper portion of the pterygopalatine fossa or inferior orbital fissure, the base of the pterygoid process is entirely resected.
- Type 3 posterior resection implies removal of the cartilaginous Eustachian tube and adjacent UPS tissues. After completing a type 2 resection, a mucosal incision surrounding the nasopharyngeal ostium of the Eustachian tube as in type 3 nasopharyngectomy is performed. The cartilaginous portion of the Eustachian tube, mandibular nerve, and adjacent soft tissues are included in the specimen. For tumors abutting the skull base, the medial portion of the greater sphenoidal wing and fibrocartilage basalis can also be removed.

Type 1 posterior resection is indicated when the tumor is inserted on the posterior wall of maxillary sinus and/or determines resorption of the same bony wall and/or for tumors of the hard palate/superior alveolar ridge/superior retromolar trigone extending behind the tuber maxillae, while type 2 should be performed when tumors extend to the PPF or medial portion of the infratemporal fossa fat. Type 3 is indicated in case of lesions involving the pterygoid plates, pterygoid muscles, or anterior portion of the tube.

11.14 Conclusion

Tumors of the maxillary sinus, due to their different patterns of growth and infiltration with reference to the critical surrounding structures, require an extremely flexible surgical approach to tailor the most appropriate oncological resection as per each patient's need. For this reason, it is crucial that surgeons dealing with maxillary sinus diseases master both endoscopic and transfacial open techniques. An accurate knowledge of the anatomy of the pterygopalatine and infratemporal fossae and of the orbit is also required to be confident during resections of the surrounding tissues, often needed to obtain clear margins.

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