Dentomaxillofacial Radiology (2016) 45, 20150362

birpublications.org/dmfr

RESEARCH ARTICLE

Intraoral ultrasonography of tongue mass lesions

[1]Chieko Sugawara, [2]Akira Takahashi, [1]Fumiaki Kawano, [3]Yasusei Kudo, [3]Naozumi Ishimaru and [2]Youji Miyamoto

[1]Department of Comprehensive Dentistry, Institute of Biomedical Sciences, Tokushima University Graduate School, Tokushima, Japan; [2]Department of Oral Surgery, Institute of Biomedical Sciences, Tokushima University Graduate School, Tokushima, Japan; [3]Department of Oral Molecular Pathology, Institute of Biomedical Sciences, Tokushima University Graduate School, Tokushima, Japan

Objectives: To demonstrate the usefulness of intraoral ultrasonography (IOUS) for tongue mass lesions, we analyzed surgery cases excluding squamous-cell carcinoma and leukoplakia and compared IOUS and pathological findings.
Methods: We used the hospital information system and Radiology Information System to evaluate the IOUS and pathological findings of patients who underwent surgeries for tongue masses in the past 11 years.
Results: Surgeries for the tongues were performed in 268 cases. Imaging examinations were carried out in 52 (19.4%) cases including 42 (15.7%) cases by IOUS. The pathological results of the surgeries were as follows: 36 cases were inflammatory lesions, 74 cases were tumours, 131 cases were hyperplasia, 8 cases were cystic lesions and 19 cases were other miscellaneous lesions. On the other hand, the number of patients who received IOUS in the same period was 87, and 42 of them had surgeries. In 32 out of the 42 (76.2%) cases, pre-operative IOUS features matched with pathological results. Most of the haemangiomas and lipomas could be diagnosed by IOUS alone.
Conclusions: IOUS of the tongue revealed the nature of the lesions including the border, size, location, depth, the presence or absence of a capsule and the internal structure including vascularity of the mass. The ultrasonographic findings well reflected the histological findings. IOUS is a simple and useful technique that provides additional information beyond inspection, clarifying the internal structure, blood flow and relationships with the adjacent tissues. In this article, we indicated 11 representative cases (fibrous polyp, haemangioma, pyogenic granuloma, lipoma, liposarcoma, chondroma, lymphangioma, schwannoma, neurofibroma, pleomorphic adenoma and amyloidosis) to show the usefulness of IOUS.
Dentomaxillofacial Radiology (2016) **45**, 20150362. doi: 10.1259/dmfr.20150362

Cite this article as: Sugawara C, Takahashi A, Kawano F, Kudo Y, Ishimaru N, Miyamoto Y. Intraoral ultrasonography of tongue mass lesions. *Dentomaxillofac Radiol* 2016; **45**: 20150362.

Keywords: intraoral ultrasonography; tongue mass lesions; tongue tumours; ultrasonographic features

Introduction

Tongue mass lesions are usually removed based on inspection and palpation by oral surgeons. CT and MRI are useful for obtaining accurate diagnoses; however, they are subject to interference by the metal artefacts from dental fillings. As a result, surgery is performed on the basis of only physical signs without imaging inspections. But, in some cases, to diagnose from only clinical signs is not easy. Clinicians may need to know the conditions of the internal tissues and vascular distribution as well as the relationships with the adjacent tissues. Compared with cross-sectional imaging modalities such as CT and MRI, ultrasonography is suitable

Correspondence to: Dr Chieko Sugawara. E-mail: sugawara@tokushima-u.ac.jp
Received 4 November 2015; revised 22 February 2016; accepted 25 February 2016

Table 1 Case distribution of tongue mass lesions

	Cases of surgery					*Cases of IOUS*	
		Pre-operative imaging					
Year	*Surgery*	*IOUS*	*CT*	*MRI*	*Total*	*IOUS*	*Received surgery*
1999	15	0	0	0	0	1	1 (autopsy case)
2000	31	4	1	0	5	7	2
2001	26	9	1	0	9	10	9
2002	16	3	0	0	3	9	3
2003	18	2	0	0	2	7	2
2004	26	6	1	1	6	6	5
2005	34	3	1	3	6	7	3
2006	22	2	1	1	2	7	3
2007	23	6	2	0	7	12	7
2008	11	3	1	3	4	12	3
2009	23	1	0	1	2	4	1
2010	23	3	3	4	6	5	4
Total	268	42	11	13	52	87	42

IOUS, intraoral ultrasonography.

for imaging tongue lesions without interference from dental alloys. Because of its high-frequency probe and useful imaging modes, such as tissue harmonic imaging and multifocus, the spatial resolution of ultrasonography is superior to that of other cross-sectional imaging modalities.[1] The extraoral approach in ultrasonography does not provide adequate images of the tongue and palate because the air spaces within the oral cavity attenuate acoustic waves, and ultrasound does not penetrate the bone well.[2] On the other hand, in case of intraoral ultrasonography (IOUS), we can place a probe above the lesion with confirmation of its position and can observe its sonographic characteristics at the same time. In the article of Natori et al,[3] which evaluated the detection of tongue carcinoma, all lesions over 1 mm in tumour thickness on histological section were detectable on IOUS images using a 7.5-MHz linear probe.

However, there have been few reports of IOUS as a diagnostic tool for tongue lesions. The purpose of this study was to show the efficacy of IOUS for the preoperative diagnosis of tongue mass lesions by comparing it with the pathological diagnosis.

Methods and materials

We used the hospital information system and radiology information system to evaluate IOUS and the pathological findings of patients who underwent surgeries for tongue masses in the past 11 years.

Using surgery case reports from 1999 to 2010, we identified the patients who underwent surgery for a tongue mass. We targeted mass lesions so that squamous-cell carcinoma and leukoplakia were excluded when oral surgeons were able to diagnose those lesions on inspection. We then investigated whether imaging examinations had been conducted before surgery. Conversely, patients who underwent IOUS during the same period were identified using the radiology information system. We followed all of the cases using the hospital information system.

All procedures followed were in accordance with the ethical standards of the Ethical Commitee of the Tokushima University and with the Helsinki Declaration of 1975, as revised in 2008(5). Informed consent was obtained from all patients for being included in the study.

Additional informed consent was obtained from all patients whose identified information is included in this article.

Ultrasonography scanning

A SONOLINE® Elegla (Siemence Medical, Germany) ultrasound unit with a 12.5-MHz linear probe or a 6.5-MHz convex-type probe and a Xario™ SSA-660A (Toshiba Medical Systems, Japan) with a 7.5-MHz linear probe were used. These probes were thinly coated with sterile gel, covered with a rubber sheath and placed directly on the surface of the tongue. The sonographic examinations were performed using both the B-mode and Doppler mode in two perpendicular directions if possible. The setup conditions of both the B-mode and power Doppler mode were adequately adjusted for each patient and lesion. All data were recorded on the imaging server.

Table 2 Pathological diagnosis of the tongue operation case

Category	*Pathological diagnosis*	*Number of cases*	*Total*
Inflammation	Pyogenic granuloma	14	
	Irritation fibroma	12	
	Granulation tissue	4	
	Mucous granuloma	3	
	Abscess formation	1	
	Granuloma	1	
	Fibrous tissue	1	36
Tumour	Haemangioma	38	
	Lipoma	14	
	Papilloma	10	
	Granular cell tumour	3	
	Schwannoma	2	
	Solitary neurofibroma	2	
	Lymphangioma	1	
	Osteoma	1	
	Chondroma	1	
	Pleomorphic adenoma	1	
	Liposarcoma	1	74
Hyperplasia	Fibrous polyp	69	
	Fibrosis	31	
	Papillary hyperplasia	23	
	Epithelial dysplasia	7	
	Papillary epithelial hyperplasia	1	131
Cyst	Mucous cyst	6	
	Blandin–Nuhn cyst	2	8
Others	Angioectasia	7	
	Lymphangiectasia	3	
	Tonsilla lingualis	2	
	Amyloidosis	1	
	Thrombus	1	
	Lymphoid tissue	1	
	No tumour tissue	4	19

Table 3 Pathological diagnosis and ultrasonographic diagnosis

Case	*Year*	*Pathological diagnosis*	*IOUS diagnosis*
1	1999	Amyloidosis	No tumour and metabolic change
2	2000	–	Normal variation
3	2000	Cavernous haemangioma	Haemangioma
4	2000	–	Atrophy
5	2000	–	Scar granulation
6	2000	–	Haematoma
7	2000	Pyogenic granuloma	Granuloma
3	2000	–	Scar or haematoma
9	2001	–	Retention cyst
10	2001	Lymphangioma	Cyst
11	2001	Liposarcoma	– (post-biopsy)
12	2001	Cavernous haemangioma	Haemangioma
13	2001	Cavernous Haemangioma	Haemangioma
14	2001	Lipoma	Lipoma
15	2001	Cavernous haemangioma	Haemangioma
16	2001	Cavernous haemangioma	Benign tumour
17	2001	Chondroma	Hard tumour
18	2001	Pyogenic granuloma	Arteriovenous malformation or haemangioma
19	2002	Cavernous haemangioma	Haemangioma
20	2002	–	Lymphangioma
21	2002	–	Scar
22	2002	Fibrous tissue	Mass formation
23	2002	–	Normal
24	2002	Cavernous haemangioma	Haemangioma
25	2002	–	Normal variation
26	2002	–	Benign tumour
27	2002	–	Scar
28	2003	Lipoma	Lipoma
29	2003	–	Fibroma
30	2003	–	Lymphangioma
31	2003	Solitary neurofibroma	Benign tumour or dermoid cyst
32	2003	–	Normal variation
33	2003	–	Lymphangioma
34	2003	–	Normal variation
35	2004	Cavernous haemangioma	Haemangioma
36	2004	Cavernous haemangioma	Haemangioma
37	2004	Cavernous haemangioma	Haemangioma
38	2004	Intramuscular lipoma	Lipoma
39	2004	–	Haemangioma
40	2004	Cavernous haemangioma	No information (too small)
41	2005	Papillary epithelial hyperplasia and fibrosis	Haemangioma
42	2005	Lipoma	Benign tumour
43	2005	–	Dermoid cyst
44	2005	–	Inflammatory change
45	2005	–	Lipoma
46	2005	Infiltrating lipoma	Multiple lipoma
47	2005		Inflammatory change
48	2006	–	Benign tumour
49	2006	Pleomorphic adenoma	Salivary gland tumour
50	2006	Lymphangioma	— (diagnosed at the previous institution)
51	2006	–	Haemangioma
52	2006	Cavernous haemangioma	Haemangioma
53	2006	–	Salivary gland tumour
54	2006	Cavernous haemangioma	Haemangioma
55	2007	Cavernous haemangioma	Haemangioma
56	2007	Fibrous polyp	Fibroma
57	2007	–	Haemangioma
58	2007	Pyogenic granuloma	Haemangioma
59	2007	Cavernous haemangioma	Haemangioma
60	2007	–	Normal variation
61	2007	–	Haemangioma
62	2007	Granulation tissue	Haemangioma
63	2007	No tumour tissue (hyperkeratosis)	Granulation tissue
64	2007	Granular cell tumour	Benign tumour
65	2007	–	Inflammatory change
66	2007	–	Haemangioma
67	2003	–	Normal change
68	2003	–	Haemangioma
69	2003	–	Normal variation
70	2003	–	Lipoma
71	2003	Cavernous haemangioma	Haemangioma
72	2003	–	Normal variation
73	2003	–	Benign tumour
74	2003	–	Normal variation
75	2003	Pyogenic granuloma	Haemangioma
76	2003	Cavernous haemangioma	Haemangioma
77	2003	–	Haemangioma
78	2003	–	Lipoma
79	2009	–	No information
80	2009	Cavernous haemangioma	Haemangioma
81	2009	–	Haemangioma
82	2009	–	Mass formation with poor vascularity
83	2010	Lipoma	Lipoma
84	2010	Cavernous haemangioma	Haemangioma
85	2010	–	Haemangioma
86	2010	Schwannoma	Lipoma
87	2010	Fibrous change	Lipoma

IOUS, intraoral ultrasonography.

Results

Table 1 shows the number of cases that received surgeries and imaging inspections of the tongue mass lesion for 11 years. From 1999 to 2010, 268 surgeries were performed on tongue mass lesions. 52 (19.4%) cases had imaging examinations. IOUS was performed in 42 of them. On the other hand, among the 87 patients who underwent IOUS, 42 (48.3 %) of them had surgeries. The remaining cases were followed up. Table 2 lists the pathological diagnoses of the 268 surgery cases. Inflammatory lesion was in 36 (13.4%) cases, tumour was in 74 (27.6%) cases, hyperplasia was in 131 (48.9 %) cases, cyst was in 8 (3.0 %) cases and other miscellaneous lesions was in 19 (7.1%) cases. Table 3 shows the pathological diagnosis of the lesions examined by IOUS before surgery. Of the 87 cases that underwent IOUS, 44 cases had a pathological diagnosis. Two of them had pathological diagnosis before IOUS because they had received biopsy before examination. Lipomas and haemangiomas could be diagnosed by IOUS. 19 cases were haemangiomas and accorded with preoperative IOUS diagnosis almost all except 1 case, which was too small to judge in ultrasonography. Six cases were lipomas and five cases of them were diagnosed as lipomas on IOUS.

Among the four cases of pyogenic tumours in pathological findings, one case was diagnosed as granuloma and three cases were diagnosed as haemangiomas,

Table 4 Agreement between pathological diagnosis and ultrasonographic diagnosis

Pathological results	*Number of cases*	*Agreement*
Haemangioma	19	18
Lipoma	6	5
Hyperplasia	6	3
Pyogenic granuloma	4	1
Chondroma	1	1
Schwannoma	1	0
Neurofibroma	1	1
Pleomorphic adenoma	1	1
Granular cell tumour	1	1
Lymphangioma	1	0
Amyloidosis	1	1

depending on the degree of the internal blood flow. In 32 (76.2%) of 42 cases, pre-operative IOUS diagnosis matched with pathological results (Table 4).

Case presentation

Case 1 fibrous polyp: A 72-year-old female presented with a 20-year history of a mass lesion on the right anterior part of the tongue (Figure 1a). She never noted any pain or change in size. For several months before admission, however, she began to feel a slight pain at the perimeter of the mass. Clinical examination revealed a pedunculated polyp with a smooth-surface mucous membrane. IOUS demonstrated a well-demarcated submucosal isoechoic appearance $9 \times 4 \times 7$ mm in size with anechoic zone (Figure 1c). Blood flow in the mass and perimeter area was almost not observed on power Doppler examination (Figure 1d). The diagnosis made based on ultrasonography was a benign tumour with poor blood flow such as a fibroma and lipoma. Excision was performed under sedation anaesthesia. The lesion was exfoliated with blunt dissection.

The pathological report described that under the epithelial layer with parakeratosis, irregular hyperplasia of the collagen fibre was observed. The pathological diagnosis was a fibrous polyp (Figure 2b).

Case 2 cavernous haemangioma: A 53-year-old female presented with a 15-year history of a mass lesion on the dorsal aspect of the right tongue (Figure 2a). She did not receive treatment because the lesion was painless. She had recently become aware of the mass increasing in size. Clinical examination revealed a palpable elastic soft well-demarcated mass. IOUS demonstrated a well-demarcated submucosal hypoechoic mass $12 \times 6 \times 18$ mm in size. A net-like structure and a hyperechoic area with a comet sign posterior acoustic shadow was observed in the lesion (Figure 2c). Power Doppler examination showed pulsatile blood flow in the anechoic area (Figure 2d). The diagnosis made based on ultrasonography was haemangioma with phlebolith.

Excision was performed under general anaesthesia. The appearance of the lesion included proliferation of the expanded blood vessel with a spongy structure and coated with partially keratinized mucosa. Thrombus was observed in the blood vessel and calcification was seen in several places. The pathological diagnosis was cavernous haemangioma with thrombus (Figure 2b).

Case 3 pyogenic granuloma: A 61-year-old female presented with a mass accompanied by an irritating feeling on the mid-dorsum of the tongue for 4 months. Ointment was applied but was ineffective. On inspection, it revealed a well-demarcated red lesion

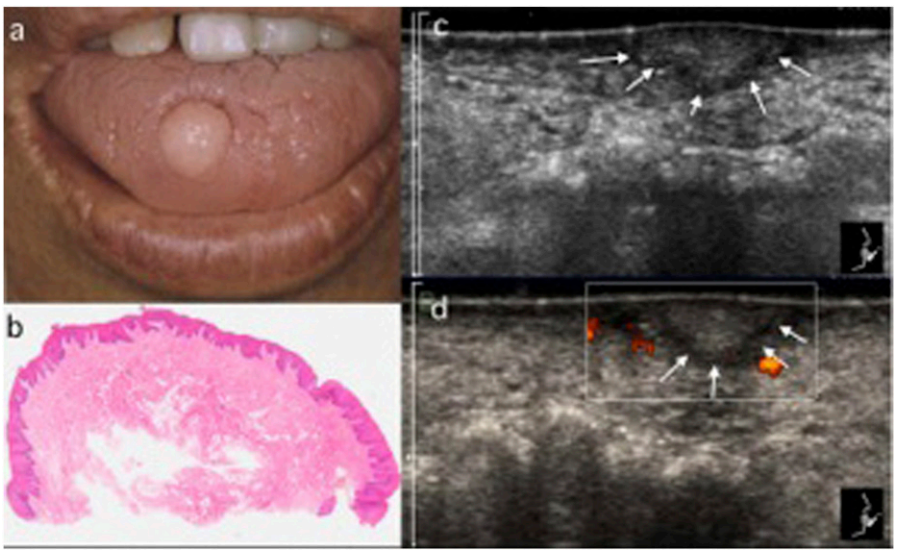

Figure 1 Fibrous polyp. (a) Clinical view of the lesion. (b) Low-power photomicrograph (haematoxylin–eosin stain) showing a polyp with irregular hyperplasia of the collagen fibre under the epithelial layer. (c) B-mode of intraoral ultrasonography (IOUS). The lesion is an isoechoic lesion (arrows) surrounded by the hypoechoic zone. (d) Power Doppler mode of IOUS. Blood flow is not observed at the centre and periphery of the lesion.

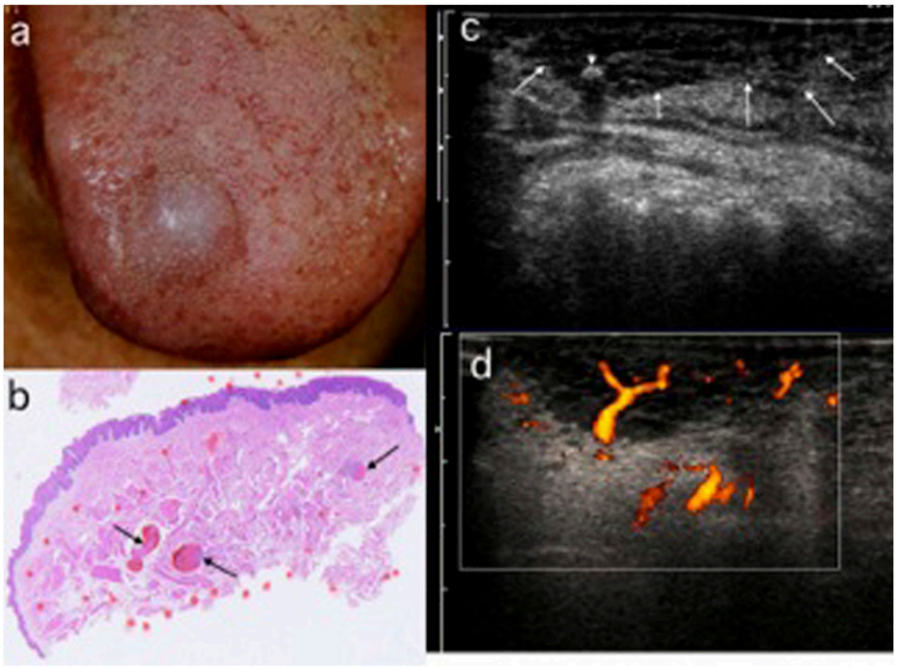

Figure 2 Cavernous haemangioma. (a) Clinical view of the lesion. (b) Low-power photomicrograph (haematoxylin–eosin stain) showing a circumscribed, submucosal tumour (the points surrounding the lesion). Hyperplasia of blood vessels including phleboliths (arrows) is observed. (c) B-mode of intraoral ultrasonography (IOUS). The lesion is a well-defined lobular hypoechoic lesion (arrows) including a calcified body (arrowhead). The lamellar echogenic septum is also observed. (d) Power Doppler mode of IOUS. Internal blood flow is observed in the anechoic area.

(Figure 3a). On IOUS, the lesion revealed a hypoechoic mass measuring $9 \times 6 \times 4$ mm; its border was not clear and no capsule was seen (Figure 3c). On power Doppler mode, there was rich vascular flow inside the lesion (Figure 3d). We diagnosed it as inflammatory change.

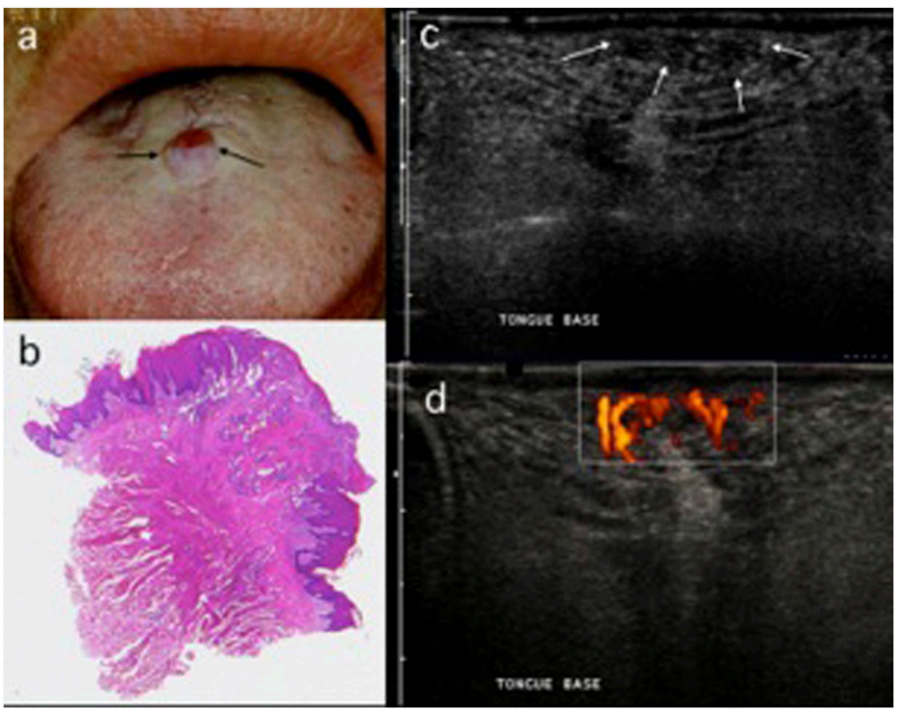

Figure 3 Pyogenic granuloma. (a) Clinical view of the lesion (arrows). (b) Low-power photomicrograph (haematoxylin–eosin stain); the lesion is a soft tissue consisting of capillary hyperplasia similar to granulation tissues. (c) B-mode of intraoral ultrasonography (IOUS) (arrows). The lesion is an irregular, ill-defined hypoechoic mass without capsule. (d) Power Doppler mode of IOUS. Rich blood flow is observed inside the lesion.

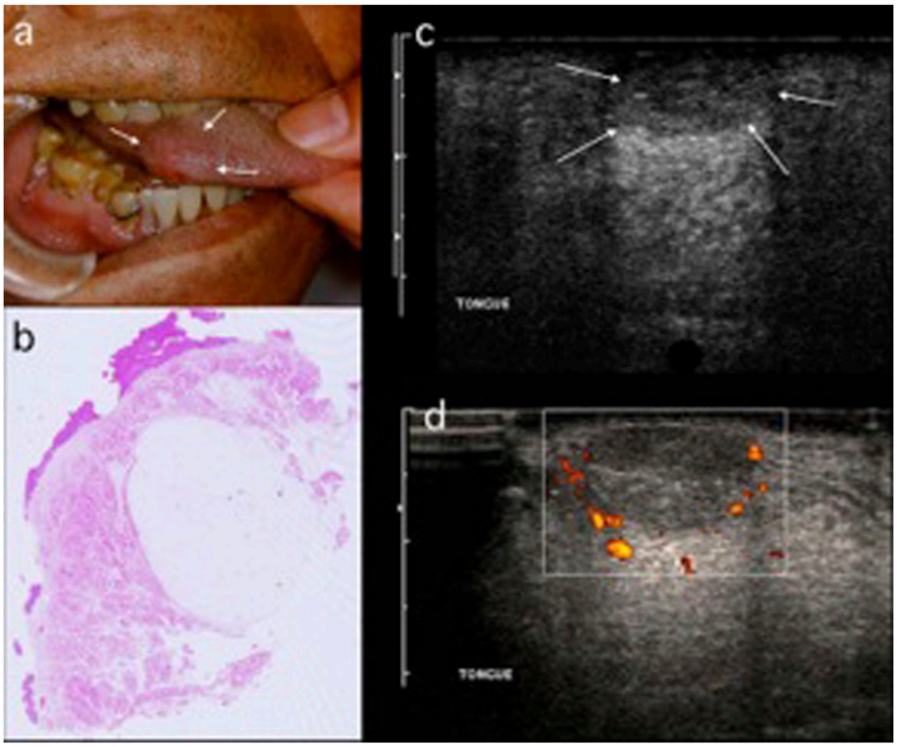

Figure 4 Lipoma. (a) Clinical view of the lesion (arrows). (b) Low-power photomicrograph (haematoxylin–eosin stain). Hyperplasia of a mature adipose tissue is found under the epithelium. (c) B-mode of intraoral ultrasonography (IOUS) showing a well-defined, elliptical homogeneous hypoechoic mass (arrows). Lamellar echogenic structure is also observed. (d) Power Doppler mode of IOUS. Marginal blood flow is observed without internal blood flow.

The lesion was removed under local anaesthesia. No invasion to the muscle layer was seen, and there was no capsular structure. The pathology report described the lesion as soft tissue consisting of capillary hyperplasia

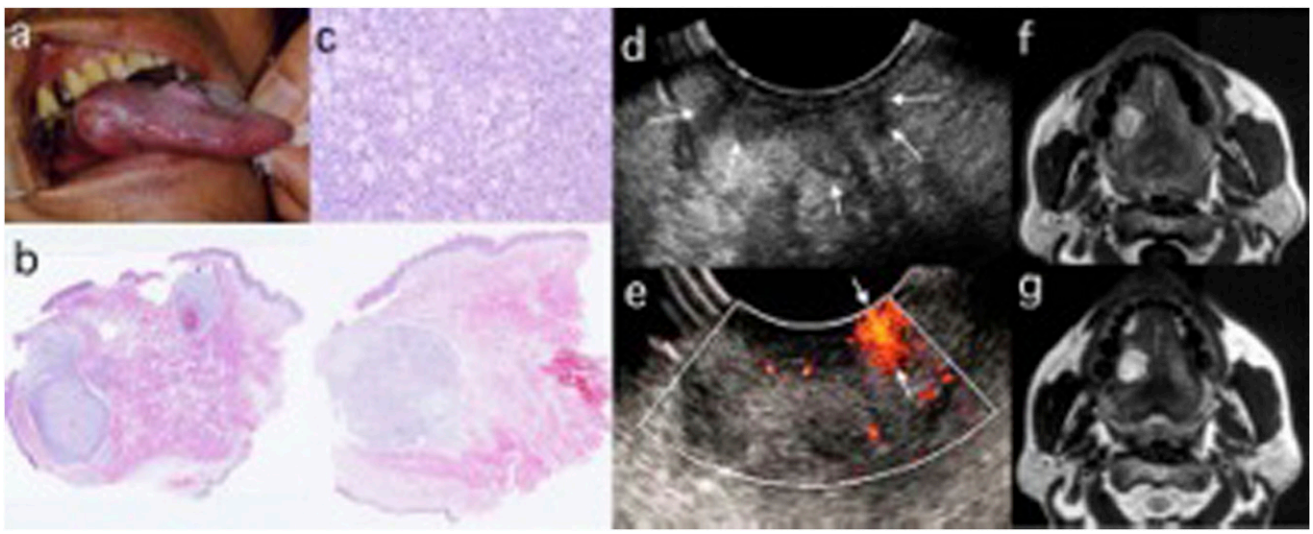

Figure 5 Liposarcoma. (a) Clinical view of the masses. Two masses with ulceration are observed in the right lateral and median dorsal part. (b) Photomicrograph [haematoxylin–eosin (HE) stain]. Two tumour masses were separately observed in the muscular layer. The tumour tissue showed an irregular lobulated pattern, and a mixed area showing high and low cellularity with basophilic mucoid substance and hyperplasia of tumour vessel was observed in the tumour stroma. (c) High-power photomicrograph (HE stain) showing anaplasia of the tumour cells. (d) B-mode of intraoral ultrasonography (IOUS) (arrows). A hypoechoic homogeneous mass with an irregular border is observed. (e) Power Doppler mode of IOUS. Blood flow is observed inside the lesion, but artefacts are observed caused by motion of the tongue (arrows). (f) T_1 weighted MR image. (g) T_2 weighted MR image. Tumour in the right side of the tongue is showing high signal intensity in both T_1 and T_2 weighted images.

similar to granulation tissues. Covered epithelial mucosa showed hyperkeratosis and elongation of rete pegs (Figure 3b).

Case 4 lipoma: A 70-year-old male presented with a painless lesion on the right border of the tongue. Clinical examination revealed a well-demarcated mass with normal mucosa (Figure 4a). The border of the mass was clear and observed as a hemispheric bulge. It was soft on palpation. IOUS revealed an elliptical heterogeneous hypoechoic mass 16×8 mm in diameter with a capsule. It showed a lateral shadow and posterior echo enhancement (Figure 4c). On power Doppler, there was poor peripheral vascular flow (Figure 3d). From these findings, we diagnosed it as a lipoma.

On histological examination, proliferation of mature adipose cells was found between the epithelial layer and muscle layer. The area around the tumour was surrounded by fibrous connective tissues (Figure 4b).

Case 5 liposarcoma: A 63-year-old male presented with two tongue masses on the right lateral and median dorsal part of the tongue. He noticed the dorsal lesion 5 years before and the lateral lesion 1 year before presentation. The right lateral lesion was accompanied by spontaneous pain. Clinical examination revealed ulceration on the surface of the tongue lesions (Figure 5a). The size of the mass in the middle of the lesion was 10 $\times$ 15 mm, while the lateral lesion was 30×25 mm. Both of the masses were elastic and hard. The patient's medical history was unremarkable. The lesions were suspected to be mal ignant; so, a biopsy was performed. The lesions were proven to be liposarcoma (low-grade malignancy).

IOUS was performed using a convex-type transducer after the pathological result was obtained. The tumours were hypoechoic masses with obscure and irregular borders (Figure 5d). Power Doppler examination showed pulsatile blood flow in the centre of the mass (Figure 5e). There were no metastatic findings in the neck lymph nodes. Both T_1 weighted (Figure 5f) and T_2 weighted MRI images (Figure 5g) revealed high signal intensity on the lesions.

Finally, the lesions were resected *en bloc* with 10-mm free margins. Histopathologically, two tumour masses were separately observed in the muscular layer. The tumour tissue showed an irregular lobulated pattern and mixed area showing high and low cellularity. Anaplasia of the tumour cells was markedly observed. In addition, basophilic mucoid substance and hyperplasia of the tumour vessel were observed in the tumour stroma (Figure 5b,c). By immunohistochemical staining, the tumour cells were diffusely positive for vimentin and S-100 (Figure 5b,c) and were negative for alpha-smooth muscle actin (α-SMA), glial fibrillary acidic protein (GFAP), cytokeratin (AE1/3), desmin, neuron-specific enorase (NSE) and factor VIII. Pathological diagnosis was liposarcoma.

Case 6 chondroma: A 64-year-old female presented with a painless mass (9×9 mm) on the left lateral part of the tongue. She noticed the lesion a few years previously.

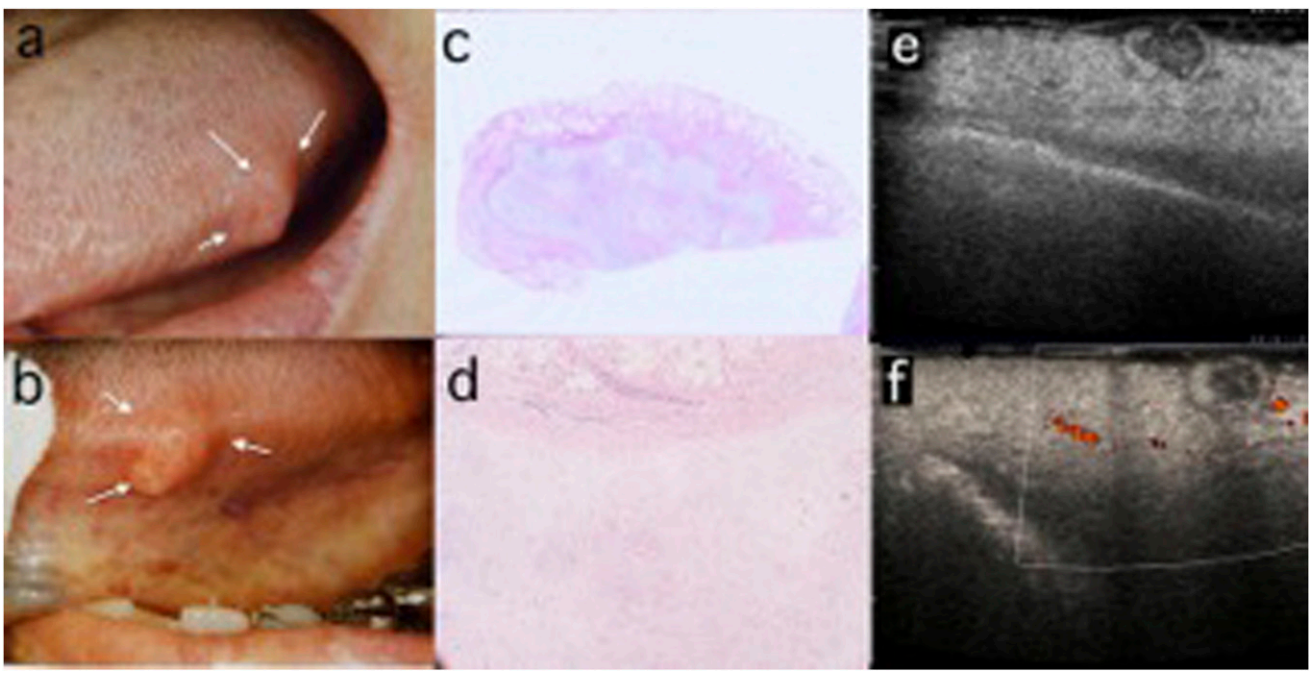

Figure 6 Chondroma. (a, b) Clinical views of the mass (arrows). (c) Low-power photomicrograph [haematoxylin–eosin (HE) stain] showing the cartilaginous tissue surrounded by the thick capsule of connective tissue and adipose tissue. (d) High-power photomicrograph (HE stain) showing the chondrocyte and cartilage matrix. (e) B-mode of intraoral ultrasonography (IOUS). The lesion is a round, well-defined hypoechoic mass with a hyperechoic zone. (f) Power Doppler mode of IOUS. No blood supply is observed.

The coated mucosa was smooth and yellowish-white (Figure 6a,b). It was comparatively hard on palpation. IOUS showed the tumour as a hypoechoic mass with a hyperechoic zone on B-mode; posterior echo enhancement was not observed (Figure 6e). Power Doppler examination did not show any blood supply in the lesion (Figure 6f). We diagnosed it as a benign tumour with a thick fibrous capsule.

The lesion was removed under local anaesthesia. The cartilaginous tissue was surrounded by a connective tissue and adipose tissue capsule (Figure 6c,d). This lesion is called an enchondroma, which grows outward from the bone.

Case 7 lymphangioma: A 42-year-old male presented with tongue enlargement. He had noticed it 10 years previously. On inspection, the left lateral part of the tongue had a hard elastic swelling and the coated mucosa was normal (Figure 7a). The patient had no symptoms of pain or respiratory or swallowing difficulty.

IOUS revealed a circumscribed lesion with thickening of the capsule (32×27 mm). Internal echo showed a heterogeneous tissue with an anechoic area observed inside the lesion (Figure 6c). Flow findings were observed in the anechoic area. On power Doppler mode, blood supply inside and at the periphery of the lesion was not observed (Figure 7d). We diagnosed the lesion as a dermoid cyst.

MRI showed a well-demarcated mass at the base of the tongue on T_2 weighted imaging (Figure 7e,f). The border of the lesion showed lobulated contours. The lesion was covered with a thick capsule that pushed the septum of the tongue towards the right side. The signal intensity inside the lesion was low on T_1 weighted images and low to high on T_2 weighted images.

Excision was performed under general anaesthesia and easily removed *en bloc*. The pathology report stated that the proliferation of remarkably enlarged lymphatic vessels was observed and haematoma was observed inside the vessel. The tumour had a fibrous capsule with infiltration of lymphocytes. It was diagnosed as a lymphangioma (Figure 7b).

Case 8 schwannoma: A 16-year-old male presented with a painless submucosal mass on the right dorsum of his tongue. He noticed the nodule 1 month earlier. Intraoral examination revealed a well-demarcated mass with normal mucosa 15×15 mm in diameter and elastic on palpation (Figure 8a). IOUS showed that the lesion had a well-defined border and presented a comparatively homogeneous echo texture with posterior echo enhancement

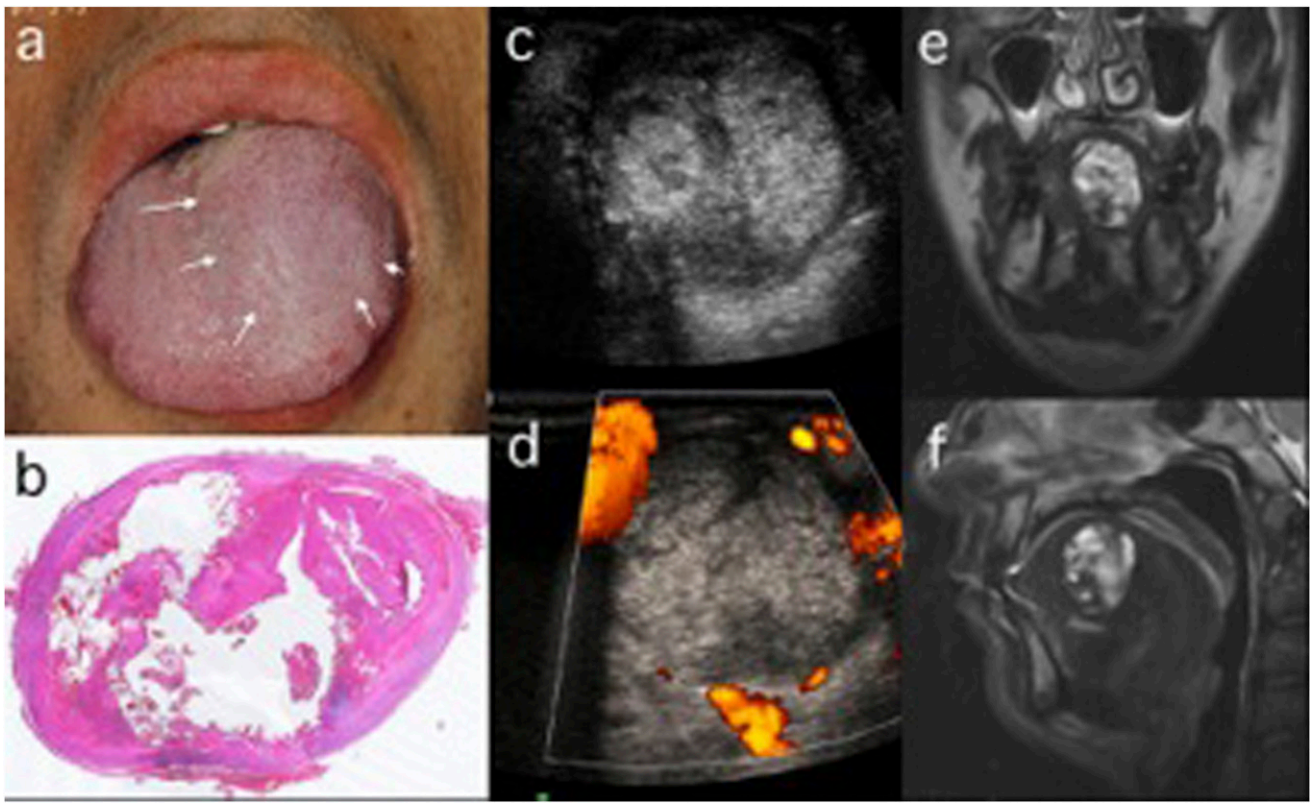

Figure 7 Lymphangioma. (a) Clinical view of the left tongue enlargement (arrows). (b) Low-power photomicrograph (haematoxylin–eosin stain). A thick fibrous capsule is surrounding the entire perimeter of the tumour. (c) B-mode of intraoral ultrasonography (IOUS) showing a well-defined heterogeneous mass having an anechoic area inside and capsular structure observed as a thick hypoechoic zone. (d) Power Doppler mode of IOUS. Blood supply is not observed inside or surrounding of the lesion. (e) T_2 weighted MR image of the coronal view. (f) T_2 weighted MR image of the sagittal view. The lesion is showing heterogeneous high signal intensity with the thick capsule showing low signal intensity.

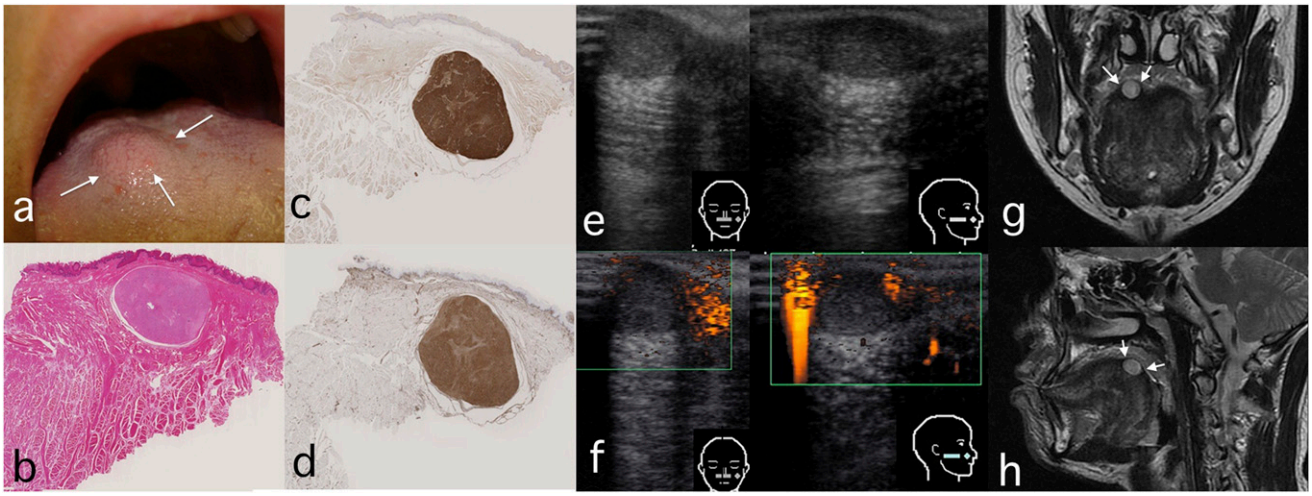

Figure 8 Schwannoma. (a) Clinical view of the mass (arrows). (b) Low-power photomicrograph (haematoxylin–eosin stain) showing an almost homogeneous solid tumour. (c) Immunohistochemical staining of S-100 is positive. (d) Immunohistochemical staining of vimentin is positive. (e) B-mode of intraoral ultrasonography (IOUS) showing an elliptical mass with a well-defined border and a comparatively homogeneous echo texture with posterior echo enhancement. (f) Power Doppler mode of IOUS is showing motion artefacts and cannot evaluate vascular condition. (g) T_2 weighted MR image of the frontal view (arrows). (h) T_2 weighted MR image of the sagittal view (arrows). The lesion is beneath the mucous membrane and is indicating high signal intensity on the T_2 weighted image.

(Figure 8e). On Doppler mode, the vascular condition could not be evaluated because the lesion was situated at the base of the tongue and the probe was not attached adequately (Figure 8f).

MRI of the oral cavity was performed and revealed a submucosal tumour in the right dorsal part of the tongue, which showed high signal intensity on T_2 weighted images (Figure 8g,h). Excision biopsy was performed under general anaesthesia. The cut surface of the specimen was a smooth tan grey.

Pathological findings revealed a dense bundle formation of tumour cells covered with a fibrous capsule.

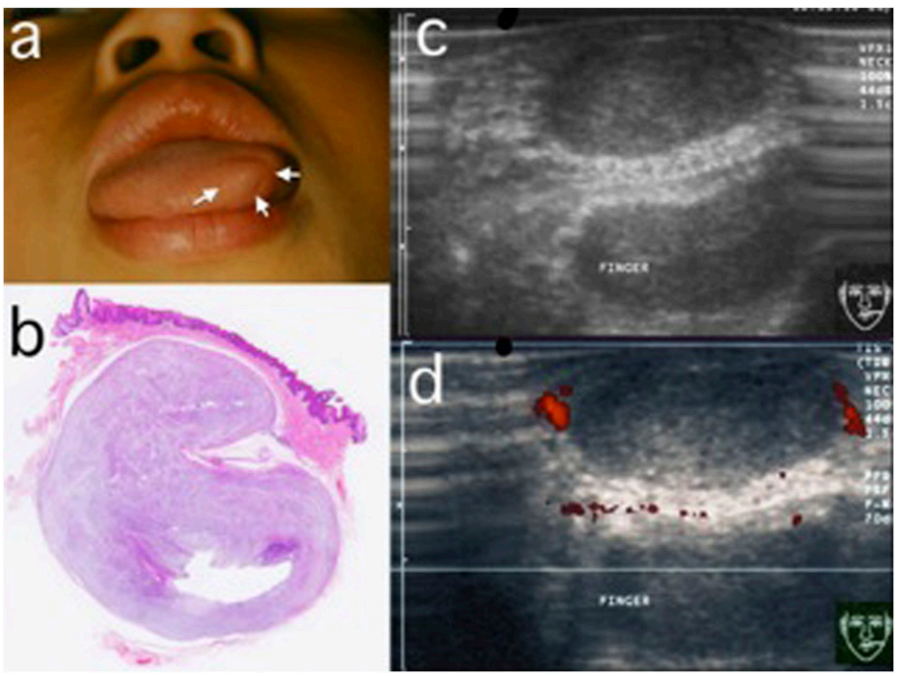

Figure 9 Neurofibroma. (a) Clinical view of the mass (arrows). (b) Low-power photomicrograph (haematoxylin–eosin stain) showing the tumour surrounding a fibrous capsule. (c) B-mode of intraoral ultrasonography (IOUS). The well-defined elliptical lesion is showing homogeneous hypoechoic internal echo with a clear border. (d) Power Doppler mode of IOUS. Slight blood flow is observed in the surrounding of the lesion, but not inside the lesion.

The tumour cells were fusiform with elongated fibrillar cytoplasm and buckled to spindled nuclei. A nuclear palisading pattern was observed. By immunohistochemical staining, tumour cells were positive for vimentin and S-100 (Figure 8b,c and d) and were negative for α-SMA and GFAP. Malignant findings were not detected. The pathology report called the mass an Antoni A-type schwannoma.

Case 9 solitary neurofibroma: A 10-year-old female presented with a painless mass on the left lateral border of the tongue. She noticed it a few years previously and had no symptoms, but the lesion was increasing in size. Intraoral examination revealed a well-demarcated submucosal mass (12 × 8 mm) that was elastic and hard on palpation (Figure 9a). The patient's medical history and family history were unremarkable. IOUS revealed that the lesion extended 1 mm beneath the tongue mucosa and was 10 × 5 × 10 mm. The border of the lesion was clear, while the internal echo of the lesion was hypoechoic and relatively homogeneous. The posterior echo was enhanced (Figure 9c). On Doppler mode, blood flow was observed slightly surrounding the lesion, but not inside the lesion (Figure 9d).

The lesion was removed with a safety margin of 3 mm. The lesion was easily removed from the surrounding tissue. The half-split surface was transparent and ash coloured. The specimen featured the arrangement of spindle-shaped tumour cells surrounding a fibrous capsule. By immunochemical staining, the tumour cells were positive for S-100, vimentin and NSE and were negative for desmin and α-SMA. Histopathology identified the mass as a neurofibroma (Figure 9b).

Case 10 pleomorphic adenoma: A 59-year-old female presented with an asymptomatic mass at the inferior surface of her tongue. She noticed it 3 months previously. She had used a medication given by an otorhinolaryngologist, but the lesion did not change. The lesion revealed a circumscribed elastic swelling with normal mucosa (16 × 12 × 13 mm) (Figure 10a). On IOUS, it had well-defined borders accompanied by posterior enhancement and lateral shadow. The lesion was heterogeneous with a few anechoic areas inside the lesion (Figure 10c). It did not show alteration of shape due to compression. On Doppler examination, blood flow was observed around the mass but a little inside (Figure 10d). Ultrasonographic diagnosis was a benign salivary tumour. On MRI, the tumour showed low signal intensity on T_1 weighted images and high intensity on T_2 weighted images. With contrast MRI, the lesion showed higher intensity; cystic degenerative change was suspected inside the lesion.

Under intravenous sedation and local anaesthesia, the lesion was removed. The tumour was diagnosed as a pleomorphic adenoma. The tumour consisted of epithelial elements, myoepithelial cells and mesenchymal elements (Figure 10b).

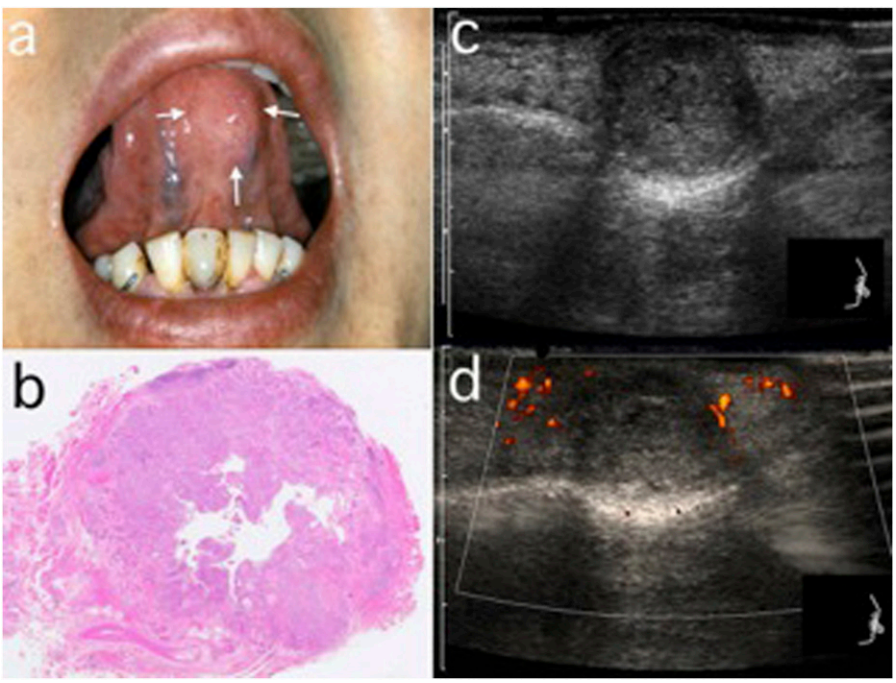

Figure 10 Pleomorphic adenoma. (a) Clinical view of the mass (arrows). (b) Low-power photomicrograph (haematoxylin–eosin stain). The lesion is surrounded by a capsule, but it is partially lacking. A luminal structure and microcyst are observed within the lesion. (c) B-mode of intraoral ultrasonography (IOUS) showing the sand-like heterogeneous hypoechoic mass with well-defined borders. Posterior echo enhancement and lateral shadow are observed, and a few anechoic areas are observed in the centre of the lesion. (d) Power Doppler mode of IOUS showing blood flow around the lesion, but little inside.

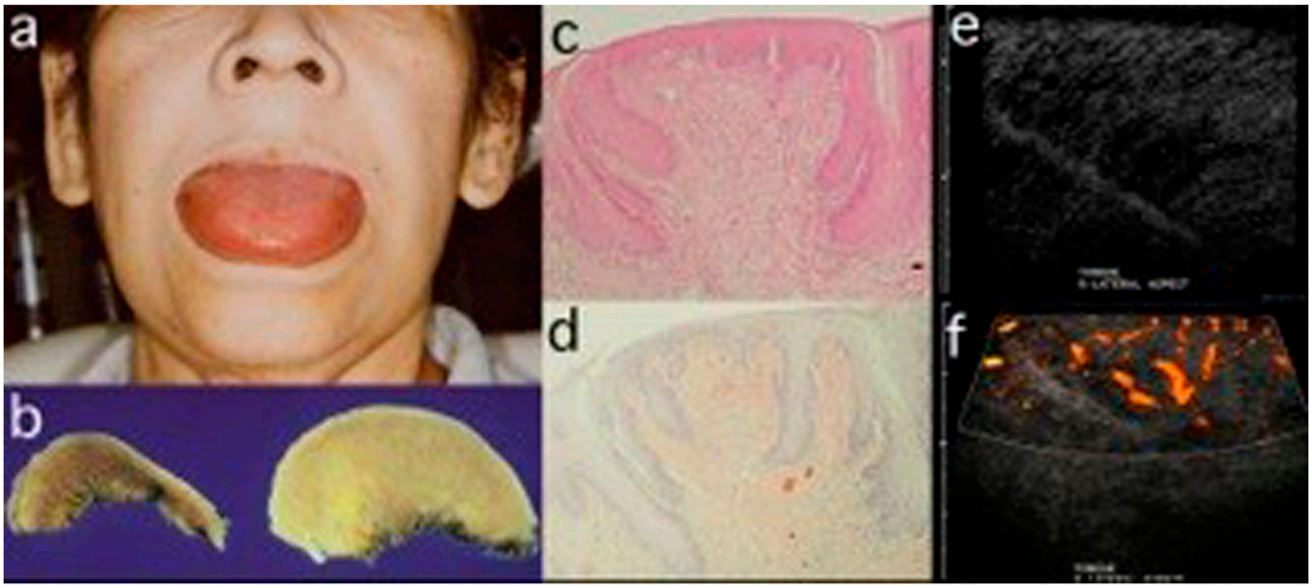

Figure 11 Amyloidosis. (a) Macroscopic view. Owing to remarkable enlargement of the tongue, the patient could not close the mouth. (b) Sagittal section of the tongue of autopsy cases (left, normal; right, in this patient). (c) Low-power photomicrograph [haematoxylin–eosin (HE) stain] showing hyaline-like material dyed in light pink beneath the mucous membrane. (d) Image of the Congo red stain showing hyaline-like material in the HE stain as an orange area. (e) B-mode of intraoral ultrasonography (IOUS). No space was occupied by the lesion, but the muscle layer is coarse compared with normal cases. (f) Power Doppler mode of IOUS showing no abnormal findings. For colour image see online.

Case 11 amyloidosis: An 82-year-old female was seen at our hospital for a complaint of rapid enlargement of her tongue. Her tongue continued to grow for a half year, and she could not eat a meal by the time of consultation. At first, she noticed the tongue enlargement when she found it difficult to put her dentures in her mouth. The patient was a non-smoker, non-drinker and had no significant family history. Her past medical history was notable for hypertension, diabetes and hyperlipidemia. When she visited our hospital, she could not close her mouth owing to her gigantic tongue, which projected out (Figure 11a). The tongue was elastic and hard, with atrophy of the tongue papilla. The motion of the tongue was poor.

CT, MRI and IOUS were performed. Findings of tumour formation could not be detected because the whole tongue had swollen homogenously. Therefore, we suspected the state was metabolic change. On IOUS, no structural abnormality was seen in her tongue, but an anechoic area between the muscular layers was noticeable (Figure 11e,f). Bence Jones protein was detected in her blood and urine, and myeloma was diagnosed. She was hospitalized to undergo a biopsy, but died suddenly owing to heart failure.

After her death, autopsy was performed. Her tongue had enlarged approximately four times the normal size (Figure 11b). Amyloid deposits were observed in various organs including the tongue, heart, oesophagus, stomach, small intestine, large intestine, kidney and thyroid gland. The amyloid deposits in her tongue were confirmed by Congo red stain (Figure 11d).

Discussion

The purpose of this study was to demonstrate the efficacy of IOUS for the pre-operative diagnosis of tongue mass lesions compared with the pathological diagnosis. We made clear the ultrasonographic characteristics of the lesions in cases including fibrous polyp, haemangioma, pyogenic granuloma, lipoma, liposarcoma, chondroma, lymphangioma, schwannoma, solitary neurofibroma, pleomorphic adenoma and amyloidosis, some of which were not described before.

The tongue includes various tissues, such as muscles, nerves and vessels, minor salivary glands and fatty tissues. To diagnose tongue mass lesions, we need to determine the origin of the tissue. In addition, it is necessary to evaluate whether the lesion represents inflammation, tumour, cyst, hyperplasia or other types. When we consider these points, IOUS is very adequate for pre-operative imaging of tongue mass lesions because IOUS can show the internal structure and vascularity of the lesion.

In this study, 32 (76.2%) of 42 cases who received IOUS before surgeries matched with pathological results. Most haemangiomas and lipomas could be diagnosed by IOUS alone. The IOUS findings nearly corresponded to the histopathological findings; therefore, it was thought to be useful for pre-operative diagnosis.

Tongue mass lesions are often removed surgically based on inspection and palpation without imaging examinations. Physical examination of the tongue is considered easy because it is easily accessible by palpation.[4] In our study, only 52 (19.4%) cases among 268

cases received imaging examination before surgeries. CT and MRI are sometimes restricted owing to the metal artefacts from dental alloys. Furthermore, CT and MRI are too weak to inspect superficial lesions, and the volume occupied by the lesion of the tongue is often too small to get clear images with these modalities.

In contrast, ultrasonography is not affected by dental alloys, and using a high-frequency probe, it provides clear and useful images for superficial and thin lesions even as small as 5 mm.[1] Common ultrasonography has the advantages of being non-invasive, rapid and easily reproducible. In addition, ultrasonography can provide vascular information on Doppler mode without the use of an intravenous contrast medium. But, in case of an extraoral approach, it does not provide adequate images especially in the tongue, oral floor and palate region, because air spaces within the oral cavity attenuate acoustic waves, and ultrasound does not penetrate the bone well.[2] Furthermore, the acoustic attenuation caused by the distance from the skin to the lesion is a serious problem. In this way, IOUS seems to be more useful and beneficial compared with extraoral ultrasonography to diagnose tongue mass lesions.

The high-resolution probe provides beneficial information of the tongue lesion, such as the size, contour, border, thickness, capsule of the lesion, vascular distribution, internal echo, posterior echo and other factors. Characteristics of the internal structures of the masses are most important to diagnose the lesion, including cystic changes, calcification and tissue formation and patterns. In this way, IOUS can provide more useful information on the nature of the mass than inspection and palpation or other imaging tools (CT, MRI and extraoral sonography). Even with follow-up cases, IOUS is useful to evaluate the change of the size and internal structure.

To judge whether a lesion is neoplastic or cystic, we routinely observe the echogenicity inside the lesion on B-mode and the vascularity inside and at the periphery of the lesion on Doppler mode. In the case of a cyst, colour signal is not observed inside the lesion. And the fluid-filled area will be observed as an anechoic and/or hypoechoic area where we can sometimes observe fluidity, a convection phenomenon caused by acoustic pressure. In the case of a tumour, there is internal echogenicity, and blood flow is observed inside and at the periphery of the lesion depending on the characteristics of the tumour. Haemangioma, pleomorphic adenoma and mucous cysts sometimes have calcified bodies inside them. The calcified bodies are observed as hyperechoic bodies with a posterior acoustic shadow. A benign tumour may have a fibrous capsule around it, and capsular structure is observed as a hyperechoic zone surrounding the lesion. The condition of the posterior echo of the lesion is dependent on the internal characteristics of it. For example, cysts, lipomas and haemangiomas which include sparse components have posterior echo enhancement, while chondromas, which have comparatively high-density contents, have isoechoic surrounding tissues. Benign tumours mostly have a capsule; so, the border will be clear. But, malignant tumours hardly have it; therefore, malignant tumours show invasive growth, and the border of the lesions will not be clear. Compressibility is an important finding to evaluate the elasticity of the lesion. Recently, the elastography mode was developed, and it enables objectively evaluating the hardness of the lesion.[5] Table 5 shows these ultrasonographic findings and the characteristics of the tissue. Tables 6 and 7 shows a summary of the ultrasonographic imaging features of the tongue lesions in this study.

Recently, IOUS has become an important diagnostic tool in oral and maxillofacial surgery, especially in tongue carcinomas, to inspect the thickness and invasion of lesions.[3,6–10] This methodology has also been useful for inspecting inflammation and tumours around the tonsils.[11] Kutluhan et al[12] reported that the pre-operative measurement of lesions for tonsillectomy by IOUS was reliable. However, the major focus of these studies was only to determine pre-operative orientation, such as measuring the tumour thickness to determine the accurate safety margin of the carcinoma and examining the

Table 5 Ultrasonographic findings and characteristic of the tissue

Ultrasonographic findings	*Characteristic based on ultrasound finding*
Shape	
Elliptical, ovoid	Benign tumour, cyst, polyp
Irregular	Inflammatory change, malignant lesion
Border	
Well defined	Tumour, cyst
Ill defined	Inflammatory change, malignant lesion
Capsule	
Present	Tumour, cyst
None	Inflammatory change, malignant lesion
Echogenicity	
Hypoechoic	Poor cellular lesion
Hypoechoic	Rich cellular lesion, solid material, debris
Isoechoic	Similar texture to the adjacent tissue
Anechoic	Cystic change, including Liquid
Homogeneity	
Homogeneous	Uniform material
Heterogeneous	A mixture of different sound effects
Internal echo character	
Echogenic line	Lamellar structure, septum
Echogenic spots	Scattering strong reflectors (debris, keratinized material, calcification, foreign body)
Anechoic area	Cystic change
Posterior echo	
Enhance	Cyst, sparseness
Acoustic shadow	Hard tissues (bone, cartilage, teeth material)
Attenuation	Denser material than the adjacent tissue
Compressibility	
Compressive	Cystic, soft mass, sparse content
Incompressive	Hard mass, rich cellular masses
Fluidity	
Accompanied flow	Liquid existence
No flow	No liquid, liquid with great viscosity
Colour Doppler signal	
Peripheral colour	Cyst wall, tumour, inflammatory lesion
Central colour	Inflammatory lesion, tumour
No colour signal	Having no feeding vessel

Table 6 Summary of ultrasonographic features

Lesion	*Shape*	*Border*	*Capsule*	*Internal echogenicity*	*Homogeneity*
Inflammation (excluding abscess)	Irregular	Ill defined	None	Hypoechoic–hyperechoic	Heterogeneous
Hyperplasia	Irregular	Well defined	None	Hypoechoic	Various
Haemangioma	Lobulated	Well defined	None	Hypoechoic	Heterogeneous
Lipoma	Ovoid	Well defined	None	Isoechoic–hypoechoic	Heterogeneous
Schwannoma	Round, ovoid	Well defined	Present	Hypoechoic	Homogeneous–heterogenous
Neurofibroma	Round, ovoid	Well defined	Present	Hypoechoic	Heterogeneous
Lymphangioma	Lobulated, septated cystic	Well defined	None	Anechoic–hypoechoic	Heterogeneous
Pleomorphic adenoma	Ovoid, lobulated	Well defined	Present	Hypoechoic	Homogeneous–heterogenous
Chondroma	Irregular	Well defined	Present (uniformly thick)	Hypoechoic	Relatively homogeneous
Cysts	Round, ovoid	Well defined	Present	Anechoic–hypoechoic	Homogeneous
Amyloidosis	N/A	N/A	N/A	N/A	N/A

N/A, not applicable.

relationship between the lesion and the adjacent tissue. There is a report of IOUS being applied to palatal tumours.[13] Similar to our reports, the article reported the efficacy of IOUS as a pre-operative evaluation tool and compared ultrasonography and histological evaluation.

There are, however, some limitations to performing IOUS. It is difficult to attach the large probe to the lesion on the tongue and to obtain a clear image of it. This technique is difficult for an operator and is unpleasant for a patient. Patient cooperation is indispensable to this procedure. We cannot eliminate these limitations even if we use a probe which is suitable for intraoral approach with small size. For these reasons, compared with extraoral sonography, the reproducibility of IOUS is poor, and the area that we can attach the probe to the patient's tongue is limited. Only anterior part of the movable tongue would be able to perform by IOUS.

Even in consideration of these disadvantages, IOUS is a great useful imaging tool, because it can observe the

Table 7 Summary of ultrasonic features continued

Lesion	*Internal echo characteristics*	*Posterior echo*	*Compressibility*	*Fluidity*	*Color Doppler signal*
Inflammation (excluding abscess)	Echogenic spots	No enhancement	None	None	Scattered (internal and peripheral)
Hyperplasia	None	No enhancement	None	None	Various
Hemangioma	Echogenic septum anechoic area Acoustic shadow in phlebolith	Enhancement	Present	Present anechoic area	Heypervascularity (in anechoic spot)
Lipoma	Echogenic lamellar structure	Enhancement	Present	None	None–poor signal
Schwannoma	Echogenic area Cystic area	Enhancement	None	None, rare	Hypervascularity (peripheral and central)
Neurofibroma	Cystic area	Enhancement	None	None	Hypervascularity (peripheral and central)
Lymphangioma	Echogenic septum multicystic	Enhancement	Present	Present in anechoic area	None–poor signal
Pleomorphic adenoma	Depends on contents cystic area Acoustic shadow in hyaline degeneration	Enhancement	None	None	Poor signal
Chondroma	Isoechoic	No enhancement	None	None	Poor signal
Cysts	None	Enhancement	Present	Present (depends on viscosity of the content)	None
Amyloidosis	N/A	N/A	N/A	N/A	Normal at a glance

N/A, not applicable.

internal structure and vascularization of small lesions without contrast media. If possible, we should perform the diagnostic test statistically among IOUS, CT and MRI to indicate the usefulness of IOUS. However, the comparison of the diagnostic accuracy is impossible because it is rare that these examinations are conducted for a tongue mass lesion for the reason mentioned above.

Conclusions

Intraoral ultrasonography of the tongue revealed the nature of the lesions including the border, size, location, depth, the presence or absence of a capsule and the internal structure including vascularity of the mass. The ultrasonographic findings well reflected the histological findings.

References

1. Sugawara C, Takahashi A. Mechanical and clinical performance of pulse-inversion tissue harmonic imaging in the superficial region. *J Med Ultrason* 2010; **37**: 107–15. doi: http://dx.doi.org/10.1007/s10396-010-0258-7
2. Yoshida H, Akizuki H, Michi K. Intraoral ultrasonic scanning as a diagnostic aid. *J Craniomaxillofac Surg* 1987; **15**: 306–11. doi: http://dx.doi.org/10.1016/S1010-5182(87)80076-8
3. Natori T, Koga M, Anegawa E, Nakashima Y, Tetsuka M, Yoh J, et al. Usefulness of intra-oral ultrasonography to predict neck metastasis in patients with tongue carcinoma. *Oral Dis* 2008; **14**: 591–9. doi: http://dx.doi.org/10.1111/j.1601-0825.2007.01423.x
4. Narayana HM, Panda NK, Mann SB, Katariya S, Vasishta RK. Ultrasound *versus* physical examination in staging carcinoma of the mobile tongue. *J Laryngol Otol* 1996; **110**: 43–7. doi: http://dx.doi.org/10.1017/S0022215100132682
5. Garra BS. Elastography: history, principles, and te chnique comparison. *Abdom Imaging* 2015; **40**: 680–97. doi: http://dx.doi.org/10.1007/s00261-014-0305-8
6. Shintani S, Nakayama B, Matsuura H, Hasegawa Y. Intraoral ultrasonography is useful to evaluate tumor thickness in tongue carcinoma. *Am J Surg* 1997; **173**: 345–7. doi: http://dx.doi.org/10.1016/S0002-9610(96)00395-9
7. Yuen AP, Ng RW, Lam PK, Ho A. Preoperative measurement of tumor thickness of oral tongue carcinoma with intraoral ultrasonography. *Head Neck* 2008; **30**: 230–4. doi: http://dx.doi.org/10.1002/hed.20678
8. Baek CH, Son YI, Jeong HS, Chung MK, Park KN, Ko YH, et al. Intraoral sonography-assisted resection of $T_{1–2}$ tongue cancer for adequate deep resection. *Otolaryngol Head Neck Surg* 2008; **139**: 805–10. doi: http://dx.doi.org/10.1016/j.otohns.2008.09.017
9. Kodama M, Khanal A, Habu M, Iwanaga K, Yoshioka I, Tanaka T, et al. Ultrasonography for intraoperative determination of tumor thickness and resection margin in tongue carcinomas. *J Oral Maxillofac Surg* 2010; **68**: 1746–52. doi: http://dx.doi.org/10.1016/j.joms.2009.07.110
10. Songra AK, Ng SY, Farthing P, Hutchison IL, Bradley PF. Observation of tumour thickness and resection margin at surgical excision of primary oral squamous cell carcinoma—assessment by ultrasound. *Int J Oral Maxillofac Surg* 2006; **35**: 324–31. doi: http://dx.doi.org/10.1016/j.ijom.2005.07.019
11. Kew J, Ahuja A, Loftus WK, Scott PM, Metreweli C. Peritonsillar abscess appearance on intra-oral ultrasonography. *Clin Radiol* 1998; **53**: 143–6. doi: http://dx.doi.org/10.1016/S0009-9260(98)80062-7
12. Kutluhan A, Sakarya ME, Cankaya H, Akkaya S. Clinical value of preoperative intraoral ultrasonography in tonsillectomy. *Auris Nasus Larynx* 1998; **25**: 181–5. doi: http://dx.doi.org/10.1016/S0385-8146(98)00019-4
13. Ishii J, Nagasawa H, Wadamori T, Yamashiro M, Ishikawa H, Yamada T, et al. Ultrasonography in the diagnosis of palatal tumors. *Oral Surg Oral Med Oral Pathol Oral Radiol Endod* 1999; **87**: 39–43. doi: http://dx.doi.org/10.1016/S1079-2104(99)70292-1