CT and MR Imaging of Squamous Cell Carcinoma of the Tongue and Floor of the Mouth

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Because contemporary treatment of oral cavity cancer involves procedures that spare the tongue and mandible, an adequate assessment of the oral cavity is essential for appropriate surgical and radiation therapy planning. Computed tomography (CT) and magnetic resonance (MR) imaging, which allow differentiation between soft tissues, are valuable tools for assessing this complex region. Their main advantage resides in their capacity to show at best the normal anatomy and the exact extent of a low-lying tumor. For display of soft tissues and tumor, MR imaging, being a multiplanar and multicontrast technique, is superior to CT. Nonenhanced T1-weighted MR imaging is better for defining the exact extent of medullary bone invasion, which appears as a low-signal-intensity area within hyperintense medullary fat. CT is optimal in detection of cortical bone invasion, which appears as an interruption or erosion of the peripheral hyperattenuating rim. Thus, in cancer of the tongue, MR imaging should be performed first. If tumor extension to the mandible is suspected (due to clinical or MR imaging findings), CT should be added. In cancer of the floor of the mouth, both MR imaging and CT should be performed in the initial work-up, especially in those cases in which there is a clinical doubt about mandibular extension of disease. The main drawback of both modalities is their lack of specificity; other methods are needed to discriminate between tumors and inflammatory or infectious diseases, particularly in the mandible. However, once the diagnosis has been confirmed histologically, treatment can be chosen based on complementary information obtained from CT and MR imaging.

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INTRODUCTION
Cancer of the oral cavity accounts for 1.8% of all cancers in men and 1.1% in women in the United States (1). In France, the figures are 5.7% and 1.4%, respectively (2). Depending on the stage of the disease, the 5-year survival rate varies between 30% and 65%, which is a substantial improvement compared with the survival rates reported for the past decade (3–5).

This improvement is related to a more aggressive and effective therapeutic approach. Simultaneously, during the past 15 years, new trends in the management of oral cancer have included increased use of procedures that spare the tongue and mandible, which substantially attenuate the aesthetic and functional damages (5,6). It is therefore essential to obtain an adequate pretherapeutic assessment of the main oral cavity structures for appropriate decision making and definition of the types and limits of tongue and bone resection to be performed.

The opinions among various institutions about the appropriate roles for various imaging modalities in this assessment are diverse. Some believe that use of computed tomography (CT) is limited because dental amalgam, which causes severe artifacts in CT scans, is so common in patients (7). On the other hand, many authors have demonstrated that CT (8–11) and magnetic resonance (MR) imaging (12–17) are valuable in determining the size and extent of a low-lying tumor of the oral cavity; they recommend use of these modalities in planning for surgery and precise radiation therapy. Use of sonography has also been advocated (18–21).

Our purpose here is to review some of the issues related to the diagnosis and staging of tumors of the oral cavity, a region that can be difficult for the general radiologist to assess. In particular, we focus on the use of CT and MR imaging in evaluating squamous cell carcinoma, which is the most common tumor of the oral cavity (3,4). In this article, we describe (a) the main anatomic landmarks of the tongue and floor of the mouth; (b) the normal appearance of the oral cavity at CT and MR imaging, (c) the clinical presentation of squamous cell carcinoma, with emphasis on its stages, patterns of spread, and main treatments; (d) the various imaging modalities and protocols for evaluating the oral cavity with their advantages and disadvantages; (e) the CT and MR imaging characteristics of squamous cell carcinoma; and (f) the differential diagnosis for oral cavity lesions. We conclude by suggesting imaging strategies.

ANATOMY
We illustrate the normal anatomy of the oral cavity by presenting sagittal, coronal, and axial MR images that have been paired with corresponding anatomic slices (Figs 1–8). The anatomic slices were prepared from cadaveric head specimens that were resected at the inferior cervical level. The common carotid arteries and internal jugular vein were catheterized, rinsed, and injected with a special polymer stained red with carmen indigo for the arteries and blue with Patent Blue V (Guerbet Laboratories, Aulnay, France) for the veins. After proper spatial orientation, 4-mm-thick slices of the specimen were obtained with a saw (Biro Manufacturing, Marblehead, Ohio). Each slice was rinsed with cold water and photographed.

Oral Cavity
The oral cavity consists of two parts (22–25): the vestibule, which is the outer smaller portion, and the oral cavity proper, which is the inner larger part. The vestibule is a splitlike aperture, bounded anteriorly and laterally by the lips and cheeks and bounded posteriorly and medially by the gums and teeth. The oral cavity proper is bounded anteriorly and laterally by the alveolar arches, which contain the teeth. Posteriorly, the oral cavity communicates with the oropharynx as a constrictor aperture formed by the facial arch.

The oral cavity has been divided into the following sites: the lips, upper and lower gingivae, retromolar trigone, buccal mucosa, hard palate, floor of the mouth, and oral tongue. The oral tongue comprises the anterior two-thirds of the tongue and is also referred to as the mobile tongue. The posterior one-third of the tongue is called the base of the tongue and belongs to the oropharynx. The floor of the mouth and the tongue are lined by a squamous mucosa, which is the site of origin of the majority of oral cavity cancers.
Figures 1, 2. (1) Midsagittal MR image (a) and corresponding cadaveric specimen (b) demonstrate the normal anatomy of the oral cavity. On a, A, B, C, D, and E represent the location of the coronal MR images; F, G, and H, the axial MR images. The following keys are used in Figures 1-8: 1 = body of the mandible, 2 = ramus of the mandible, 3 = mandibular canal, 4 = hyoid bone, 5 = epiglottis, 6 = digastric muscle (anterior belly), 7 = mylohyoid muscle, 8 = geniohyoid muscle, 9 = genioglossus muscle, 10 = hyoglossus muscle, 11 = styloglossus muscle, 12 = palatoglossus muscle, 13 = superior longitudinal muscle, 14 = transverse muscle, 15 = intrinsic muscles, 16 = masseter muscle, 17 = temporal muscle, 18 = medial pterygoid muscle, 19 = lateral pterygoid muscle, 20 = platysma muscle, 21 = buccinator muscle, 22 = orbicularis oris muscle, 23 = veli palatini muscles, 24 = pharyngeal constrictor muscles, 25 = sublingual space, 26 = submandibular space, 27 = sublingual gland, 28 = submandibular gland, 29 = submandibular canal, 30 = submental triangle, 31 = buccal fat pad, 32 = parapharyngeal space, 33 = lingual tonsil, 34 = palatine tonsil, 35 = palatine glands, 36 = lingual septum, 37 = lingual mucosa, 38 = internal carotid artery, 39 = external jugular vein, 40 = facial artery, 41 = facial vein, 42 = lingual artery, 43 = sublingual artery, 44 = lateral floor of the mouth, 45 = anterior floor of the mouth, 46 = hard palate, 47 = soft palate, 48 = vallecula, 49 = base of the tongue, 50 = uvula. (2) Coronal MR image (a) and corresponding cadaveric specimen (b) demonstrate the normal anatomy of the oral cavity. Position of the MR section is indicated by letter B on Figure 1a. Refer to Figure 1 for an explanation of the keys.
Figures 3–5. (3) Coronal MR image (a) and corresponding cadaveric specimen (b) demonstrate the normal anatomy of the oral cavity. Position of the MR section is indicated by letter C on Figure 1a. (4) Coronal MR image (a) and corresponding cadaveric specimen (b) demonstrate the normal anatomy of the oral cavity. Position of the MR section is indicated by letter D on Figure 1a. (5) Coronal MR image demonstrates the normal anatomy of the oral cavity. Position of the section is indicated by letter E on Figure 1a. Refer to Figure 1 for an explanation of the keys in Figures 3–5.
Figures 6–8. (6) Axial MR image (a) and corresponding cadaveric specimen (b) demonstrate the normal anatomy of the oral cavity. Position of the MR section is indicated by letter F on Figure 1a. (7) Axial MR image (a) and corresponding cadaveric specimen (b) demonstrate the normal anatomy of the oral cavity. Position of the MR section is indicated by letter G on Figure 1a. (8) Axial MR image demonstrates the normal anatomy of the oral cavity. Position of the section is indicated by letter H on Figure 1a. Refer to Figure 1 for an explanation of the keys in Figures 6–8.
• **Floor of the Mouth**

The floor of the mouth is a crescent-shaped area between the lower gingiva and the undersurface of the tongue. Clinicians differentiate the medial and anterior portions of the floor of the mouth, which are inferior to the oral tongue, from the posterior and lateral portions, which are lateral and inferior to the tongue (one on each side).

Anatomically, the main supporting structure of the floor of the mouth is the mylohyoid muscle. This muscle originates along the mylohyoid line, on the medial surface of the mandible, from the third molar to the mandibular symphysis. It is a flat, triangular muscle that joins with its contralateral counterpart to form a sort of sling between the medial aspects of the right and left sides of the mandible. The anterior and middle fibers insert into a midline fibrous raphe, whereas the posterior fibers insert into the body of the hyoid bone. The posterior border of the muscle is free, allowing communication between the sublingual and submandibular spaces. Underneath the mylohyoid muscle lies the anterior belly of the digastric muscle, which courses anteriorly and medially from the tendon of the digastric muscle (connected to the greater cornua and body of the hyoid bone) to the digastric fossa, which is located on the inferior border of the mandible, beneath the chin.

The geniohyoid muscle lies on the oral side of the mylohyoid muscle. It runs sagittally from the inferior genial tubercle of the mandibular symphysis to the body of the hyoid bone and is parallel and contiguous with its counterpart.

• **Tongue**

The division between the two sections of the tongue—the anterior mobile or oral portion and the posterior or base portion—is manifested (at inspection but not radiologically) by the line of the circumvallate papillae. The circumvallate papillae are eight to 12 large emi-

ences that form an inverted letter V. The oral tongue, which forms two-thirds of this structure, is divided into the tip (or apex), lateral borders, dorsum, and undersurface or ventral surface. Although the base of the tongue belongs to the oropharynx, it can be discussed with the oral cavity because it is composed of the same muscles as the oral tongue. The base of the tongue, which is almost parallel to the oropharyngeal posterior wall, is limited anteriorly by the circumvallate papillae and laterally by the glossotonsillar sulci. It is covered by lymphoid tissue forming the lingual tonsil, which varies in size and shape among individuals. The anterior aspect of the suprahypoid epiglottis is connected to the base of the tongue by the medial and lateral glossoepiglottic folds, which enclose the valleculae.

The tongue is composed of a fibrous skeleton and a complex musculature. The fibrous skeleton consists of the hyoglossal membrane and the lingual septum. The hyoglossal membrane is a small but strong fibrous lamina that connects the undersurface of the tongue to the upper surface of the body of the hyoid bone between its lesser horns. The lingual septum separates the tongue into two symmetric halves. It inserts on the hyoglossal membrane and extends throughout the entire length of the tongue but does not reach the dorsum. It is thicker posteriorly than anteriorly and may contain fibrocartilage.

The tongue contains intrinsic and extrinsic musculature, with the latter having a point of attachment to the surrounding structures. There are four pairs of extrinsic muscles: the genioglossus, hyoglossus, styloglossus, and palatoglossus muscles.

The genioglossus muscle forms the main bulk of the tongue. This fan-shaped muscle arises by its apex from the superior genial tubercle, behind the mandibular symphysis, and radiates posteriorly to the whole dorsum of the tongue, from the base to the apex. The pair of muscles lie on each side of the median plane and are related laterally to the neurovascular bundle of the tongue.
The hyoglossus muscle is a thin, flat, quadrilateral muscle that originates from the greater horn of the hyoid bone and passes vertically upward to enter the side of the tongue. This muscle can be identified on coronal MR images, which helps one define the lateral aspect of the tongue.

The styloglossus muscle originates from the styloid process, passes between the internal and external carotid arteries, becomes almost horizontal and enters the side of the tongue, and interdigitates with the hyoglossus muscle.

The palatoglossus muscle arises from the anterior surface of the soft palate on each side of the uvula; passes downward, forward, and outward in front of the palatine tonsil; and inserts into the posterolateral part of the tongue. This muscle forms the anterior pillar of the tonsil and has mucosa covering its surface.

The intrinsic muscles comprise the vertical muscle, the transverse muscle, the inferior longitudinal muscle, and the superior longitudinal muscle. The last muscle, which is impair, can be identified at MR imaging beneath the lingual mucosa. The other muscles, which are pair, intermingle and cannot be differentiated radiologically.

The neurovascular bundle of the tongue is formed on each side by the lingual artery (third branch of the external carotid artery) and veins, the hypoglossal nerve (cranial nerve XII), and the lingual nerve (a branch of the mandibular nerve, which is cranial nerve V3). Anatomically, surgically, and radiologically, the hyoglossus muscle is the important landmark for locating these neurovascular structures. The lingual artery courses medial to the hyoglossus muscle, whereas the hypoglossal nerve, accompanied by the lingual veins, lies lateral to this muscle. At the anterior margin of the hyoglossus muscle, the lingual artery provides the sublingual artery, which supplies the floor of the mouth. Then, the lingual artery bends sharply upward toward the genioglossus muscle and runs along its lateral side, close to the ventral surface of the tongue. The lingual nerve is found lateral to the hyoglossus muscle, above the hyoglossus nerve. It twists around the submandibular duct (Wharton duct) and then enters the tongue and rejoins the hypoglossal nerve and lingual artery.

- **Sublingual and Submandibular Spaces**

The mylohyoid muscle cleaves the lower oral cavity into the sublingual and submandibular spaces (26). The sublingual space, which is deep to the mylohyoid muscle, contains the anterior extension of the hyoglossus muscle, the lingual nerve, cranial nerves IX and XII, the lingual artery and vein, the sublingual glands and ducts, the deep portion of the submandibular gland, and the submandibular duct.

The submandibular space, which is superficial to the mylohyoid muscle, contains the anterior belly of the digastric muscle, the superficial portion of the submandibular gland, the submandibular and submental lymph nodes, the facial vein and artery, and the inferior loop of cranial nerve XII. The fatty space enclosed within the anterior belly of the two digastric muscles is often called the submental triangle.

Posteriorly, at the level of the free edge of the mylohyoid muscle, there is no fascial separation: The submandibular space communicates with the sublingual space and the inferior parapharyngeal fatty space.
NORMAL APPEARANCE OF THE ORAL CAVITY AT CT AND MR IMAGING

• Muscles
At CT, the various groups of muscles in the oral cavity cannot be differentiated on the basis of their tissue attenuation. The identification of muscles is based on the analysis of adjacent fatty planes and vessels (9,27).

With T1-weighted MR images, one can discriminate between different groups of muscles because they do not have the same fat content (Figs 9, 10). The mylohyoid and geniohyoid muscles and the anterior belly of the digastric muscle, all of which are devoid of fatty infiltration, consistently show low signal intensity. In contrast, the signal intensity of the muscles of the tongue may change from low to high because their fat content is variable. On T2-weighted images, all muscles of the oral cavity have a low signal intensity.

• Sublingual and Submandibular Glands
At CT, the sublingual glands are not routinely identified within the sublingual space. The submandibular glands are depicted as slightly heterogeneous structures of intermediate attenuation.

On T1-weighted MR images, the sublingual and submandibular glands have a signal intensity that is intermediate between that of the muscles of the floor of the mouth and fat (Fig 10). On T2-weighted images, these glands are depicted with a high signal intensity compared with that of muscle. They enhance on gadolinium-enhanced MR images.

• Fatty Tissue
Fat is found in the sublingual and submandibular spaces and in the tongue. It typically exhibits low attenuation on CT scans and high signal intensity on T1-weighted MR images. Fat suppression techniques nullify the signal of fat and therefore are not valuable in demonstrating the normal anatomy of the tongue and floor of the mouth because they reduce the conspicuousness of these structures. Fat suppression techniques are used with gadolinium to differentiate between pathologic contrast material uptake and surrounding fatty tissue.

• Bone
On CT scans, the cortex of the mandible is displayed as a high-attenuation linear band, which contrasts with the low-attenuation aspect of the medullary bone. The inner (lingual) and outer (vestibular) cortices are seen on both the axial and coronal views, whereas the superior (alveolar) and inferior (basilar) ridges of the mandible are visible only on coronal images.

At MR imaging, regardless of pulse sequence used, the cortex of the mandible (and the teeth) has a low signal intensity. The medullary bone is displayed as an area of high signal intensity on T1-weighted images (underlying the inferior alveolar nerve) and as an area of intermediate signal intensity on T2-weighted images.
Figure 10. Normal oral cavity as seen on T1-weighted (a), proton-density-weighted (b), T2-weighted (c), and T1-weighted fat-suppressed (d) images. The tongue possesses few fatty components, which appear as high-signal-intensity foci on the T1-weighted and proton-density-weighted views (arrowheads in a and b). Globally, the signal intensity of the tongue is close to that of the inferior group of muscles: the geniohyoid (open arrows) and digastric (**) muscles; the mylohyoid muscle cannot be differentiated from these muscles. The sublingual glands (solid arrows) have a higher signal intensity than that of muscle, regardless of the pulse sequence used.

CLINICAL PRESENTATION AND TREATMENT OF SQUAMOUS CELL CARCINOMA

More than 95% of tumors of the oral cavity are squamous cell carcinomas arising from the oral mucosa (3,4,28). Squamous cell carcinoma occurs mostly in men aged 45 years and older and is associated with tobacco and alcohol consumption.

The typical squamous cell carcinoma is an ulcerated, infiltrative lesion (Fig 11). However, some tumors may be superficial without deep extension, which accounts for possible discrepancies between clinical and radiologic findings.
Figure 11. Squamous cell carcinoma in three different patients. (a) Photograph shows an infiltrating tumor of the anterior floor of the mouth (arrowheads). (b) Photograph of an infiltrating lesion of the lateral aspect of the tongue demonstrates the superficial portion of the lesion (arrowheads) and a deep submucosal part that extends toward the contralateral part of the tongue (arrows). (c) Photograph shows an exophytic squamous cell carcinoma (arrows) that developed on the lateral aspect of the tongue and had an ulcerative portion (arrowheads).

(14). Other lesions may be partially or exclusively exophytic. Therefore, accurate radiologic localization of a lesion may be difficult, particularly in cases of exophytic lesions, because the patient’s mouth is closed during CT and MR imaging examinations (Fig 12). The radiologist should also perform a physical examination of the patient.

- **Tumor Staging**

The American Joint Committee on Cancer (29) and the International Union against Cancer (UICC) (30) use the same staging system for squamous cell carcinoma of the oral cavity: T0, no evidence of a primary tumor; T1, greatest diameter of the primary tumor is 2 cm or less; T2, greatest diameter of the primary tumor is more than 2 cm but less than 4 cm; T3, greatest diameter of the primary tumor is more than 4 cm; and T4, a massive tumor of more than 4 cm in diameter with deep invasion involving the antrum, pterygoid muscles, base of the tongue, or skin of the neck.

Approximately one-third of the patients with squamous cell carcinomas of the oral cavity have clinical evidence of lymph node invasion at initial presentation (28). Distant metastases are not frequent.

- **Patterns of Spread**

**Floor of the Mouth.**—Ninety percent of squamous cell carcinomas originate within 2 cm of the anterior midline floor of the mouth (28). They penetrate beneath the mucosa into the
Figure 12. Exophytic lesion of the tongue. Axial T1-weighted (a) and coronal proton-density-weighted (b) images demonstrate a tumor (arrowheads) that, without the clinical findings, could have been described as arising from the floor of the mouth. Note the mass effect on the buccinator muscle (arrows).

Figure 13. Squamous cell carcinoma of the anterior floor of the mouth. (a) Sagittal T1-weighted image demonstrates a low-signal-intensity tumor (arrowheads). The right submandibular duct (Wharton duct) is dilated (arrow) because its orifice is obstructed by the tumor. (b) Axial T2-weighted image demonstrates the dilated right submandibular duct (straight solid arrow), mylohyoid muscles (open arrows), and hyoglossus muscles (curved arrows).

sublingual gland and subsequently result in obstruction of the submandibular duct (Fig 13) and chronic inflammation or infection of the submandibular gland. Inferior extension of the neoplasm to the midline geniohyoid muscle and especially to the genioglossus muscle is associated with possible invasion of the entire tongue, since the latter muscle is an essential
part of both the floor of the mouth and the tongue (Fig 14). In the case of a lesion that clinically appears to be limited to the anterior floor of the mouth, MR imaging can be used to determine if a partial glossectomy is also needed. Invasion of the mylohyoid muscle signifies that a tumor has extended from the sublingual into the submandibular space (Fig 15). Extension to the oral vestibule is easily recognized clinically, since the tumor extends over the occlusal ridge of the mandible.

In contrast, mandibular invasion may be difficult to assess clinically. Mandible invasion is usually a late manifestation of squamous cell carcinoma, although extension toward the gingivae and peristem of the mandible occurs early and frequently. The periosteum is an effective barrier against mandibular invasion. However, in partially dentate and edentulous patients (who represent the bulk of patients with squamous cell carcinoma), the route of entry is primarily the occlusal ridge, with subsequent spread occurring in the bone marrow fat of the horizontal branch and ramus of the mandible (31). Massive tumors may destroy the inner cortex of the mandible.

Figure 14. Squamous cell carcinoma of the anterior floor of the mouth with mandibular extension. (a, b) T1-weighted (a) and T2-weighted (b) images demonstrate a tumor that extends anteriorly to the oral vestibule (straight solid arrow) and posteriorly to the anterior oral tongue (curved arrow). The mandible is invaded (open arrow). (c, d) Photographs of histologic specimens show the invasion of the medullary bone (arrow in c) and extension along the genioglossus muscle (arrowheads in d). Ant = anterior, 1 = anterior floor of the mouth, 2 = ventral aspect of the tongue, 3 = apex of the tongue, 4 = dorsal aspect of the tongue.
**Figure 15.** Squamous cell carcinoma of the floor of the mouth with extension to the submandibular space. 
(a) Coronal contrast-enhanced CT scan shows a tumor that enhances only slightly (●). The mylohyoid muscle is not recognized. (b) Coronal T2-weighted image demonstrates disruption of the left mylohyoid muscle and the tumor (●), which extends into the submandibular space. Medially, it is difficult to differentiate the tumor from the sublingual glands (arrow). Arrowheads = normal right mylohyoid muscle.

**Figure 16.** Tumor of the lateral floor of the mouth with extension to the masticator space. Axial (a) and coronal (b) T1-weighted images demonstrate a tumor (straight solid arrow) that has invaded the mandible (arrowhead) and the masseter (curved arrow) and medial pterygoid (open arrow) muscles. Note a submandibular lymph node (*).

Tumors arising in the lateral floor of the mouth are less common but have the same general dissemination patterns. Advanced lesions may extend beyond the oral cavity and infiltrate the other spaces of the suprahoid neck that are contiguous to the submandibular and sublingual spaces. Particularly at risk are the fatty parapharyngeal space and the masticator space. The medial pterygoid muscle, which belongs to this last space, inserts into the inner cortex of the angle of the mandible, and can be invaded by tumors of the lateral floor of the mouth (Fig 16).

**Tongue.**—Nearly all squamous cell carcinomas of the oral tongue occur on the lateral and undersurface of the tongue. Most of the lateral border lesions occur on the middle and posterior thirds of the oral tongue (28). Squamous cell carcinomas tend to remain in the tongue until they are quite large. Infiltrating lesions extend medially in the tongue itself. They first
Figure 17. Tumor of the tongue. (a, b) Coronal contrast-enhanced CT scan (a) and T2-weighted image (b) show a tumor (arrowheads) that has extended to the lingual septum (curved arrow). CT scan shows the close contact with the lingual artery (straight arrow in a). (c) Photograph of the histologic specimen helps confirm the relationship between the tumor (arrowheads) and the lingual artery (arrow). Inf. = inferior, Sup. = superior.

In invade the muscles located laterally (in particular, the hyoglossus, styloglossus, and palatoglossus muscles). Then they reach successively the lingual pedicle (Fig 17), the genioglossus muscle, the lingual septum, and the contralateral half of the tongue. Tumors may also extend in the anteroposterior direction, from the tip to the base of the tongue.

Because of the anatomic disposition of the genioglossus muscle, it constitutes a natural route for advanced lesions to extend toward the anterior floor of the mouth. Middle-third lesions invade the lateral floor of the mouth and mandible (Fig 18). Lesions of the posterior third grow into the floor of the mouth, the glosso-tonsillar sulcus, the oropharyngeal tonsil, and underlying deep spaces. Lesions may extend superiorly to the soft palate via the palatoglossus muscle (Fig 19) and from the soft palate to the nasopharynx via the veli palatini muscles.

- **Treatment**
  The treatment of malignant neoplasms of the tongue and floor of the mouth is based on a compromise between oncotherapeutic imperatives and functional and aesthetic requirements (3,4,28). There is no general consensus among clinicians, and treatment protocols vary among institutions. Currently, treatment options for the primary tumor include surgery (with or without postoperative radiation therapy), brachytherapy, external-beam radiation therapy (with hyperfractionation), and induction chemotherapy. In our institution, small tumors (T1)
are treated with surgery or brachytherapy; larger tumors are treated with surgery and postoperative radiation therapy. Advanced T4 lesions that cannot be resected totally are treated with hyperfractionated radiation therapy. Neck dissection is routinely performed, either as a curative procedure or as a diagnostic procedure, in patients with a clinically negative neck.

In surgical planning, increasing efforts have been made to refrain from unnecessary resection of the mandible and the tongue to avoid causing varying degrees of speech impediment and difficulties in swallowing (5,6).

Small or superficial lesions of the floor of the mouth are treated transorally with a wide local excision. In cases of larger tumors, a myocutaneous graft may be needed to cover the excision. A rim (or marginal) resection, which preserves continuity of the mandible, is usually performed if the tumor is adherent to the periosteum. In cases of mandibular invasion, a mandibulectomy is needed; this resection can
Figures 20, 21. (20) Diagrams illustrate the various types of mandibulectomy: rim mandibulectomy (anterior view) (a), vertical (also called segmental) mandibulectomy (anterior view) (b), and hemimandibulectomy (lateral view) (c). In the latter procedure, the ramus of the mandible is resected; the anterior limit of the resection depends on the tumor extent. (21) Diagrams illustrate the various types of glossectomy: partial lateral glossectomy (a), partial anterior glossectomy (b), hemiglossectomy of the oral tongue (c), glossectomy of the oral tongue (d), hemiglossectomy of the oral tongue and base of the tongue (e), and total glossectomy (f).

range from removal of a limited segment of the mandible to a hemimandibulectomy (Fig 20). Reconstruction of the mandible is performed with metallic plates. Use of free flaps (eg, from the fibula or iliac crest) is currently favored because they offer both the bony and myocutaneous portions of the graft. The original vessels are anastomosed with the carotid artery (usually the external branch) and internal jugular vein (or one of its branches).

Tumors of the tongue are resected either perorally or through a mandibulotomy. Resection can range from partial to total glossectomy (Fig 21). In a partial or marginal glossectomy, the amount of tongue removed varies with each case, but preservation of the ipsilateral lingual artery is ensured. In a hemiglossectomy, the involved lingual artery is sacrificed and the remaining lingual artery is preserved, without risk of necrosis for the contralateral part of the tongue. A total glossectomy is needed in cases in which the tumor reaches or endangers both lingual arteries; if it is not performed, necrosis of the remaining tissue may develop. If the lesion invades the base of the tongue, a partial or total laryngectomy may be needed to avoid aspiration. In large excisions, a myocutaneous flap is used to cover the defect. The mandible, if invaded, should be resected and reconstructed if needed.

With such a highly variable set of therapeutic approaches, it is extremely important for the radiologist to cooperate closely with the referring clinician. The radiologist should be aware of the crucial points in the decision-making process of his or her clinical colleagues, and these points may vary among institutions.

**RADIOLOGIC EVALUATION**

- **Standard Imaging Modalities and Protocols**

Several imaging modalities can be used to evaluate the oral cavity and surrounding structures, including plain radiography, scintigraphy, ultrasonography (US), CT, and MR imaging. Each has its own advantages and limitations; however, the advantages offered by some modalities do not outweigh their limitations.

Plain radiography of the mandible includes the panoramic radiograph, the posteroanterior view, the left and right lateral oblique views, the lateral views, and intraoral dental views (7,32). Conventional radiographs yield the best information on the patient's dentition. Panoramic radiography, which is routinely used in the work-up of oral cancer, offers a good overview of the mandible (7). Panoramic radiography can show the extent of gross invasion of the cortical bone in large tumors. However, this examination is not helpful in evaluating minimal invasion or involvement of the inner cortex of the mandible (7). It does not demonstrate the medullary bone at all and does not depict the mandibular symphysis accurately. In addition, it can be affected by a great number of artifacts and technical errors (32).

Scintigraphy performed with technetium-99m-labeled diprophosphonate can demonstrate pathophysiologic changes in bone earlier than conventional radiography because osteoblastic activity is increased (33). However, radiotracer
uptake occurs not only in tumors but also in infarction and infection. Scintigraphy is therefore a highly sensitive but nonspecific technique. Because of its lack of specificity, bone scintigraphy is not recommended for evaluation of oral cancer patients, since this population often has poor dental status, such as dental abscesses and infection, which can simulate neoplastic infiltration (7,33).

US has been advocated by some authors (18-21) and can be used to confirm the diagnosis of benign cystic lesions (ranulas). US is performed with a 5-MHz probe, with the patient's head in hyperextension (18-21,34). On coronal and sagittal views, the mylohyoid, genioglossus, and hyoglossus muscles are identified as relatively hyperechoic structures. The lingual septum is displayed as a vertical hyperechoic band. The lingual artery, the submandibular duct, and the sublingual and submandibular glands are also visible. The main drawback of this technique is the lack of visibility of the anterior portion of the tongue (because of air interposition) and the oropharynx. US is not recommended for the evaluation of oral cancer because it does not clearly depict the tumor extension and does not demonstrate the mandible at all. Moreover, it is an operator-dependent technique and does not provide the clinician with an objective document for therapeutic planning.

The usefulness of CT in the depiction of oral cavity tumors is well established (8-11). CT should be performed in the axial plane, parallel to the mandible. Avoiding dental material often requires the acquisition of two series of scans with different gantry angles. The initial examination should include the neck to help confirm or identify a possible second squamous cell carcinoma in the oropharynx, hypopharynx, or larynx (10% of patients [35]) and to look for lymphadenopathy. Use of intravenously administered contrast material is mandatory, and unenhanced CT studies are unnecessary. Coronal images are extremely useful because they provide an excellent view of the soft tissues and mandible. However, they are technically feasible in only two-thirds of patients because patient positioning is uncomfortable and because of dental amalgam artifacts. In practice, the scout view obtained before the axial acquisition can be used to decide whether coronal acquisition will be feasible. Use of more than one window width (one for soft tissues and one for bone) is always necessary for CT scans of the mandible.

MR imaging can clearly demonstrate the anatomy of the oral cavity and thus is valuable in demonstrating the exact extent of oral cavity tumors (12-17). MR imaging is performed with a head coil or, if available, a specialized neck coil capable of covering the area from the hard palate to the lower neck. The patient must be carefully instructed to maintain quiet breathing and to minimize swallowing during image acquisition. We routinely immobilize the patient's chin with a Velcro strap fixed on the edge of the coil.

The MR imaging study comprises a combination of sagittal, coronal, and axial views. Spin-echo sequences are used rather than gradient-echo sequences because artifacts from dental amalgam can be minimized (i.e., there are fewer susceptibility artifacts with spin-echo imaging). Imaging protocol includes at least one T1-weighted spin-echo sequence and one T2-weighted sequence. T2-weighted images can be acquired with either conventional spin-echo sequences (which provide proton-density-weighted images in the same set of images) or fast spin-echo sequences. The latter sequence can be used with fat-suppression techniques, if available. Fast spin-echo MR imaging, with its shorter acquisition times, is preferable to conventional spin-echo MR imaging because the risk of motion artifacts is minimized.

In MR imaging examinations of cancer patients, we routinely use gadolinium because it is the only reliable technique for detecting perineural extension (36). We use 0.2 mL/kg of gadolinium. After injection of the contrast agent, image acquisition is performed in two or three orthogonal planes, with a fat-suppression technique being used for at least one of the planes (37-39). Gadolinium-enhanced images should never be interpreted without considering the findings from unenhanced T1-weighted images, which are mandatory for assessing the medullary bone correctly.

The choice of field of view, matrix size, section thickness, and number of signals averaged is a compromise between the signal-to-noise ratio and spatial resolution and therefore depends on the magnetic field. On a 1.5-T unit, for a T1-weighted sequence, we routinely use a 14- or 16-cm field of view, with a 4-mm section thickness, a 192 x 256 matrix, repetition times of 600 msec, echo times of 11 msec, and one or two signals. The fast T2-weighted sequence is acquired with a 18- or 20-cm field of view, repetition times of 4,000 msec, echo times of 100 msec, and echo train length of 12.
Figure 22. Squamous cell carcinoma of the anterior floor of the mouth. (a) Axial contrast material-enhanced CT scan shows a lesion (arrowheads) that mildly enhances with contrast media but is not easily recognized because of beam hardening artifacts. (b) On an axial gadolinium-enhanced T1-weighted MR image, the visibility of the lesion (arrowheads) is not hampered by the mandible or the teeth.

Figure 23. Infiltrating squamous cell carcinoma of the lateral aspect of the tongue. (a) Coronal T2-weighted MR image shows a high-signal-intensity tumor (arrow). (b) On a coronal gadolinium-enhanced T1-weighted MR image, the medial border of the tumor is visible (arrowheads) because the tongue is not infiltrated by fat.

CT and MR Imaging Characteristics of Squamous Cell Carcinoma

At CT, all lesions enhance with contrast material, usually moderately (8–11). Uptake of contrast material may be difficult to identify, particularly when the lesion develops in the anterior part of the floor of the mouth, because of beam hardening artifacts due to a dense mandible (Fig 22) and dental amalgam artifacts. The larger the tumor, the more heterogeneous it is (because of areas of necrosis).

On T1-weighted MR images obtained without fat-suppression techniques, tumors have a low signal intensity (comparable with that of the muscles of the floor of the mouth). Therefore, tumors of the tongue will be clearly delineated if the tongue has a high fat content and poorly depicted if the fat content is low. On T2-weighted images, tumors usually have a high signal intensity (Fig 23). Tumors enhance with gadolinium: On contrast-enhanced T1-weighted images, the conspicuousness of the lesion may diminish if the tongue has a high fat content. Use of fat-suppression sequences (37) negates this inconvenience (Fig 24). On the other hand, it may become difficult to distinguish tumor enhancement from physiologic uptake in the salivary glands (Fig 25).

Cortical bone invasion is depicted as an interruption or an erosion of the peripheral hyperattenuating rim at CT or hypointense rim at MR imaging. CT depicts cortical bone invasion the best. However, the exact extent of the medullary bone invasion is better defined with
Figure 24. Infiltrating squamous cell carcinoma of the lateral aspect of the tongue. (a) Coronal contrast-enhanced CT scan shows an enhancing lesion (arrowheads); its medial aspect contrasts with the fatty, low-attenuation, right side of the tongue. (b) On the coronal T1-weighted MR image, accurate localization of the tumor is difficult. The normal portion of the tongue is on the right side, as demonstrated by the presence of high-signal-intensity fatty areas (straight arrows). However, the bulging aspect of the right portion of the dorsal aspect of the tongue (curved arrow) is suspicious. (c) On the coronal gadolinium-enhanced T1-weighted image, the uptake of contrast material diminishes the conspicuity of the lesion. (d) Coronal fat-suppressed gadolinium-enhanced T1-weighted image clearly demonstrates the lesion (arrowheads). Extension to the lateral floor of the mouth (sublingual space) is seen along the mylohyoid muscle (arrow).

Figure 25. Squamous cell carcinoma of the anterior third of the tongue. Fat-suppressed gadolinium-enhanced T1-weighted image demonstrates an enhancing lesion (●). Physiologic enhancement of the sublingual glands (arrows) should not be misinterpreted as an extension of the tumor. The contiguity between the tumor and the sublingual gland is an artifact caused by the examination being performed while the patient’s mouth is closed. At clinical examination, the lesion was at the apex and left side of the tongue, above the anterior floor of the mouth.
Figure 26. Squamous cell carcinoma of the anterior floor of the mouth with mandibular extension. (a–d) Sagittal (a, c) and axial (b, d) T1-weighted images obtained before (a, b) and after (c, d) injection of gadolinium show a tumor (arrowheads) extending over the occlusal ridge of the mandible to the oral vestibule (open arrows in a and c). The medullary bone has low signal intensity on T1-weighted views (○ in a and b) and enhances with contrast material. Limits of the mandibulectomy to be performed are clearly defined, just medial to the course of the alveolar nerve (curved arrow in b). Note the obstruction of the right submandibular duct (Wharton duct) (double arrows in d). (e) CT scan (bone window) shows a high-attenuation area (arrow) in the mandible.

MR imaging (Figs 14, 18, 26). At CT, medullary bone disease may be visualized as a replacement of the normal fat by a high-attenuation area. At MR imaging, the T1-weighted hyperintense medullary fat is replaced by an area with lower signal intensity (17) (Figs 27, 28). On gadolinium-enhanced MR images, the conspicuity of the lesion is decreased because the signal in the tumor tends to equalize with that of the surrounding normal fat.

The main drawback of both CT and MR imaging is their lack of specificity (16,17). For example, an area of bone lysis on CT scans or an area of low signal intensity on T1-weighted images may correspond to tumor or to recent or old dental abscesses and osteoradionecrosis (Figs 29, 30). The use of gadolinium does not help discriminate between tumors and inflammatory or infectious diseases.
Figure 27. Squamous cell carcinoma of the lateral floor of the mouth with mandibular invasion. T1-weighted MR image shows the tumor (curved arrow) and its extension into the medullary bone (straight arrow) as low-signal-intensity areas.

Figure 28. Squamous cell carcinoma of the lateral floor of the mouth with extension to the tongue, submandibular space, subcutaneous fat, and mandible. (a) Coronal T1-weighted image clearly depicts the medial limits of the lesion (arrowheads). The medullary bone of the right ramus is invaded and appears as a low-signal-intensity area (straight arrow), compared with the high signal intensity of the normal contralateral side (curved arrow). (b) On the gadolinium-enhanced T1-weighted image, the limits of the tumor are more difficult to define. The right ramus seems to have normal high signal intensity.

Figure 29. Dental abscess mimicking invasion of the mandible by squamous cell carcinoma. Coronal CT scan (bone window) (a) and coronal fat-suppressed gadolinium-enhanced T1-weighted image (b) demonstrate on the left a squamous cell carcinoma of the lateral floor of the mouth with bone lysis and medullary invasion of the mandible (straight arrow). On the right side, bone lysis (arrowhead in b) and contrast material uptake (curved arrow in a) are due to a 6-month-old dental abscess adjacent to the tooth.
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**Differential Diagnosis**

The differential diagnosis for squamous cell carcinoma of the oral cavity includes other malignant tumors, benign tumors, a variety of congenital anomalies, and infections and inflammatory lesions (26,40).

Other malignant tumors of the oral cavity are rare. Imaging findings have little specificity, and histologic diagnosis is always needed. A special mention should be given to adenoid cystic carcinoma, which can develop in the minor salivary glands and submandibular gland. This neoplasm has a propensity for perineural spread, a characteristic that underscores the importance of using gadolinium-enhanced MR imaging to check the complete course of the mandibular nerve V₃ up to the foramen ovale and the trigeminal ganglion.

The most common benign tumors of the oral cavity include lipomas and pleomorphic adenomas. Lipomas display a typical high signal intensity on T1-weighted images. They displace and compress adjacent structures and, unlike squamous cell carcinoma, rarely infiltrate them (40). Pleomorphic adenomas of the submandibular or sublingual gland have nonspecific imaging characteristics. The diagnosis must be made on the basis of histologic findings.

Congenital anomalies of the oral cavity include vascular lesions, dermoid and epidermoid cysts, and lingual thyroid tissue. For vascular lesions, Mulliken and Glowacki (41) differentiate between hemangiomas, which are neoplastic, and vascular malformations, which are classified into capillary, venous, and arterial malformations. Most vascular lesions are hyperintense relative to muscle on T2-weighted images and enhance following administration of contrast material. MR imaging can be useful in differentiating high-flow lesions (arterial) and low-flow lesions (capillary, venous). Identification of phleboliths at CT is extremely suggestive of the diagnosis of venous malformation (40).

Cystic lymphangiomas (hygromas) also belong to the group of vascular malformations. However, they occur more frequently in the cervical region (posterior triangle) than in the oral cavity. They typically are hypointense or isointense relative to muscle on T1-weighted images and hyperintense relative to fat on T2-weighted images. Cyst walls and septae enhance after contrast material injection.

Dermoid and epidermoid cysts of the oral cavity are usually located in the floor of the mouth. Dermoids are easily identified at CT and MR imaging if they contain fat components. If they do not, they cannot be differentiated radiologically from the epidermoids. MR imaging is valuable in displaying the relationship of these cysts to the mylohyoid muscle and therefore is the best modality to use in planning surgery (intraoral or external cervical approach) (15).

Lingual thyroid tissue is typically asymptomatic and discovered incidentally. It is located in the midline dorsum of the tongue and strongly enhances with contrast material at both CT and MR imaging.

Infections of the oral cavity can arise from either stenosis or calculi within the salivary gland ductal system or dental manipulation or infections. Abscesses correspond to areas of well-defined fluid (pus), which are not found in cellulitis. Ludwig angina is a severe form of cellulitis that can develop 2–4 days after dental extrac-

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**Figure 30.** Osteoradionecrosis of the mandible mimicking squamous cell carcinoma. (a) CT scan (bone window) shows the internal cortical bone lysis (arrowheads). (b) On the T1-weighted image, the same area of the medullary bone appears hypointense (arrow).
tion. CT is useful for identifying calculi, gas bubbles, osteomyelitis, and the site of any drainable pus (26). MR imaging is not recommended because it does not depict calculi and gas bubbles. In fact, imaging findings by themselves, particularly MR imaging results, may be confusing with those encountered in advanced cases of squamous cell carcinoma. The diagnosis of the disease is essentially made clinically, because the patients usually present with general symptoms of infection.

Ranulas are caused by obstruction of the sublingual or minor salivary glands. They are “simple” if confined to the sublingual space and “diving” or “plunging” when they rupture into the submandibular space (and occasionally into the upper cervical soft tissues). They have homogeneous low signal intensity on T1-weighted images and high signal intensity on T2-weighted images. However, this appearance is not specific to ranulas, and the diagnosis of epidermoid cysts or cystic lymphangioma should be considered.

■ CONCLUSIONS: IMAGING STRATEGIES

The role of dental plain radiography has been diversely appreciated. Many centers still favor the use of panoramic views because it is a low-cost technique that is familiar to clinicians and is not degraded by dental amalgam artifacts (7). However, we believe that the technique should be used only as a screening examination because of its limitations (neither the medullary bone nor minimal invasion of the cortical bone can be seen with panoramic radiography). In a practical situation (which nowadays includes awareness of health care cost issues), we advocate the use of CT if the cortex of the mandible must be checked.

In cancer of the tongue, the first study to order is MR imaging. If tumor extension to the mandible is suspected (based on either clinical or MR imaging findings), CT should be performed to detect a small cortical lysis. MR imaging should be used to study not only the primary tumor but also the lymph nodes. Because the latter assessment requires use of a specialized head and neck coil, a device that is not available at many MR imaging sites, CT (or US) must be performed to survey for adenopathy.

In cancer of the floor of the mouth, we perform both MR imaging and CT in the initial work-up, especially in those cases in which there is a clinical doubt or uncertainty about mandibular extension of disease. The type of mandibulectomy to be performed can be chosen based on complementary information obtained from CT and MR imaging.

In conclusion, the role of CT and MR imaging in the management of oral cavity cancer has dramatically increased in recent years. Although the information has not led to a consensual therapeutic approach, the clinicians who are aware of the advantages of these techniques increasingly rely on them. With the expected technical progress, one can have little doubt that this trend will continue and develop in the future.

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