PICTORIAL REVIEW

Imaging the oral cavity: key concepts for the radiologist

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ABSTRACT. The oral cavity is a challenging area for radiological diagnosis. Soft-tissue, glandular structures and osseous relations are in close proximity and a sound understanding of radiological anatomy and common pathways of disease spread is required. In this pictorial review we present the anatomical and pathological concepts of the oral cavity with emphasis on the complementary nature of diagnostic imaging modalities.

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The oral cavity is a challenging area for radiological diagnosis. Soft-tissue, glandular structures and osseous relations are in close proximity and a sound understanding of radiological anatomy, common pathology (Table 1) and pathways of disease spread is required. Imaging of the oral cavity can be limited by artefacts from dental amalgam and opposed mucosal surfaces; however, imaging protocols can be tailored to the patient's specific presentation using a combination of CT, MRI and ultrasonography. In this pictorial article we review normal cross-sectional anatomy and subsites of the oral cavity and present six key imaging concepts that are pertinent to imaging of this region.

Overview of anatomy

The borders of the oral cavity are the lips, anteriorly; mylohyoid muscle, alveolar mandibular ridge and teeth, inferiorly; gingivobuccal regions, laterally; circumvallate papillae, tonsillar pillars and soft palate, posteriorly; and the hard palate and maxillary alveolar ridge and teeth, superiorly [1]. The submandibular space as well as the traditionally held oral cavity subsites of the sublingual space, mucosal space and root of tongue (Figure 1 and 2) will be addressed. The muscles of the oral cavity form an important framework for understanding the anatomy and are summarised in Table 2.

Contents of the submandibular space include the anterior belly of the digastric muscles, the superficial portion of the submandibular gland, the submandibular (Level 1b) and submental (Level 1a) lymph nodes, the facial vein and artery, fat and the inferior loop of the hypoglossal nerve [3].

The sublingual space is not encapsulated by fascia. Its contents include the anterior aspect of hyoglossus muscle, lingual nerve, artery and vein, glossopharyngeal

and hypoglossal cranial nerves, sublingual glands and ducts, deep portion of the submandibular gland, and Wharton's (submandibular) duct [3]. The mucosal space

Table 1. Summary of oral cavity pathology [1, 2]

Category	Process
Inflammatory/ infection	Abscess/ phlegmon Sialoliths/ sialoceles/ sialadenitis Cellulitis/ Ludwig's angina Ranula
Neoplastic (benign)	Pleomorphic adenoma (most common) Aggressive fibromatosis Lipoma Haemangiomas Nerve sheath tumours, e.g. schwannoma, neurofibroma Torus (exostoses) Fibro-osseous lesions, e.g. fibrous dysplasia, central cemento-ossifying fibroma, osteoma (e.g. lingual) Other/miscellaneous, e.g. osteochondroma/ chondroma, odontogenic lesions
Neoplastic (malignant)	Rhabdomyomas (rare) Squamous cell carcinoma (most common) Nodal metastases Minor salivary gland tumours (adenoid cystic carcinoma, adenocarcinoma, mucoepidermoid carcinoma), lymphoma, sarcoma (liposarcoma, rhabdomyosarcoma) and mandibular neoplasms
Congenital	Vascular/lymphatic malformations, e.g. cavernous lymphangioma, Dermoid/epidermoid cysts Lingual thyroid Thyroglossal duct cyst Accessory salivary (e.g. parotid) tissue Congenital absence of tongue Digastric muscle anomalies
Miscellaneous	Denervation muscular atrophy Macroglossia

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Figure 1. Normal oral cavity structures and spaces on coronal T_1 weighted MR with schematic diagram. M, mylohyoid muscle; ABD, anterior belly of digastric muscle; H, hyoglossus muscle; GH, geniohyoid muscle; GG, genioglossus muscle; LS, lingual septum; SLS, sublingual space (orange); SMS, submandibular space (brown); ROT, root of tongue (green); and MS, mucosal space (blue).

includes the mucosal lip, upper and lower alveolar ridge mucosa, retromolar trigone (RMT), buccal mucosa, floor of mouth mucosa, hard palate mucosa and oral tongue

mucosa [3]. The root of tongue consists of the lingual septum, and genioglossus and geniohyoid (extrinsic tongue) muscles [1].

Figure 2. Normal oral cavity structures and spaces (at level of the floor of mouth) on axial T_1 weighted MR with schematic diagram. SLG, sublingual gland; SMG, submandibular gland; M, mylohyoid muscle; H, hyoglossus muscle; GG, genioglossus muscle; LS, lingual septum; WD, Wharton's duct; SLS, sublingual space (orange); SMS, submandibular space (brown).

Table 2. Summary of key muscles of the oral cavity spaces [3, 4]

Muscle	Origin	Insertion	Comments	Space
Anterior belly of digastric	Digastric fossa on posterior surface of symphysis menti	Lesser cornua of hyoid bone	Lies below mylohyoid sling, fibres run in anterior-posterior direction	Submandibular space
Mylohyoid	Mylohyoid ridge, medial aspect body of mandible	Anterior $\frac{3}{4}$: midline raphe, posterior $\frac{1}{4}$: superior border of hyoid body	Sling-like muscle lining floor of mouth	Divides submandibular and sublingual spaces
Genioglossus	Superior mental spine of mandible	Mucous membrane of tongue, inferior fibres insert onto hyoid	Fan shaped, directed toward intrinsic muscles of tongue, lies lateral to lingual septum	Root of tongue
Geniohyoid	Inferior mental spine of mandible	Superior border of hyoid bone	Runs perpendicular to and above mylohyoid sling, below genioglossus muscle	Root of tongue
Hyoglossus	Superior border of greater cornua of hyoid bone	Lateral side of tongue	Runs obliquely, directed toward the apex of the tongue, medial to Wharton's duct	Sublingual space

Imaging technique

CT and MRI are complementary in the assessment of head and neck pathology [5]. CT is readily accessible and offers faster image acquisition; therefore, it usually serves as a first-line investigation to broadly distinguish pathological processes. In imaging head and neck cancer, CT provides a better assessment of cortical bone involvement [5, 6], and MRI has the advantage of better characterising local tumour extent, bone marrow involvement [7] and detection of perineural spread [8]. Both modalities suffer from artefacts in the setting of dental amalgam; however, an angled gantry may aid the reduction of artefacts with CT. Head and neck imaging protocols used at our institution are described in Table 3.

Ultrasound with a high-resolution linear transducer can be used to assess the submandibular region and to guide biopsy. Intra-oral ultrasound is used less frequently and will be discussed later.

Table 3. Head and neck imaging protocols for CT and MR

CT	MRI
Contrast injection	T_1 axial 3.0 mm thick/0.3 mm space FOV 180 mm
50 ml Omnipaque 300 ^a at 2 ml s ⁻¹	T_1 coronal 3.0/0.3 mm FOV 180 mm
50 ml normal saline at 2 ml s ⁻¹	T_2 axial fat saturated 3.0/0.3 mm FOV 180 mm
Delay 45–60 s	T_2 coronal fat saturated 3.0/0.3 mm FOV 180 mm
Ask patient to puff cheeks out during scan	Axial DWI b500 4.0/1.0 mm FOV 240 mm
Scan from pituitary fossa to aortic arch	T_1 axial and coronal fat saturated post contrast 3.0/0.3 mm FOV 180 mm
If dental artefact, rescan oral cavity angle along line of mandible	

^aOmnipaque Iohexol, Amersham Health, Princeton, NJ. FOV, field of view; DWI, diffusion weighted image.

Concepts

Concept 1: Oral cavity spaces communicate

The mylohyoid muscle separates the submandibular space, inferiorly, from the sublingual space, superomedially. Both these spaces are horseshoe-shaped and communicate

Figure 3. Contrast-enhanced axial CT image through the floor of the mouth in a 27-year-old male with a diving ranula shows the communication between the posterior sublingual space (SLS) and submandibular space (SMS). A ranula is a mucus retention cyst of the sublingual gland. When a simple ranula ruptures its epithelial lining posteriorly and extends back into the SMS it is called a diving ranula. The tail of the ranula lies in the SLS (*), and the head extends into the SMS (#). Diving ranulas may also penetrate through deficiencies in the mylohyoid muscle.

Figure 4. 20-year-old female presents with a lump in the floor of the mouth. (a) Axial and (b) contrast-enhanced CT images and (c,d) fat saturated T_2 MR images through the floor of the mouth demonstrate a ranula (r) of the right sublingual gland. On images (a) and (c), the ranula spreads across the midline through the subfrenular region into the left sublingual space (arrow). Images (b) and (d) demonstrate a diving component (*) passing through mylohyoid defect (thin arrow) to fill the right submandibular space.

Figure 5. (a) Coronal CT image with puffed cheeks on soft-tissue window. A small tumour is seen arising from the buccal surface of the gingiva of the right maxillary alveolus (arrow). (b) Axial CT bone window at the level of the maxillary alveolus demonstrates cortical destruction of the right maxillary alveolus (thin arrow), making this a T4 lesion.

Table 4. Common routes of spread of oral cancer [2]

Tumour site	Routes of spread
Tongue	Intrinsic and extrinsic musculature, invasion of neurovascular bundle, floor of mouth, mandible
Retromolar trigone	Mandible, PNS inferior alveolar nerve/V3, pterygomandibular raphe-buccinator and superior constrictor
Lip (lower and upper)	Orbicularis oris, skin, buccal mucosa, mandible/maxilla
Floor of mouth	Submucosal spread, invasion of lingual neurovascular bundle/extrinsic tongue musculature, mylohyoid and hyoglossus muscles, mandible
Palate (soft and hard)	Osseous erosion of hard palate, PNS greater and lesser palatine nerves to PPF
Buccal mucosa/gingiva	Submucosal spread, erosion of maxilla/mandible

PNS, perineural tumour spread; PPF, pterygopalatine fossa; V3, third division (mandibular) of the trigeminal nerve.

(a)

(b)

(c)

(d)

(e)

Figure 6. 60-year-old male presenting with left facial pain. (a) Orthopantomogram demonstrates a destructive lesion in the left lateral maxilla (arrow). (b) Axial T_1 weighted MRI at the level of the maxillary alveolus demonstrates a destructive lesion involving the left lateral maxilla (asterisk) found at surgery to be squamous cell carcinoma. (c) Axial T_1 weighted MRI post-contrast with fat suppression at the level of the maxillary sinuses demonstrates abnormal enhancement in the left pterygopalatine fossa (short arrow) compatible with tumour spread. (d) and (e) Coronal T_1 MRI post-contrast demonstrate perineural tumour spread via foramen rotundum (thin arrow) into the left cavernous sinus (open arrow).

Figure 7. 76-year-old male presenting with ill-fitting dentures. (a) Coronal T_1 MRI post-gadolinium with fat saturation demonstrates a mass in the right hard palate (short arrow) histologically confirmed to be adenoid cystic carcinoma. (b) and (c) axial T_1 MRI post-contrast with fat saturation through the nasal cavity demonstrate spread via the lesser and greater palatine foramina (open arrow) into the right pterygopalatine fossa (arrow).

Figure 8. (a) Axial T_2 MRI with fat suppression at the level of the body of the mandible demonstrates a tumour (squamous cell carcinoma) in the right floor of the mouth (asterisk) and necrotic right submandibular lymph node (arrow). (b) Coronal T_2 fat suppressed MRI demonstrates spread of tumour to the right ventrolateral tongue (thin arrow). The tumour does not extend through the mylohyoid muscle (short arrow).

Figure 9. (a) Axial T_1 weighted MRI at the level of the maxillary alveolus demonstrating thickening of the right buccinator muscle (arrow) compatible with buccal squamous cell carcinoma. (b) Coronal T_1 post-gadolinium with fat suppressed MRI demonstrates moderate submucosal spread of the buccal tumour (thin arrow), which extends from the maxillary alveolus to the body of the mandible. (c) Axial CT bone window at the level of the maxillary alveolus demonstrates cortical destruction of the right maxillary alveolus (short arrow), making this a T4 lesion.

Figure 10. (a) Axial T_2 fat-saturated MRI demonstrating a large left lateral tongue squamous cell carcinoma (asterisk). (b) Axial CT image at the level of the mandible demonstrates a left Level 1b (submandibular) lymph node measuring 7 mm but having a rounded appearance (arrow). (c) Follow-up imaging 3 months later demonstrates disease progression in the untreated left submandibular node (open arrow).

across the midline. The submandibular, sublingual and inferior parapharyngeal spaces are also contiguous with one another [3]. The communication of these spaces is demonstrated by a diving ranula (Figures 3 and 4).

Concept 2: Oral cancers exhibit a typical pattern of spread

Oral cancers can spread by the following routes: extension along the submucosa, direct invasion into adjacent structures, perineural spread and lymph node metastasis. The common routes of spread are presented in Table 4 and cases are illustrated in Figures 5–9. The oral mucosal space has bilateral drainage to the submental and submandibular lymph nodes. Any asymmetrically enlarged lymph nodes in the primary drainage site should

be regarded as suspicious, even if they are subcentimetre (Figure 10). The RMT and root of tongue are two important sites of tumour spread:

The retromolar trigone—a source of multidirectional tumour spread

The RMT is a triangular region of mucosa posterior to the last mandibular molar (Figure 11). Squamous cell carcinomas (SCC) can arise primarily from, or spread secondarily into, the RMT from the tonsils or base of tongue. When assessing the RMT tumour, it is pertinent to understand the potential pathway of spread and assess the structures at risk [5]. There may be direct invasion into the mandible (Figure 12) and inferior alveolar nerve, or extension posteriorly along the pterygomandibular raphe.

The pterygomandibular raphe is a fibrous band extending from the posterior mylohyoid line to the hook of the hamulus of the medial pterygoid plate. It is a central structure that serves as an origin point for the buccinator and superior constrictor muscles [5]. Tumour invasion into the pterygomandibular raphe therefore potentiates the spread in multiple directions into the buccal space and oropharynx.

Root of tongue—a subtle but important review area for tumour spread

The root of tongue consists of the lingual septum and extrinsic tongue muscles [1] (Figure 1). This should not be confused with the base of tongue, which is the posterior third of the tongue and is considered to be part of the oropharynx. The root of tongue is bounded inferiorly by the mylohyoid muscle, anteriorly by the mandibular symphysis and along with the laterally positioned sublingual space forms the floor of the mouth. Involvement of the root of tongue upstages oral cavity tumours to T4 by the TNM staging system. Involvement of the lingual septum renders the patient unsuitable for hemiglossectomy [9, 10] (Figure 13).

Both genioglossus muscles should join to insert onto the genial tubercle. Any convexity to their lateral margins at insertion is abnormal (Figures 14 and 15).

Figure 11. Photograph of the normal retromolar trigone. The triangular region of mucosa posterior to the last mandibular molar is the retromolar trigone.

Figure 12. 63-year-old female with clear cell mucoepidermoid carcinoma in the retromolar trigone. (a) Axial (level of mandibular alveolus) and (b) coronal enhanced CT images demonstrate a left retromolar trigone mass (arrows). Evaluation of the retromolar trigone on CT can be obscured by dental artefact, in this case bone destruction is evident. (c) Axial (level of the mandibular alveolus) and (d) coronal enhanced fat-saturated T_1 weighted MRI demonstrate local invasion into the left mandible (short arrow) and buccinator muscle (thin arrow).

Figure 13. 66-year-old female with poorly differentiated squamous cell carcinoma of the tongue. (a) Axial T_1 weighted gadolinium-enhanced MRI with fat suppression through the level of the mandible and (b) coronal T_2 weighted MRI with fat suppression show an enhancing mass (black arrow) with heterogeneous T_2 signal (white arrow) in the left tongue invading into the superficial tongue muscles and genioglossus muscle, but with preservation of lingual septum. Invasion of extrinsic tongue musculature is considered T4 disease.

Figure 14. 29-year-old female with a dermoid cyst in the root of tongue. (a) Axial T_2 weighted MRI through the floor of mouth and (b) coronal post-contrast T_1 with fat suppression MRI show an ovoid T_2 hyperintense, non-enhancing mass (long arrow) that splays both genioglossus muscles (g). The mass also obstructs the right submandibular (Wharton's) duct (small arrow).

Figure 15. 61-year-old female with poorly differentiated squamous cell carcinoma of the root of tongue. (a) Initial evaluation by contrast-enhanced CT at the level of the mandibular alveolus demonstrated an ill-defined hyperdense mass (arrow) in the anterior floor of mouth. (b) Further characterisation with axial T_2 MRI at the same level demonstrates a well-defined T_2 hyperintense mass in the anterior floor of mouth extending posteriorly to involve the genioglossus muscle. The mass obstructs the submandibular ducts bilaterally (small arrows). Sagittal (c) gadolinium-enhanced T_1 and (d) fat-suppressed T_2 weighted MRIs demonstrate the full extent of the anterior floor of mouth lesion (arrows), which is seen to involve the anterior fibres of the genioglossus muscle and the ventral surface of the tongue. This necessitates more complex resection and reconstructive surgery.

Figure 16. 51-year-old male with acute hypoglossal denervation secondary to right internal carotid artery dissection. Initial presentation was of 1 week of dysarthria and hoarse voice. Subsequent clinical assessment of a right posterior tongue mass led to nasendoscopy and biopsy. Further evaluation with T_1 weighted MRI through the floor of the mouth demonstrates (a) increased volume within the right posterior tongue with mass effect (arrow), (b) heterogeneous enhancement post contrast (s, submandibular gland) (arrows) and (c) subtle increased signal on T_2 weighted images in keeping with acute hypoglossal denervation. (d) Axial T_1 weighted MRI through the level of the nasopharynx demonstrates the causative right internal carotid dissection (short arrow). Normal left internal carotid artery (thin arrow).

Concept 3: Cranial nerve pathology can lead to a pseudolesion

Cranial nerve injury at a remote site can manifest in the oral cavity as acute or chronic denervation. Owing to the asymmetry, a pitfall is to interpret these changes as a mass. Acute denervation causes acute muscular injury with findings of mass effect, increased T_2 signal and enhancement (Figure 16). Chronic denervation results in

volume loss and increased T_1 and T_2 signal in keeping with fatty atrophy [11]. The affected muscles are those innervated by trigeminal and hypoglossal nerves. Hypoglossal denervation affects the intrinsic and extrinsic tongue muscles (except for the palatoglossus muscle) (Figure 17), while denervation of the mandibular division of trigeminal nerve will involve the mylohyoid and the anterior belly of the digastric muscles. Imaging of the oral cavity must extend from midbrain to hyoid bone to ensure the entire

Figure 17. 72-year-old male with hypoglossal denervation secondary to haemangiopericytoma. Axial contrast-enhanced CT images through the level of the (a) mandibular alveolus and (b) maxillary alveolus show fatty atrophy of the right tongue (arrow) involving the intrinsic and extrinsic muscles owing to a skull base haemangiopericytoma (open arrow) involving the right hypoglossal canal. (c) Axial and (d) coronal T_1 weighted MRI shows well-demarcated T_1 hyperintensity and volume loss in the intrinsic and extrinsic muscles of the right tongue (arrows). The normal left tongue has a “mass-like” appearance compared with the atrophic right side.

paths of the trigeminal and hypoglossal nerves are assessed.

Concept 4: Variant anatomy should not be mistaken for tumour

While classical anatomical teaching suggests that mylohyoid muscle is a continuous muscular sheet that

separates sublingual and submandibular spaces, the mylohyoid muscle is frequently found to be discontinuous in multiple cadaveric and imaging studies [12–15]. Mylohyoid muscle deficiencies, present in 77% of routine CT neck examinations [12], have been previously described as “mylohyoid boutonnières” with the projection of salivary tissue through these defects as “sublingual boutons” [13] (Figure 18). On imaging, herniated sublingual tissue can be misinterpreted as a submandibular node.

Figure 18. 55-year-old female with a tumour involving the left lateral tongue. (a) The lesion is well depicted with intra-oral ultrasound (arrow). Clinical assessment suggested ipsilateral lymphadenopathy. (b) Coronal and (c) axial T_2 weighted MRI with fat suppression through the level of the floor of mouth demonstrated the palpable abnormality to represent herniation of the sublingual gland through a defect in the mylohyoid muscle (short arrows). (d) This lesion is difficult to identify on CT (arrow).

Figure 19. 56-year-old male with left buccal mucosa squamous cell carcinoma (SCC). (a) Post-contrast CT examination through the level of the mandibular neck and (b) coronal reformation. Note that the buccal mucosal SCC is easily discerned by puffed cheek CT (arrows). This technique requires patients to puff out their cheeks during CT scanning.

Figure 20. Differences in image quality obtained from angled gantry. (a) Routine axial CT of the oral cavity and (b) scout view with corresponding gantry angle demonstrates dental amalgam artefact obscuring anatomical detail. (c) and (d) angled gantry along plane of the mandible improves visualisation of the oral cavity by reducing dental amalgam artefact. Note concurrent use of puff cheek technique.

Coronal imaging is helpful in demonstrating the defect and the submandibular mass as contiguous with the sublingual gland.

Concept 5: CT technique can be modified to demonstrate pathology

Puffed cheek CT has a useful role in assessing mucosal tumours where mucosal surfaces are opposed [16]. Small tumours in the mucosa may otherwise not be seen on radiographs (Figure 19).

CT dental amalgam artefact is common, and can completely obscure oral cavity detail. In these circumstances, a

limited repeat scan with imaging along the line of the mandible (*i.e.* parallel to the plane containing the metal) will provide another imaging plane to visualise oral cavity structures [17] (Figure 20).

Concept 6: Value of oral ultrasound

High-resolution imaging can be obtained with a small footprint intra-oral probe for assessment of salivary duct or gland pathology, and tongue tumour thickness. Since the latter is a significant independent prognostic factor for nodal metastasis and overall survival [18, 19], nodal dissection is suggested if tumour thickness is >4 mm

Figure 21. 57-year-old man with right tongue squamous cell carcinoma. (a) Coronal T_2 weighted MRI with fat saturation, the tongue tumour (arrow) is poorly delineated with the depth of invasion difficult to ascertain. (b) Longitudinal ultrasound image of the right lateral tongue obtained with an intra-oral probe. There is excellent delineation of the hypoechoic tumour relative to the hyperechoic intrinsic tongue musculature.

[19]. Recent literature suggests that intra-oral ultrasound is an acceptable alternative to MRI for assessment of tumour thickness [20] and, as a comparable modality, ultrasound is more accessible and less expensive (Figure 21).

Conclusion

Although the oral cavity poses particular complexity in head and neck imaging, a sound understanding of radiological anatomy, common pathways of disease spread and current complementary technical approaches will improve detection and characterisation of oral cavity pathology.

Conflicts of interest

Jenny Hoang is a GE AUR Fellow 2010–2011

References

- MacDonald AJ, Harnsberger HR. Oral cavity anatomy and imaging issues. In: Harnsberger HR, Wiggins RH, Hudgins PA, Michel MA, Swartz J, Davidson HC, et al, eds. *Diagnostic imaging: head and neck*. Salt Lake City, UT: Amirsys 2004;III-42–5.
- Smoker WRK. The oral cavity. In: Som PM, Curtin HD, eds. *Head and neck imaging*, 4th edn. St Louis, MO: Mosby 2003;1377–1464.
- Harnsberger HR. *Handbook of head and neck imaging* 2nd edn. Saint Louis, MO: Mosby 1995.
- McMinn RMH, ed. *Last's anatomy: regional and applied*. New York, NY, USA, Churchill Livingstone 1994.
- Stambuk HE, Karimi S, Lee N, Patel SG. Oral cavity and oropharynx tumours. *Radiol Clin N Am* 2007;45:1–20.
- Mukherji SK, Isaacs DL, Creager A, Shockley W, Weissler M, Armao D. CT detection of mandibular invasion by squamous cell carcinoma of the oral cavity. *AJR Am J Roentgenol* 2001;177:237–43.
- Beil CM, Kerberle M. Oral and oropharyngeal tumours. *Eur J Radiol* 2008;66:448–59.
- Caldemeyer KS, Mathews VP, Righi PD, Smith RR. Imaging features and clinical significance of perineural spread or extension of head and neck tumors. *Radiographics* 1998; 18:97–110.
- Kirsch C. Oral cavity cancer. *Top Magn Reson Imaging* 2007;18:269–80.
- Yasumoto M, Shibuya H, Takeda M, Korenaga T. Squamous cell carcinoma of the oral cavity: MR findings and value of T_1 -versus T_2 -weighted fast spin echo images. *AJR Am J Roentgenol* 1995;164:981–7.
- Russo CP, Smoker WRK, Weissman JL. MR appearance of trigeminal and hypoglossal motor denervation. *AJNR Am J Neuroradiol* 1997;18:1375–83.
- White DK, Davidson C, Harnsberger HR, Haller J, Kamya A. Accessory salivary tissue in the mylohyoid boutonnière: A clinical and radiologic pseudolesion of the oral cavity. *AJNR Am J Neuroradiol* 2001;22:406–12.
- Gaughran GRL. Mylohyoid boutonnière and sublingual bouton. *J Anat* 1963;97:565–8.
- Hopp E, Mortensen B, Kolbenstvedt A. Mylohyoid herniation of the sublingual gland diagnosed by magnetic resonance imaging. *Dentomaxillofac Radiol* 2004;33:351–3.
- Kiesler K, Gugatschka M, Friedrich G. Incidence and clinical relevance of herniation of the mylohyoid muscle with penetration of the sublingual gland. *Eur Arch Otorhinolaryngol* 2007;264:1071–4.
- Weissman JL, Carrau RL. “Puffed-cheek” CT improves evaluation of the oral cavity. *AJNR Am J Neuroradiol* 2001; 22:741–4.
- Simon LL, Rubinstein D. Imaging of oral cancer. *Otolaryngol Clin N Am* 2006;39:307–17.
- Yuen APW, Lam KY, Lam LK, Ho CM, Wong A, Chow TL, et al. Prognostic factors of clinically stage I and II oral tongue carcinoma – a comparative study of stage, thickness, shape, growth pattern, invasive front malignancy grading, Martinez-Gimeno score and pathological features. *Head Neck* 2002;24:513–20.
- Kurokawa H, Yamashita Y, Takeda S, Zhang M, Fukuyama H, Takahashi T. Risk factors for late cervical lymph node metastases in patients with stage I or II carcinoma of the tongue. *Head Neck* 2002;24:731–6.
- Yuen APW, Ng RW, Lam PK, Ho A. Preoperative measurement of tumor thickness of oral tongue carcinoma with intraoral ultrasonography. *Head Neck* 2008; 30:230–4.