Anatomic Basis of Tumor Surgery. 2nd Edition

W. C. Wood, C. A. Staley and J. E. Skandalakis
William C. Wood · C. A. Staley
John E. Skandalakis (Eds.)

Anatomic Basis of Tumor Surgery

Springer
Dedication

To our best friends

_Judy, Kim, and Mimi_

who bring joy to every day
Preface

The old saying that “the best anatomist makes the best surgeon” is but a variation on the venerable saw that “you have to know the territory.” Neoplastic disease has no respect for anatomical boundaries, making detailed familiarity with anatomy that exists beyond the margins of a standard surgical method a great facilitator for many surgical procedures. The biology of cancer and knowledge of all modalities appropriate for its management continues to define new approaches to both common and rare cancers.

We are pleased to present this update of Anatomic Basis of Tumor Surgery, the 2nd edition of the book that interweaves the form of an atlas, the shape of an anatomy text, and a pervasive understanding of multimodality therapy in light of the expanding knowledge of oncologic biology. In addition to welcoming many new authors to this edition, Charles Staley has joined us as an editor. We also honor John Skandalakis for holding aloft the torch of surgical anatomy with so many contributions over the nearly ninety years of his life.

Many thanks are owed to Sean Moore, Editor for the Department of Surgery at Emory, whose diligent reviews and persistent efforts brought this book to completion.

Atlanta, Georgia, USA
William C. Wood
Charles A. Staley
John E. Skandalakis †
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Oral Cavity and Oropharynx

John M. DelGaudio
Amy Y. Chen

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Chapter 1  Oral Cavity and Oropharynx

Introduction

Malignant tumors of the oral cavity and oropharynx are predominantly (greater than 90–95%) squamous cell carcinomas. Less common tumors include minor salivary gland tumors (especially on the hard palate), verrucous carcinomas, lymphomas, melanomas, and sarcomas. The most common risk factors are tobacco, smoked and smokeless, and alcohol abuse. Less common factors include poorly fitting dentures, poor dentition with irregular surfaces, and poor oral hygiene. Nonsmokers can also be diagnosed with oral cavity and oropharynx cancer. Among nonsmokers, human papillomavirus (HPV) has recently been associated with malignancies of the oropharynx, and may portend better outcomes when compared to those without HPV infection. Malignancies of the oral cavity and oropharynx account for approximately 4% of all newly diagnosed nonskin malignancies, with a 2:1 male predominance. Approximately 34,000 new cases are diagnosed each year. Two-thirds of these are in the oral cavity and one-third in the oropharynx. Oral cancer accounts for an estimated 7,550 deaths yearly (Cancer Facts and Figures, 2007).

While oral cavity and oropharynx cancer accounts for only a small number of all new cancers, the functional problems created by these tumors and their treatment are significant. Oral cavity and pharyngeal dysfunction affects speech, oral competence, the first and second (oral and pharyngeal) phases of swallowing, and in some instances, the ability to adequately protect the airway. Even small tumors may result in significant weight loss due to pain, dysphagia, and odynophagia, resulting in malnutrition. Dysarthria affects interpersonal communication and frequently results in withdrawal from public situations.

An important consideration in the treatment of oral cavity and oropharyngeal malignancies is the high incidence of second primary tumors. These tumors may be synchronous or metachronous, and occur in approximately 20% of patients. More than half of these second primary tumors are found in the upper airway and digestive tract, most commonly in the esophagus, larynx, oral cavity, and pharynx, as a result of the widespread carcinogenic effects of tobacco and alcohol. Second primary cancers of the lung are also common and for the same reasons. Pretreatment evaluation with chest radiography or computed tomography (CT), positron emission testing (PET), and rigid laryngoscopy and esophagoscopy, is advised to fully stage these tumors.

Staging of oral cavity and oropharyngeal tumors is based on the TNM staging system. Treatment options include surgery, radiation, and combined modality treatment. In general, early squamous cell carcinomas of the oral cavity and oropharynx (i.e., T1 and T2) are treated equally effectively with either surgery or radiation therapy. When deciding on the appropriate treatment modality the physician needs to take into account patient characteristics such as age, overall health, and whether the patient will continue using tobacco or alcohol. Those patients who will continue smoking and drinking are better served with surgical treatment, to reserve radiation
Table 1.1 Clinical classification of squamous cell carcinoma of the oral cavity and oropharynx

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<tr>
<td><strong>Primary tumor (T)</strong></td>
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<tr>
<td>• TX: Primary tumor cannot be assessed</td>
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<tr>
<td>• T0: No evidence of primary tumor</td>
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<tr>
<td>• Tis: Carcinoma in situ</td>
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<td>• T1: Tumor 2 cm or less in greatest dimension</td>
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<tr>
<td>• T2: Tumor more than 2 cm but not more than 4 cm in greatest dimension</td>
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<td>• T3: Tumor more than 4 cm in greatest dimension</td>
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<td>• T4: (lip) Tumor invades adjacent structures (e.g., through cortical bone, inferior alveolar nerve, floor of mouth, skin of face) (oral cavity) Tumor invades adjacent structures (e.g., through cortical bone, into deep [extrinsic] muscles of tongue, maxillary sinus, skin. Superficial erosion alone of bone/tooth socket by gingival primary is not sufficient to classify as T4)</td>
</tr>
<tr>
<td><strong>Regional lymph nodes (N)</strong></td>
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<tr>
<td>• NX: Regional lymph nodes cannot be assessed</td>
</tr>
<tr>
<td>• N0: No regional lymph node metastasis</td>
</tr>
<tr>
<td>• N1: Metastasis in a single ipsilateral lymph node, 3 cm or less in greatest dimension</td>
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<tr>
<td>• N2: Metastasis in a single ipsilateral lymph node, more than 3 cm but not more than 6 cm in greatest dimension; or in multiple ipsilateral lymph nodes, none more than 6 cm in greatest dimension; or in bilateral or contralateral lymph nodes, none more than 6 cm in greatest dimension</td>
</tr>
<tr>
<td>• N2a: Metastasis in a single ipsilateral lymph node more than 3 cm but not more than 6 cm in dimension</td>
</tr>
<tr>
<td>• N2b: Metastasis in multiple ipsilateral lymph nodes, none more than 6 cm in greatest dimension</td>
</tr>
<tr>
<td>• N2c: Metastasis in bilateral or contralateral lymph nodes, none more than 6 cm in greatest dimension</td>
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<tr>
<td>• N3: Metastasis in a lymph node more than 6 cm in greatest dimension</td>
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<tr>
<td><strong>Distant metastasis (M)</strong></td>
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<td>• MX: Presence of distant metastasis cannot be assessed</td>
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<tr>
<td>• M0: No distant metastasis</td>
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<tr>
<td>• M1: Distant metastasis</td>
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<td>Stage II T2, N0, M0</td>
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<tr>
<td>Stage III</td>
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<tr>
<td>• T3, N0, M0</td>
</tr>
<tr>
<td>• T1, N1, M0</td>
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<tr>
<td>• T2, N1, M0</td>
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<tr>
<td>• T3, N1, M0</td>
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<tr>
<td>Stage IVA</td>
</tr>
<tr>
<td>• T4a, N0, M0</td>
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<tr>
<td>• T4a, N1, M0</td>
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<td>• T1, N2, M0</td>
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<tr>
<td>• T3, N2, M0</td>
</tr>
<tr>
<td>• T4a, N2, M0</td>
</tr>
<tr>
<td>Stage IVB</td>
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<tr>
<td>• Any T, N3, M0</td>
</tr>
<tr>
<td>• T4b, any N, M0</td>
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<th>Oropharynx Staging</th>
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<tr>
<td><strong>Tumor</strong></td>
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<tr>
<td>• T1 - confined to nasopharynx</td>
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<tr>
<td>• T2 - extends to soft tissues</td>
</tr>
<tr>
<td>• T2a - extends to oropharynx and/or nasal cavity without parapharyngeal extension</td>
</tr>
<tr>
<td>• T2b - any tumor with parapharyngeal extension (i.e. beyond the pharyngobasilar fascia)</td>
</tr>
<tr>
<td>• T3 - involves bony structures and/or paranasal sinuses</td>
</tr>
<tr>
<td>• T4 - intracranial extension and/or involvement of cranial nerves, infratemporal fossa, hypopharynx, orbit, or masticator space</td>
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(continued)
therapy for possible future primary tumors or recurrent lesions. It is also important to consider the functional morbidity related to treatment (i.e., the consequences of surgical resection or reconstruction). Advanced tumors, T3 or T4, or N+, are best treated with primary surgical resection and postoperative radiation therapy. Bone invasion mandates surgical resection because of the poor response of these tumors to radiation therapy. CT scanning is helpful in assessing the presence and degree of bone invasion. When cervical nodal metastases are present, neck dissection is indicated. Also, when the risk for occult metastases exceeds 30%, prophylactic treatment of the neck, whether with surgery or radiation therapy, should be included in the treatment plan. Concurrent chemoradiotherapy is also employed for advanced stage cancers of the oropharynx. Concurrent chemoradiotherapy was found to be superior to induction chemotherapy followed by radiation in RTOG 91–11 for laryngeal cancer, and the results were extrapolated to oropharyngeal cancer. Posner’s recent study in NEJM details the effectiveness of induction chemotherapy followed by chemoradiation in improvement of survival.

Cetuximab is the only new agent approved by the Food and Drug Administration for use in head and neck cancer in 40 years. Erbitux blocks epidermal growth factor, which is expressed among most epithelial-based cancers, such as squamous cell carcinoma. A randomized clinical trial demonstrated the superiority of Erbitux and radiation to radiation alone for head and neck cancers. Unfortunately, no comparison can be made to the other chemotherapy given concurrently with radiation, such as cisplatin. Other small molecule inhibitors, such as tyrosine kinase inhibitors, are also being investigated as effective agents in ongoing Phase I and Phase II clinical trials. The role of chemotherapy continues to be under evaluation.
Adjuvant Treatment

Adjuvant treatment may be necessary after surgery for head and neck cancers. Recently published articles detail the advantage of postoperative concurrent cisplatin with radiation for lesions with extracapsular extension in the lymph nodes or positive margins on resection. Postoperative adjuvant radiation is indicated for lesions demonstrating pathologic perineural invasion or with more than one regional lymph node involved with cancer.

Surgical Anatomy

Figure 1.1

Vermilion
Incisive foramen
Greater palatine n.
Bony palate
Greater palatine a.
Greater palatine foramen
Tensor palatini m.
Hamulus
Buccinator m.
Superior constrictor m.
Palatopharyngeus m.
Palatoglossus m.
Chapter 1  Oral Cavity and Oropharynx

The oral cavity extends posteriorly from the lips to the junction of the hard and soft palates superiorly, the anterior tonsillar pillars laterally, and the line of the sulcus terminalis and circumvallate papillae of the tongue inferiorly. The oral cavity is subdivided into multiple entities: lips, oral tongue, floor of the mouth, buccal mucosa, lower alveolar ridge, retromolar trigone, hard palate, and upper alveolar ridge.

The oropharynx is a posterior continuation of the oral cavity and extends superiorly to the level of the soft palate and inferiorly to the level of the hyoid bone. The oropharynx is subdivided into multiple sites: the tonsils, soft palate, tongue base, valleculae, and posterior pharyngeal wall. Each component of the oral cavity and pharynx is discussed individually because each presents unique problems with regard to surgical resection and reconstruction.
Oral Cavity

The tongue occupies portions of both the oral cavity and the oropharynx. The mobile anterior two-thirds is part of the oral cavity and is referred to as the oral tongue. The fixed posterior one-third occupies the oropharynx and is referred to as the tongue base. The line of demarcation of the oral tongue and the tongue base is at the sulcus terminalis, which is a V-shaped groove just behind the circumvallate papillae. The dorsum, or upper surface, of the tongue is velvety because it is covered by numerous filiform papillae, with interspersed larger fungiform papillae. Just anterior to the sulcus terminalis are a row of large circumvallate papillae, which contain the taste buds. The foramen cecum, a small blind pit at the apex of the sulcus terminalis, represents the site of origin of the thyroid gland, and it may also be the site of ectopic thyroid tissue or a true lingual thyroid gland. The dorsum of the tongue base is covered by lymphoid tissue, which represents the lingual tonsils. The mucosa of the ventral tongue, or undersurface, is smooth and transitions into the floor of the mouth mucosa anteriorly and laterally. Anteriorly, the lingual frenulum attaches the tongue to the anterior floor of the mouth. More posteriorly is the root of the tongue, which is the attached part of the tongue through which the extrinsic muscles reach the body of the tongue.

The tongue is a muscular structure composed of three sets of paired intrinsic muscles and three sets of paired extrinsic muscles. The intrinsic muscles are the longitudinal...
(superior and inferior), vertical, and transverse muscles. These muscles make up the body of the tongue and function to alter the shape of the tongue during speech and swallowing. The extrinsic muscles include the paired genioglossus, hyoglossus, and styloglossus muscles, which serve to move the tongue and change its shape.

The hyoglossus is a flat muscle that rises from the body and greater horn of the hyoid bone, partly above and partly behind the mylohyoid muscle, and extends superiorly and anteriorly into the tongue, interlacing with fibers of the other muscles. The styloglossus muscle originates from the styloid process and stylohyoid ligament, and runs anteroinferiorly and medially to insert into the side of the tongue. The genioglossus muscle originates from the mental spine on the inner surface of the mandible, immediately above the geniohyoid muscle, and fans out as it extends posteriorly. The lower fibers insert into the body of the hyoid bone, but the majority of fibers run superiorly and posteriorly to insert into the tongue, from the base to the
tip. The palatoglossus muscles, which insert into the posterolateral tongue, probably do not function in tongue movement (see section on soft palate). The area through which these muscles enter the tongue to attach to the body is the root. The midline of the tongue has a fibrous septum that attaches it to the hyoid bone posteriorly and provides an avascular plane that separates the two sides of the tongue. The septum is present through the entire tongue but does not reach the dorsum.

The connective tissue that separates the muscular bundles of the tongue provides a weak barrier to the spread of tumor. This results in deep invasion of the tongue by malignant tumors because significant symptoms do not occur until speech or swallowing are affected or the lingual nerve is invaded. Tumors of the tongue frequently are large before diagnosis. Also, the deeply invasive nature of carcinoma of the tongue results in greater difficulty in obtaining clear resection margins without resecting large portions of the tongue. It is recommended that approximately 2 cm of normal tissue be resected around tongue cancers and that frozen-section sampling of the margins be performed. This is especially true in tongue-base tumors, which grow large before becoming symptomatic, frequently invading the root of the tongue. With invasion of the root of the tongue, surgical extirpation requires total glossectomy because all attachments of the tongue are transected with removal of the root.

The relationship of the oral tongue to the floor of mouth is important in maintaining tongue mobility. Squamous cell carcinoma of the oral tongue is most commonly located on the lateral surface of the middle third of the tongue, in proximity to or involving the floor of mouth. After resection of tumors of the tongue or floor of mouth, attempts should be made to reconstitute a sulcus between the tongue and the mandibular alveolus to prevent or minimize tethering of the tongue, allowing optimum postoperative rehabilitation of speech and swallowing. With resection of up to half of the tongue, primary closure, healing by secondary intention, skin grafting, or a thin pliable flap (i.e., platysma flap, free radial forearm) will accomplish this goal and allow better tongue function postoperatively. More extensive resection of the tongue presents more difficult problems and usually requires reconstructive techniques to restore bulk to the tongue (i.e., pectoralis major or other pedicled myocutaneous flap, or free tissue transfer). A bulky or sensate flap is necessary for reconstruction of the tongue base to prevent or minimize aspiration.

The arterial supply to the tongue is from the paired lingual arteries, which originate from the external carotid artery at the level of the greater horn of the hyoid bone. The lingual artery passes deep to the hyoglossus muscle and gives off one or two deep lingual branches that supply the tongue base. The sublingual artery originates near the anterior border of the hyoglossus muscle and continues forward between the mylohyoid and genioglossus muscles to supply these muscles, the geniohyoid muscle, and the sublingual gland. The remainder of the lingual artery proceeds forward as a dorsal lingual artery between the genioglossus and longitudinal muscles. It reaches the ventral surface of the tongue just deep to the mucosa, where it is accompanied by the deep lingual vein, which can be seen through the thin mucosa of the ventral tongue. The remainder of the venous drainage accompanies the arterial branches, ultimately joining the deep lingual vein to form the lingual vein, which empties into
the internal jugular vein. Only at the tip of the tongue is there any anastomosis across the midline between the lingual arteries.

The hypoglossal nerve (cranial nerve XII) supplies motor innervation to the extrinsic and intrinsic muscles of the tongue. As it travels beneath the lateral fascia of the hyoglossus muscle, it innervates the extrinsic muscles, and as it reaches the anterior border of this muscle, it penetrates the tongue around the midportion of the oral tongue to supply the intrinsic muscles. Sensory innervation of the tongue is from the lingual nerve (a branch of V3) and the glossopharyngeal nerve (cranial nerve IX). The lingual nerve travels in the floor of the mouth above the hypoglossal nerve, between the mylohyoid and hyoglossus muscles, to innervate the anterior two-thirds of the tongue and floor of mouth. The chorda tympani branch of the facial nerve travels with the lingual nerve and supplies taste to the anterior two-thirds of the tongue. Sensation and taste are supplied to the base of the tongue by the glossopharyngeal nerve. This nerve enters the oropharynx laterally through the interspace between the superior and middle pharyngeal constrictor muscles and enters the base of the tongue posterior to the hyoglossus muscle.

During glossectomy, preservation of at least one hypoglossal nerve is necessary to maintain some tongue mobility and prevent severe oral dysfunction. Referred otalgia to the ipsilateral ear is a common symptom of carcinoma of the tongue because V3 (the mandibular division of the trigeminal nerve) also provides sensory branches
Oral Cavity

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to the external auditory canal, tympanic membrane, and temporomandibular joint through the auriculotemporal nerve. The glossopharyngeal nerve also provides sensation to the middle ear via Jacobsen’s nerve.

The tongue has an extensive submucosal lymphatic plexus that ultimately drains to the deep jugular lymph-node chain. In general, the closer to the tip of the tongue the lymphatic vessels arise, the lower the first echelon node. The tip of the tongue drains to the submental nodes, the lateral tongue to the submandibular and lower jugular nodes (jugulo-omohyoid), and the tongue base to the jugulocarotid and jugulodigastric nodes. In addition, there is communication of lymphatic vessels across the midline of the tongue, which results in a high incidence of bilateral metastases of tumors of the tip of the tongue and tumors that approximate the midline of the tongue. The rich lymphatic network results in early metastases to cervical lymph nodes, even from small tumors (T1 or T2). Therefore, consideration of treatment of one or both sides of the neck, either by neck dissection or radiation therapy, is advised in most tongue cancers.

The floor of the mouth is a crescent-shaped region of the oral cavity extending from the root of the tongue to the lower gingiva. Posteriorly it ends at the level where the anterior tonsillar pillar meets the tongue base. Anteriorly it is divided into two sides by the lingual frenulum. On either side of the lingual frenulum are the papillae of

Figure 1.6

Floor of Mouth
the submandibular ducts. Posterolateral to these papillae lie the sublingual folds, elevated areas of mucosa over the sublingual glands.

The floor of mouth is supported by a muscular sling composed of the mylohyoid, geniohyoid, and hyoglossus muscles. The paired mylohyoid muscles extend from the mylohyoid line on the inner surface of the mandible to insert on the hyoid bone, meeting in the midline as a median raphe. It is innervated by the mylohyoid branch of the lingual nerve. The hyoglossus muscle lies posterior and deep to the mylohyoid muscle, extending from the greater horn and body of the hyoid bone to insert into the body of the tongue. This muscle partly supports the posterior floor of mouth. The geniohyoid muscles, which are paired triangular muscles extending from the apex of the mental spine of the mandible to the body of the hyoid bone, are located in the midline floor of mouth superficial to the mylohyoid muscles but deep to the genioglossus muscles. Their lateral borders are in contact with the mylohyoid muscle. These muscles function in laryngeal elevation with speech and swallowing and are innervated by V3.

The submandibular gland lies mostly superficial to the mylohyoid muscle. The space between the mylohyoid and hyoglossus muscles is an important surgical area. Posteriorly these muscles are separated by the tail of the submandibular gland, which wraps around the posterior border of the mylohyoid muscle before sending the submandibular duct anteriorly to open in the floor of mouth next to the lingual frenulum. The posterior part of the submandibular duct is surrounded by the sublingual gland. The lingual nerve, which gives sensory innervation to the floor of mouth, enters the floor of mouth superiorly to the submandibular duct and crosses it laterally before ascending on the medial surface of the duct adjacent to the hyoglossus muscle. The hypoglossal nerve always lies along the most inferior part of this plane deep to the fascia of the hyoglossus muscle.

Deep to the plane of the hyoglossus muscle lie three structures: the lingual artery, which supplies the floor of mouth, and more posteriorly the glossopharyngeal nerve and the stylohyoid ligament. The floor of mouth musculature, specifically the
mylohyoid muscle, provides a fairly good barrier to the deep spread of tumor in the floor of mouth.

The lymphatic drainage in the floor of mouth arises from an extensive submucosal plexus. The anterior floor of mouth drains into the submental and preglandular submandibular nodes, with the medial anterior floor of mouth having cross-drainage to the contralateral side of the neck. The posterior floor of mouth drains directly to the ipsilateral jugulodigastric and jugulocarotid nodes.

Treatment of tumors of the floor of mouth greater than 2 cm should include treatment of the neck because of the approximately 40% risk for occult cervical metastases. For midline lesions, consideration should be given to bilateral prophylactic selective (supraomohyoid) neck dissection.

Tumors of the floor of mouth usually spread superficially to adjacent structures such as the root of tongue and the mandible prior to invading deeply into the floor of mouth. It is important to perform bimanual palpation to evaluate the depth of invasion and to determine whether the lesion is fixed to the mandible. This will allow adequate surgical planning, with resection, including a 1.5–2-cm margin of normal tissue around the tumor. This frequently includes resection of a portion of the tongue and may require cortical, rim, or segmental mandibular resection. The depth of invasion is important for planning reconstruction after tumor ablation, as reconstruction options are vastly different if the resection results in a full-thickness defect, connecting the oral cavity to the neck. Primary closure is sometimes possible for full-thickness defects, but more commonly pedicled flaps (i.e., platysma, sternocleidomastoid, nasolabial, and pectoralis major) or free tissue transfers (radial forearm or lateral arm) are necessary to reconstitute the floor of mouth and prevent tethering of the tongue.

In resecting floor of mouth tumors attention must be given to the position of the submandibular duct. Tumors may spread along the submandibular duct to involve the submandibular triangle. In this instance, the submandibular duct and gland should be resected along with the primary tumor, usually as part of a neck dissection. If the submandibular duct is not involved but excision of floor of mouth tumor results in transecting the submandibular duct, the duct should be reimplemented into the remaining floor of mouth mucosa or the submandibular gland should be removed.

The buccal mucosa forms the lateral wall of the oral cavity. It consists of the mucous membranes lining the internal surface of the cheeks and lips, extending posteriorly to the pterygomandibular raphe and vertically to the mucosa of the alveolar ridges. Topographically, the only structure present is the papillae of the parotid gland duct (Stensen’s duct), which opens into the buccal mucosa opposite the second maxillary molar. The buccinator muscle, which originates in the superior constrictor muscle posteriorly and inserts into the perioral musculature, forms the lateral muscular wall of the oral cavity. The buccinator muscle assists in providing oral competence. Lateral to this muscle lie the buccal fat pad and the buccal branches of the facial and trigeminal nerves.

The motor innervation of the buccinator muscle is through the buccal branch of the facial nerve. Sensory innervation to the buccal mucosa is from the buccal branch of the
trigeminal nerve, with the infraorbital nerve and the mental branches of V3 supplying the anterior buccal mucosa. The vascular supply is from the facial vessels. Lymphatic drainage of the buccal mucosa is into the submental and submandibular nodes.

Deep invasion of the buccal mucosa by squamous cell carcinoma can result in invasion of the buccal fat pad. When this occurs, full-thickness resection of the cheek is necessary to obtain adequate surgical margins. Also, with deep cheek invasion consideration should be given to performing a parotidectomy to remove intraparotid lymph nodes, which may be at risk for metastases. Reconstruction of full-thickness defects of the cheek may be accomplished with pedicled flaps, rotational flaps, or more pliable fasciocutaneous free flaps.

The lower alveolar ridge is the mucosa and alveolar process of the mandible in the oral cavity. It is bounded by the junctions with the floor of mouth mucosa on the lingual surface and the buccal mucosa. It extends posteriorly to the retromolar trigone. The mucosa of the alveolar ridge, or gingiva, is tightly adherent to the underlying periosteum and bone. The periosteum provides the first line of defense against tumor spread into the mandible. The healthy dentulous mandible provides a barrier to tumor invasion into bone because of the tight periodontal ligaments. In the edentulous mandible, as is frequently the case with oral cavity cancer, cortical remodeling of the alveolus results in vertical loss of height of the mandible and areas of incomplete cortical bone that can be a site of tumor invasion.

The vascular supply of the lower alveolar ridge and teeth is by the inferior alveolar artery, a branch of the internal maxillary artery. Sensory innervation of the mandibular teeth is from the inferior alveolar nerve, a branch of V3. These structures enter the mandible on the medial aspect of the ramus through the mandibular foramen, travel through the inferior alveolar canal, and exit at the mental foramen, opposite the second bicuspid, as the mental nerve and artery. The gingiva of the lower alveolus receives sensory innervation from the lingual nerve on the lingual aspect and from the buccal and mental branches crowded on the buccal aspect. The lymphatic drainage for the lower alveolus is through the submental, submandibular, and upper jugular nodes.

The alveolar ridge is more often involved with tumor as a result of extension from adjacent structures than by primary tumor involvement. This is true of the underlying mandible also. Treatment of mandible and oral cavity cancers is an important consideration with respect to both oncologic resection and reconstruction, and oral rehabilitation. When oncologically safe, the best function and cosmesis are provided with mandible-sparing procedures, either completely sparing the mandible or resecting a partial thickness, thus preserving mandibular arch continuity. Tumors with radiologically demonstrable or gross invasion are best treated with segmental resection and sampling of the margin of the inferior alveolar nerve to ensure clear margins. If invasion is superficial and does not involve the medullary canal, a rim or cortical mandibular resection can be considered, although segmental resection is oncologically safer. Tumors that are fixed to the mandibular periosteum but are not invading bone can be safely treated with a rim or cortical mandibulectomy, in which the alveolar process and medullary cavity are removed, saving an inferior cortical rim.
For tumors within 1 cm of the mandible but not involving the periosteum, stripping the periosteum and evaluating this as a surgical margin on frozen section may be adequate. If the periosteum is involved, partial bony resection is indicated. For patients who have had previous radiation therapy to the oral cavity, segmental resection of the mandible is the recommended treatment for tumors that invade the periosteum or bone. Partial-thickness resection brings with it the risk of osteoradionecrosis.

The need for mandibular reconstruction after segmental resection of the mandible is dependent on multiple factors. Lateral mandibular defects do not require reconstitution of the bony arch, in most circumstances, for adequate function and cosmesis. Patients with full dentition should undergo reconstruction of the lateral arch to restore postoperative dental occlusion. With anterior mandibular arch defects, reconstruction is necessary for adequate function and cosmetic results. This is best accomplished with free tissue transfer (fibular or iliac crest free flaps), although pedicled myocutaneous flaps and reconstruction plates may work in some cases.

The retromolar trigone is the portion of the alveolar gingiva overlying the ramus of the mandible. Its anterior base is posterior to the last molar. The superior apex lies at the maxillary tuberosity. It is laterally bounded by the oblique line of the mandible as it extends up to the coronoid process and is medially bounded by a line from the distal lingual cusp of the last molar to the coronoid process. This small triangular area blends laterally with the buccal mucosa and medially with the anterior tonsillar pillar. The mucosa of the retromolar trigone is tightly adherent to the underlying bone, which allows malignant tumors to infiltrate the mandible at an early stage. Also, the lingual nerve enters the mandible just posterior and medial to the retromolar trigone and may become involved with tumor relatively early. By the time of diagnosis, tumors of the retromolar trigone commonly invade surrounding structures, including the tonsil, soft palate, buccal mucosa, floor of mouth, and tongue. Conversely, the retromolar trigone is frequently involved with tumors extending from these adjacent areas. This makes it difficult to determine where the tumor originated.

Sensory innervation of the retromolar trigone is through the branches of the glossopharyngeal and lesser palatine nerves (V2). The blood supply is similar to that of the nearby tonsil, predominantly from the tonsillar and ascending palatine branches of the facial artery, with contributions from the dorsal lingual, ascending pharyngeal, and lesser palatine arteries. Venous drainage is to the pharyngeal plexus and common facial vein. Lymphatic drainage is to the upper deep jugular chain.

The upper alveolar ridge is the mucosa and alveolar process of the maxilla. It is bounded laterally by the gingivobuccal sulcus and medially is continuous with the hard palate. The hard palate is the roof of the oral cavity, extending from the alveolar ridge to its junction with the soft palate posteriorly. The hard palate is composed of mucosa covering the bony hard palate. The bony palate consists of the premaxilla, which is the part anterior to the incisive foramen and includes the incisor teeth. The secondary palate is posterior to the incisive foramen and is formed by the paired palatine processes of the maxilla and the horizontal plates of the palatine bones.
Multiple foramina are present in the hard palate and transmit the neurovascular bundles. The incisive foramen transmits the nasopalatine nerve and the posterior septal artery from the anterior nasal cavity to supply the premaxilla and lingual surface of the premaxillary gingiva.

Posterolaterally, near the junction of the hard and soft palates, are the greater and lesser palatine foramina, which transmit the greater and lesser palatine nerves and blood vessels from the pterygopalatine fossa. The greater palatine nerve and vessels supply the hard palate and lingual surface of the upper alveolus, excluding the premaxilla. Different neurovascular bundles supply the teeth and the buccolabial surfaces of the upper alveolus. The posterosuperior alveolar vessels, which descend on the infratemporal surface of the maxilla, supply the upper alveolar teeth and the buccolabial gingiva. Sensory innervation to the maxillary teeth and the buccolabial gingiva posterior to the premaxilla is from the posterosuperior alveolar nerves. The labial gingiva of the premaxilla is supplied by the branches of the infraorbital nerve. All of these nerves and vessels are terminal branches of the maxillary nerve (V2) and the sphenopalatine branch of the internal maxillary artery, respectively.
Lymphatic vessels of these structures, especially the hard palate, are sparse compared with other sites in the oral cavity. Lymphatic drainage from the hard palate and lingual surface of the upper alveolus is to the upper jugular or lateral retropharyngeal nodes. The premaxilla also drains to the submandibular nodes. The buccolabial surface of the upper alveolus drains to the submandibular nodes. The sparse lymphatics draining the hard palate result in infrequent cervical metastases from malignancies of the hard palate (10–25%). For this reason, neck dissection is reserved for clinically positive lymph nodes.

The foramina of the hard palate provide pathways of extension of malignancy to the nasal cavity through the incisive foramen, and the pterygopalatine fossa through the palatine foramina. Evaluation of tumors of the hard palate and upper alveolus requires radiologic evaluation for possible perineural spread to the skull base. Magnetic resonance imaging (MRI) with gadolinium is useful for this purpose.

Although squamous cell carcinoma is the most common malignancy found in the hard palate, minor salivary gland tumors are nearly as frequent. Adenoid cystic carcinomas are the most common lesions, followed by mucoepidermoid carcinomas. These tumors have a higher likelihood of neural spread.

Treatment of hard palate and upper alveolar ridge malignancies, except in small tumors or those superficial tumors limited to the mucosa, may require partial or total maxillectomy. This results in communication of the oral and sinonasal cavities. Unlike other areas of the oral cavity where flap reconstruction is usually performed, palatal rehabilitation is best achieved with use of a palatal obturator or modified denture to restore oral competence.

**Oropharynx**

Along with being continuous with the oral cavity anteriorly, the oropharynx forms a tube continuous with the nasopharynx superiorly and the hypopharynx inferiorly. The oropharynx is first considered as part of the larger structure, the pharynx, and then separately. The pharynx is constructed of a myofascial framework that encloses the pharyngeal lumen and its contents. The external surfaces of the pharynx make up portions of the borders of important deep neck spaces involved in various disease processes, such as the parapharyngeal space.

The pharyngeal wall is composed of stratified squamous epithelium that covers the internal surface of the myofascial layer, which extends from the skull base superiorly to the level of the inferior border of the cricoid cartilage inferiorly. This myofascial layer is composed of three paired muscles, which are U-shaped with the opening anteriorly. These muscles form a telescoping structure, with the lower muscles overlapping the upper muscles at the inferior border. All three sets of muscles insert posteriorly on a midline posterior pharyngeal raphe, which is suspended superiorly from the pharyngeal tubercle of the basiocciput.
These paired pharyngeal constrictor muscles (superior, middle, and inferior) are covered internally and externally by fascial layers. Internally the constrictor muscles are covered by the pharyngobasilar fascia, which is thick superiorly and thin inferiorly and covers the constrictor muscles the length of the pharynx. Superiorly the pharyngobasilar fascia is attached to the pharyngeal tubercle of the occiput, extends along the petrous portion of the temporal bone, and attaches anteriorly to the medial pterygoid plate and the pterygomandibular raphe. This upper, thick portion of the fascia suspends the superior constrictor muscle from the skull base. The external surface of the pharyngeal constrictor muscle is covered by the buccopharyngeal fascia, which covers the pharynx at the level of the superior constrictor muscle and fuses below this level with the middle layer of deep cervical fascia, which forms the remainder of the external fascial covering of the pharynx.

The superior pharyngeal constrictor muscle originates from the medial pterygoid plate and pterygomandibular raphe anteriorly, its fibers extending posteriorly in a horizontal and slightly superior and inferior direction to insert on the posterior pharyngeal midline raphe. This muscle surrounds the oropharynx.

Between the overlapping layers of pharyngeal constrictor muscles are intervals through which structures enter the pharynx. The interval between the superior and middle constrictor muscles is traversed by the stylopharyngeus muscle, which extends from the styloid process and extends inferiorly and anteriorly in an oblique fashion to attach to the medial aspect of the middle constrictor muscle. The glossopharyngeal nerve, which supplies sensory innervation to the base of tongue and the pharynx, also traverses this interspace and, along with the lingual artery, runs deep to the hyoglossus muscle. The stylohyoid ligament, which attaches to the lesser cornu of the hyoid bone, also traverses this interval. This interval between the superior and middle pharyngeal constrictor muscles lies at the inferior pole of the tonsil and provides a pathway of extension of tumor to the parapharyngeal space, which lies lateral to the superior constrictor muscle.

The motor innervation of the pharyngeal muscles is from the pharyngeal plexus, which is composed of the pharyngeal branches of the glossopharyngeal and vagus nerves. The glossopharyngeal nerve supplies only the stylopharyngeus muscle and the vagal contribution supplies all the other muscles, including the muscles of the soft palate (with the exception of the tensor palatini muscle, which is supplied by the mandibular branch of the trigeminal nerve).

The vascular supply of the oropharyngeal mucosa is from the ascending pharyngeal artery, a branch of the external carotid artery. The venous drainage of the pharynx is through the pharyngeal plexus on the posterior surface of the pharynx, which drains into the pterygoid plexus, the superior and inferior thyroid veins, and the facial vein, and directly into the internal jugular vein. The lymphatic drainage of the oropharyngeal mucosa varies depending on the anatomic level. The posterior drainage is through the retropharyngeal lymph nodes (nodes of Rouvier), located behind the pharynx at the level of the carotid bifurcation. Drainage of the lateral pharyngeal structures is to the jugulodigastric and midjugular lymph nodes in the deep jugular chain.