10 Dentomaxillofacial Ultrasonography: Basic Principles and Radiographic Anatomy

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10.1 Introduction

Ultrasound is a common radiographic exam in patients with clinical findings and symptoms from the neck, buccal area, and oropharynx.

Adequate evaluation of a pathological structure should be based primarily on the recognition of normal anatomical structures. This presupposes the appropriate equipment, the familiarity of the operator, and the understanding of the examination techniques.

In the following sections we will describe the methods and the way of handling the ultrasound unit in order to achieve the optimal display of the anatomical structures of the soft tissues of the face and neck area in individuals—volunteers with normal non-pathological findings.

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10.2 Equipment and Method

Ultrasound imaging of the structures of the face, upper neck, and the floor of the oral cavity is achieved using high-frequency transdermal transducers and a linear probe. Appropriate frequencies for an adequate scan range from approximately 6–15 MHz.

The choice of the appropriate frequency of ultrasound is individualized depending on the body types of the examinee and depends mainly on the thickness of the tissues that will absorb the sound, i.e., the skin, subcutaneous fat, muscle layers and the target organ. Low frequencies allow tissue imaging at greater depths compared to high frequencies, but lag far behind in sharpness and resolution. Therefore in people with increased thickness of soft particles we prefer the lowest frequencies 6–9 MHz. In contrast to patients with thin soft tissue, higher frequencies of 10–15 MHz are usually sufficient to examine deep tissues and produce higher resolution images.

It is of high significance and most helpful to the examiner, that the ultrasound equipment used in the maxillofacial area, should include color and spectral Doppler. With Color Doppler the examiner can control the perfusion of the tissues and the direction of blood flow while with Spectral Doppler the examiner can record the flow velocities in units of cm/s. The detection of a chromatic signal in the lumen of the arteries

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and veins helps initially to distinguish the vascular branches from the secretory ducts of the salivary glands. In some tissues, such as the lymph nodes, the emergence of a characteristic pattern of perfusion allows them to be easily separated and located in the anatomical compartments of the neck, between the muscle groups and within the fatty layers [1].

The power Doppler method is a complementary test that detects weaker flows and measures the amount of vascularization with high resolution and higher resolution images compared to the Color Doppler. It cannot, however, determine the direction of flow and therefore separate the arterial from the venous network (Fig. 10.1).

In recent years, strain and shear wave elastography techniqyes have been added to the most advanced ultrasonographic equipment. They capture on a special color map and measure with Kpa units the rigidity of the tissues. This is obtained with the use of mechanical oscillation of the soft molecules at the device of the transducer in the first case and the electric emission, horizontal waves from the transducer in the second case.

Differences in tissue elasticity can confirm and to some extent determine the examiner's findings regarding the composition of the depicted anatomical structures such as muscle, cartilage, fat, and solid organs (Fig. 10.2).

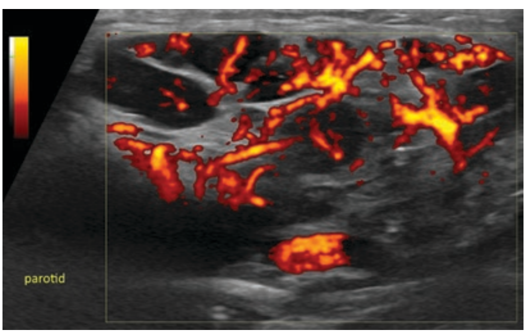


Fig. 10.1 The power Doppler method reveals in detail the increased perfusion of the parotid gland in a patient with chronic Sjogren's syndrome. Disorganization of the gland texture with reduced echogenicity, parenchyma reduction, and fibrous septa

10.3 Bone Structures

The visceral skull consists of the bones of the nasal cavity and the bones of the face. The second category includes the maxilla, zygomatic bones, and mandible [1–3].

The two maxillas are the main part of the facial skeleton. They form a triangular pyramid shape bone with three walls: anterior, posterior, and upper.

The maxilla as a bone has a body and four protuberances, the frontal, the buccal, the palatal, and the alveolar. The two alveolar ones join at the midline and form the alveolar arch or hard palate. They are areas of sonographic interest because they are directly related to the pathology of the oral cavity and teeth (Fig. 10.3).

The lower jaw or mandible is the largest bone in the face. It consists of the (A) body and the two (B) branches.

(A) The mandibular body shows in the midline the genial tuberocity and on the upper surface the alveoli of the mandibular teeth. On the inner surface of the body one can observe the sublingual and submandibular fossae for the homonymous salivary glands.

(B) The two rami of the mandible are merged with the body and form the two mandibular angles. The upper surface of the ramus ends in the coronary process towards the front and in the condylar process towards the back. The temporomandibular joint is created by the condylar process and the articular eminence of the temporal bone. A cartilaginous disc is located between the two articular surfaces, the anterior surface of which is concave in front due to the projection of the articular tubercle and convex to the back due to the temporal lobe.

The hyoid bone lies in the midline of the upper cervical region and serves mainly to support the tongue. It is U-shaped with the convex part facing forward and shows a middle degree, the body,

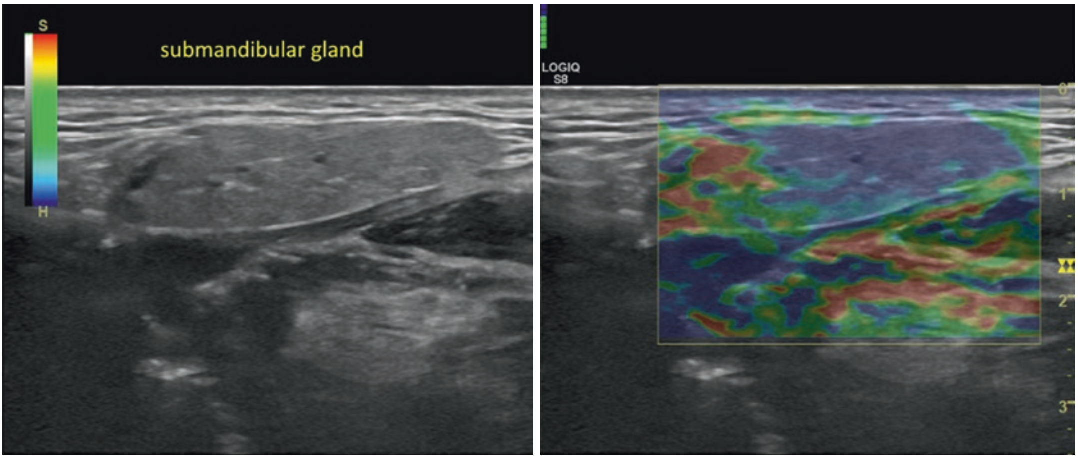


Fig. 10.2 Strain elastography of the submandibular salivary gland. The red areas correspond to soft tissues, while the dark blue ones to the hard ones. The normal submandibular gland (light blue color) shows increased stiffness compared to the surrounding tissues. In the elderly, the gland becomes harder due to fibrosis and parenchyma atrophy

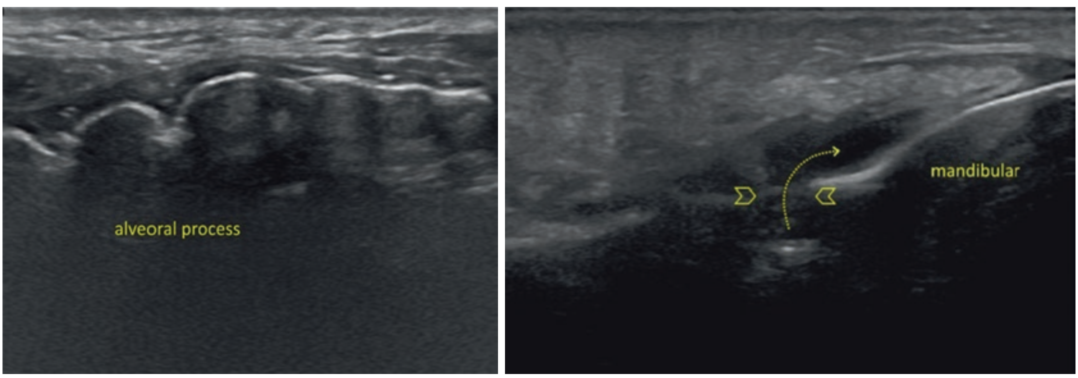


Fig. 10.3 Arched shaped morphology of the alveolar process in the normal maxilla. Osteomyelitis of the lower jaw with ultrasonographic disruption of the bone capsule (arrowheads) and diffusion of the inflammatory contents into the soft tissues of the area (arrow)

and two pairs of protuberances, the major and minor horns (Fig. 10.4).

10.3.1 Head Muscles

They are subdivided into (A) mimics and (B) masseter group of muscles [3–6].

(A) The mimic muscles that are located within the subcutaneous tissue, are small in size and are not surrounded by fascia. They adhere to the skin and are extremely sensitive to facial nerve impulses. With their contractions they change the facial expressions depending on the psychological state and the emotional changes of the person.

They are summarized to the muscles of the skull, mouth, nose, eyelids, and outer ear.

The buccal fat layer is located between the anterior edge of the massager and the buccinator muscle. The buccinator is a thin base of the buccal country, has a quadrangular shape and occupies the space between the upper and lower jaw. The duct of the parotid gland, pierces the buccinator muscle at the height of the second molar of the upper jaw.

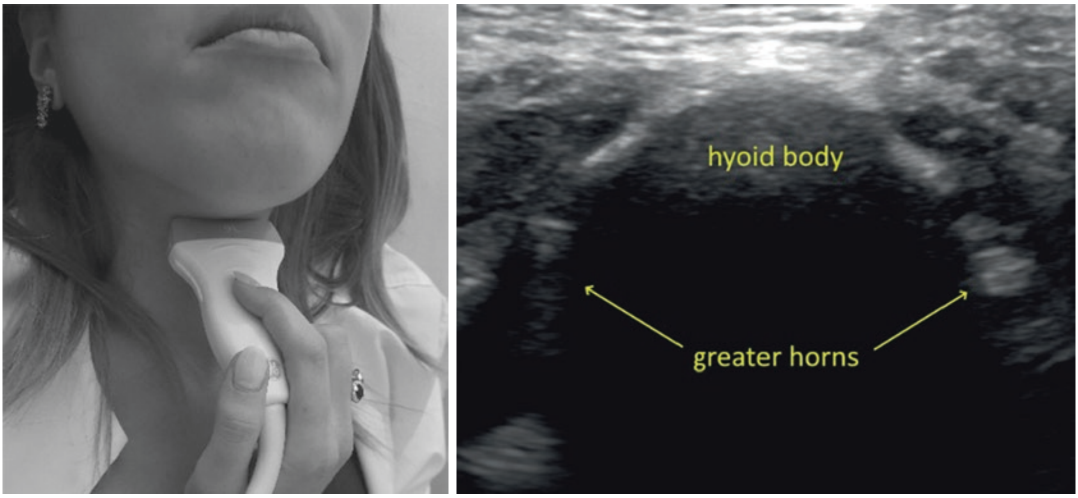
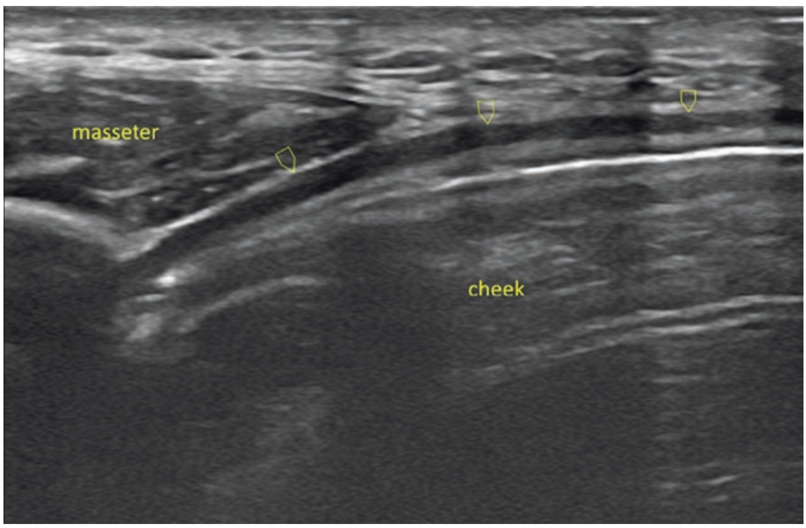


Fig. 10.4 The transducer is placed transversely at the boundaries between the floor of the oral cavity and the upper neck area. The hyoid bone is depicted as a curvilinear, hyperechoic formation

Fig. 10.5 Buccinator muscle (arrow heads) has the morphology of a thin hypoechoic zone and is readily visualized with the patient puffing (blowing and extending) his cheeks



The buccinator muscle helps in swallowing movements and air exhaling. Due to the close anatomical relationship with the oral cavity it is important to include it in our ultrasound examination (Fig. 10.5).

(B) The masseter muscles are four on each side: masseter, temporalis, median, and lateral pterygoid.

These are very strong muscles that rest on the lower jaw and control the chewing movements. They are innervated by the third branch of the trigeminal nerve.

The masseters show superficial and deep area. It arises from the cheek and ends in the masticatory area of the mandibular ramus. The outer surface of the muscle intersects with the parotid duct (Fig. 10.6).

The temporalis muscle is large and different from the masticatory muscles. It exits from the temporal fossa and the temporal bone and ends at the coronoid process of the mandible (Fig. 10.7).

The lateral pterygoid muscle appears with two sections the upper and lower. The

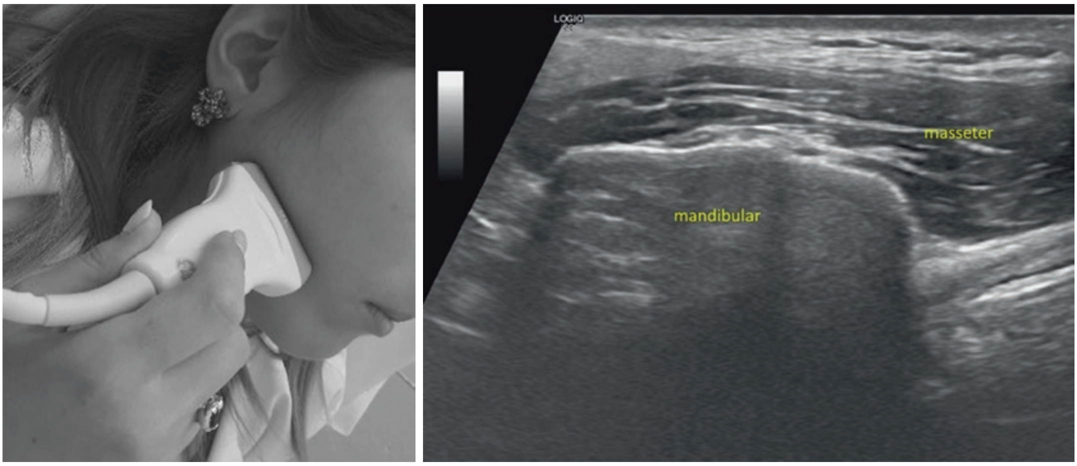


Fig. 10.6 Cross section of the masseter muscle at the corner of the lower jaw. Scanning the area starts at the height of the coronoid process of the mandible and continues downward

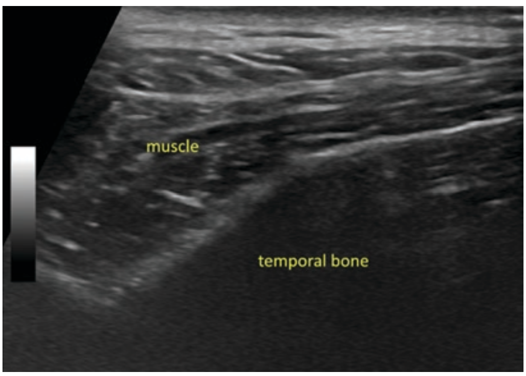


Fig. 10.7 Elongated cross section of the temporalis muscle above the zygomatic arch. The longitudinal, transverse, and vertical groups of muscle fibers are highlighted with proper positioning of the transducer and are depicted as linear or spotted/dotted sound reflections

upper surface rises from the infratemporal fossa. The lower section is larger and arises from the outer part of the pterygoid process of the sphenoid bone. The two sections proceed sagitally in the submandibular fossa, with a common tendon and lead to the pterygoid hamulus of the maxilla and the termporomandibular joint disc (Fig. 10.8).

10.4 Muscles of the Neck

One can readily distinguish the (a)anterior, (b) laterals, and (c) posterior or prevertebral.

The muscles that can be identified by ultrasonography are the mandibular digastor, geniohyoid muscle, sternocleiodomastoid muscle, and the platysma (Fig. 10.9).

The digastric muscle belongs to the anterolateral group of cervical muscles located above the hyoid bone. It shows two bellies the anterior and posterior which are connected by an intermediate tendon. The posterior section rises from the mastoid process of the temporal bone and passes to the interstitial tendon that pierces the stylohyoid muscle and connects to the body of the hyoid. The anterior belly starts from the medial tendon and rests in the digastric fossa of the mandible at the inner surface of the mandibular angle [2–7].

The maxillohyoid belongs to the group of anterior cervical muscles located above the hyoid bone. It is triangular in shape and joins with its insertion of a central suture with the opposite muscle, forming a kind of septum between the oral cavity and the cervix. It protrudes from the inner oblique line of the lower jaw and lodges in the body of the hyoid bone.

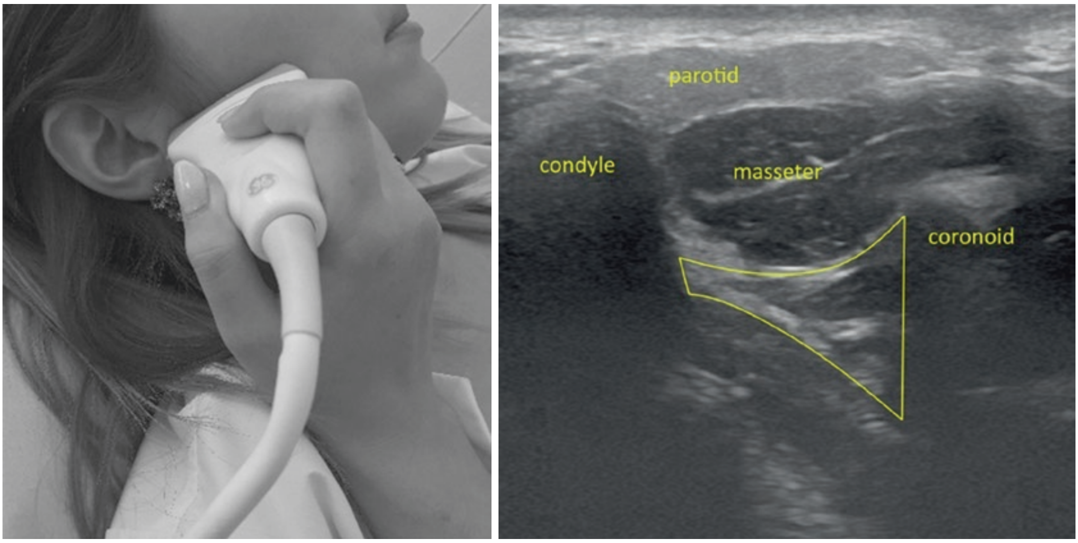


Fig. 10.8 The lateral pterygoid muscle (yellow frame) is shown in the cross-sections as a triangular formation interposed between the acoustic shadow of the coronoid process and the mandibular condyle

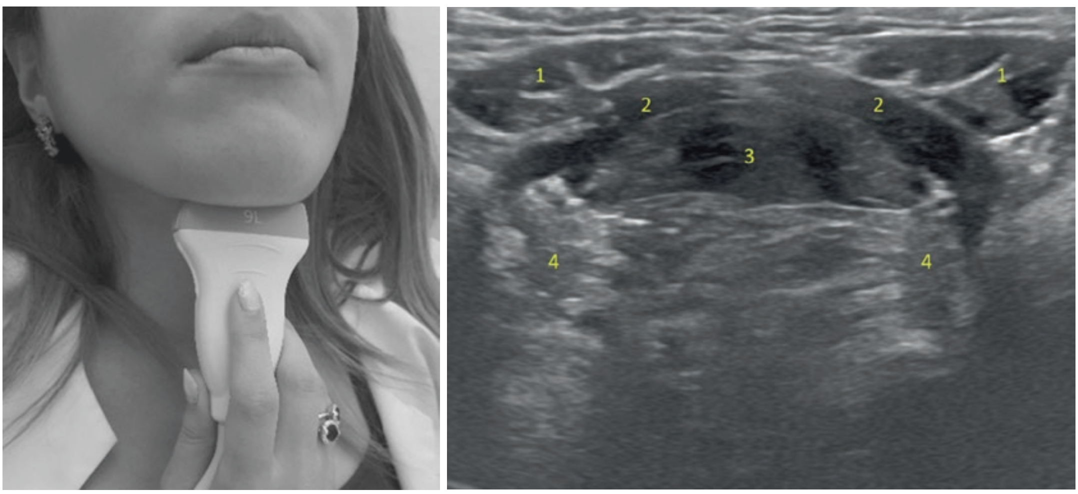


Fig. 10.9 Cross section by placing the transducer in the anterior part of the floor of the oral cavity (1) Digastric muscle, (2) Mylohyoid muscle, (3) geniohyoid muscle, (4) Sublingual salivary gland

Genoihyoid muscle lies above the previously mentioned muscle. It arises from the genial tubercle of the mandible and ends at the body of the hyoid bone.

The sternocleidomastoid muscle is responsible for the movements of the head. In abnormal contraction or shortening it causes differences in the skull shape. It is visible upon palpation in clinical examination. It consists of two sections, the sternal and the clavicular. They course obliquely upwards and outwards, they join in a common belly, which eventually rests on the mastoid process of the temporal bone (Fig. 10.10). Deep in the muscle is the angioneural bundle of the cervix and from its posterior rim emerge the dermal branches of the cervical plexus and the vagus nerve.

The platysma muscle is located in the subcutaneous fascia of the cervix, has a quadrilateral shape and a thin membrane morphologically. It

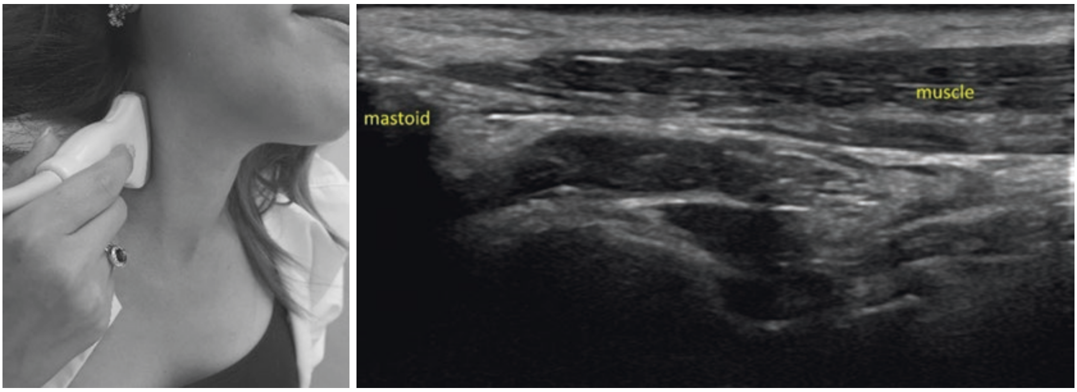


Fig. 10.10 Depiction of the linear morphology of the sternocleidomastoid muscle with superficial location

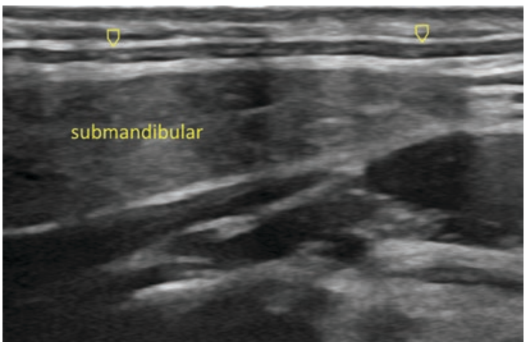


Fig. 10.11 The muscular platysma is relatively indistinguishable. It has the form of a hypoechoic wall on the anterior surface of the neck, below the subcutaneous fat (arrowheads)

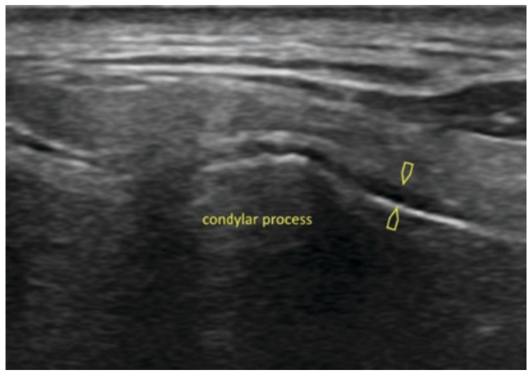


Fig. 10.12 Horizontal section. The normal synovial sac is depicted as a thin, subechoic edge at the neck of the mandibular condyle (arrowheads). In situations of increased amount of fluid the follicle swells and acquires the shape of a biconvex lens

protrudes from the upper part of the chest and penetrates the lower rim of the lower jaw and the skin of the lower lip of the face (Fig. 10.11).

10.4.1 Temporomandibular Joint

The temporomandibular joint is formed by the mandibular condyle and the articular eminence of the temporal bone. With the insertion of the articular disc, it is divided into two smaller structures, the upper and lower compartments or sections. In the non pathological temporomandibular joint the distance between the tubercle and the temporomandibular joint ranges from 1.5 mm to 2.5 mm and is even.

The articular capsule is extremely loose, allowing the lower jaw to move freely in all directions during chewing and speaking (Fig. 10.12). The most important ligaments that strengthen the joint are the outer lateral that surrounds the pocket from the outer surface and the inner mesial one, that covers the pocket from the inner surface.

The articular disc or meniscus is not static, but moves normally within the joint. When the mouth is closed, the mandibular condyle rests firmly on the posterior border of the disc. At the beginning of the contraction, it is displaced forward by the action of the lower part of the outer pterygoid muscle, moving at the same time the anterior lip of the disc on the articular ridge of the temporal bone (Fig. 10.13).

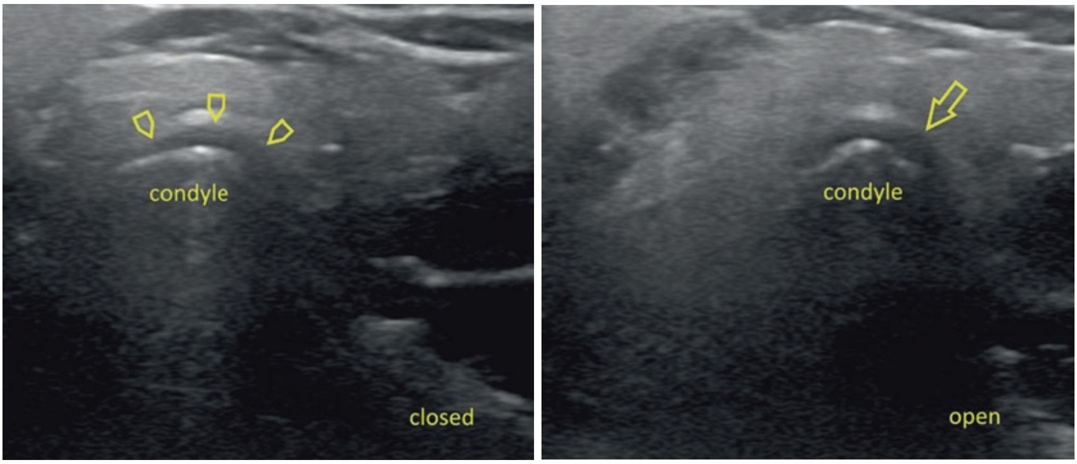


Fig. 10.13 Transverse sections of the disc in the preauricular region. With the mouth closed, the articular disc is recognized as a lunar formation of low echogenicity that touches the condyle of the lower jaw (arrowheads). With the mouth open there is a slight change in the position and thickness of the disc, more visible in the anterior section (arrow)

10.4.2 Tongue

The tongue is a muscular organ surrounded by mucosa and is used for speech, taste, chewing, and swallowing. It has a conical shape and shows three anatomical borders, the top, the body, and the root. Between the body and the root of the tongue there is a V-shaped groove, the apex of which corresponds to the blind foramen. This corresponds to the apex of a thin tube that extends down to another cervical level length and is the embryonic remnant of the thyroglossal canal.

Descriptively the tongue displays the upper and lower surface and the two lateral edges or borders or lips. On the lower surface there is a mucosal fold, the frenulum, which holds the tongue in the ground of the oral cavity. On either side of the base of the frenulum, the two sublingual salivary glands protrude, adjacent to the outlets of the submandibular gland and the major duct of the sublingual gland. From these tubercles rise the lunar folds of the mucosa, which have as a base the sublingual glands and on which the minor excretory pores flow.

The pharyngeal part of the dorsal surface of the tongue shows on the right and left side two appendages, the palatal tonsils that have as their base large lymph nodes and lymph follicles. Further down and backward, the lingual mucosa recovers on the anterior surface of the epiglottis forming elongated folds that enclose the lingual epiglottis.

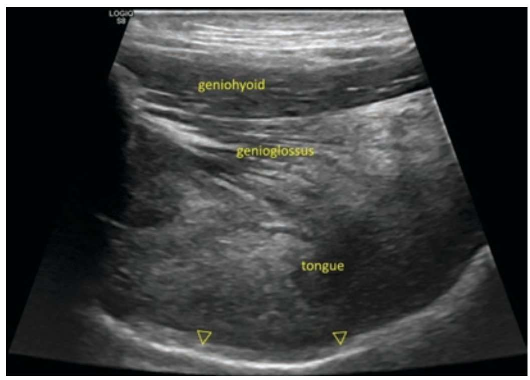


Fig. 10.14 Elongated section of the tongue in submandibular view. It is a compact instrument with a relatively homogeneous texture and intermediate echogenicity, surrounded by hypoechoic mucosa of increased thickness on the upper surface (arrowheads). The penetration depth of the ultrasound for the examination of the whole tongue should be set at 70 mm, with appropriate adjustments of frequency and degree of contrast

The muscles of the tongue are divided into heterogeneous and indigenous. They are lined and all ribbed by the 12th cranial nerve branch (sublingual nerve). The genioglossus muscle belongs to the group of intrinsic muscles of the tongue and is easily accessible during the ultrasound examination (Fig. 10.14).

10.4.3 Lymph Nodes

Normal lymph nodes are small kidney-shaped structures ranging from 0.1 up to 2.5 cm in size. They are surrounded by a thick connective tissue capsule. The parenchyma of the lymph nodes is distinguished in the cortical, subcortical, and medullary sections. A small opening in the middle of the glands creates an area rich in fibrous and fatty tissue designated as a portal. The medullary section surrounds the gate and is separated from the cortical section by insertion of the transitional zone of the subcortex. The blood supplying artery enters through the gate and the corresponding vein and the lymph nodes exit through it [10].

The lymph nodes are innervated by autonomic nervous system fibers and their innervation include in sections, the capsule, the inner diaphragms, and the smooth muscle of the blood vessels [8, 9].

They drain into the following groups.

Based on older and more recent literature data cervical lymph nodes are classified at least in six different anatomical levels (level I-VI) with different varying subclassifications aiming aid to the classification of pathology, surgical planning and better programming of the treatment head and neck cancer [10].

The major lymph node groups are classified according to their drainage and the major divisions are:

– Facial: skin and mucosa of the eyelids, the nose, the buccal area the temporal and subtemporal region and rinopharynx.
– Parotid: Skin of the temporal and frontal region. The maxilla, the buccal area, the external acoustic meatus and ear drum, the eyelids, and section of the nose (Fig. 10.15).
– Retroauricular: side section of the hairy part of the skin, the skin at the external acoustic meatus region and the external ear.
– Submental: Posterior section of the hairy part of the head.

Lymph nodes of the neck also drain the soft tissues of the region and the organs. In the upper section of the neck, the most important groups are as follows.

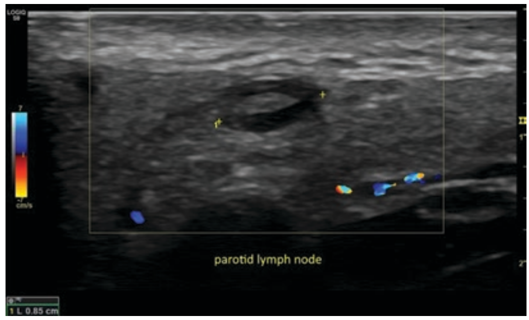


Fig. 10.15 Benign lymph node with donut morphology and elongated diameter <1 cm in the parenchyma of the parotid gland. In the parenchyma of the lymph nodes, the cortex is distinguished as a peripheral zone of low echogenicity and the hyperechoic marrow that is surrounded by the cortex and is located centrally

- Submental: Lower lip, tongue tip, gums, and anterior teeth (Fig. 10.16).
- Submandibular: Upper and lower lip, intraoral mucosa, tongue, mandible gums, and teeth (Fig. 10.17).
- Jugulodigastric: Lingual and pharyngeal tonsils, hard palate, sections of the tongue (Fig. 10.18).
- Deep cervical: Larynx, trachea, thyroid gland, parathyroid glands, and upper esophagus.
- Supraclavicular: Anterior thoracic wall, armpit region, shoulder, and upper limb.
- Superficial cervical lymph nodes on the surface of the sternocleidomastoid muscle, they drain the skin, and the superficial tissues.

10.4.4 Salivary Glands

The salivary glands produce the saliva that is necessary for the digestion of food in the oral cavity. They are divided into main and auxiliary. They consist of many small lobes, between which is inserted a thin connective tissue that forms the substrate of the pores. Individual lobes consist of glandular cells that erupt into the interstitial pores. The interstitial pores converge and form the large excretory pores that secrete saliva into the oral cavity.

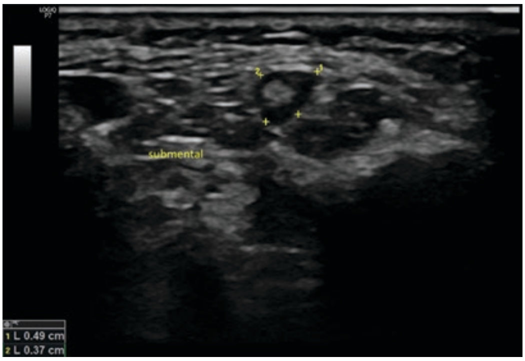


Fig. 10.16 Submental lymph nodes are smaller in size and often round in shape

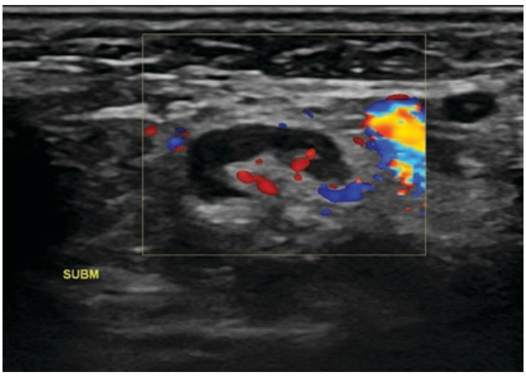


Fig. 10.17 Submandibular lymph node with color Doppler. In normal and reactive lymph nodes, the nutrient artery and the accompanying vein are depicted with small branches that are limited to the area of the hyperechoic portal and not beyond it

From the ultrasonographic point of view, the main salivary glands are:

(a) parotid,
(b) submandibular, and.
(c) sublingual gland.

and they should all be included in our imaging control.

10.4.5 The Parotid

(a) The parotid gland is the largest salivary gland weighing about 25 g. It is located in the retromandibular area and has the shape of a three-sided pyramid, with the top (or deep lobe) facing inwards into the pharynx and the base (or superficial lobe) facing outwards on the skin. In 20% of patients, an extra small lobe that often rests on the masseter muscle may coexist. The upper surface of the parotid gland comes in contact with the temporomandibular joint and the external auditory canal. The base of the parotid gland is covered by the skin and the muscular platysma (Fig. 10.19). The external carotid artery, the posterior facial vein, and the facial nerve pass through the parotid gland, with the former being located deeper than the latter (Fig. 10.20).

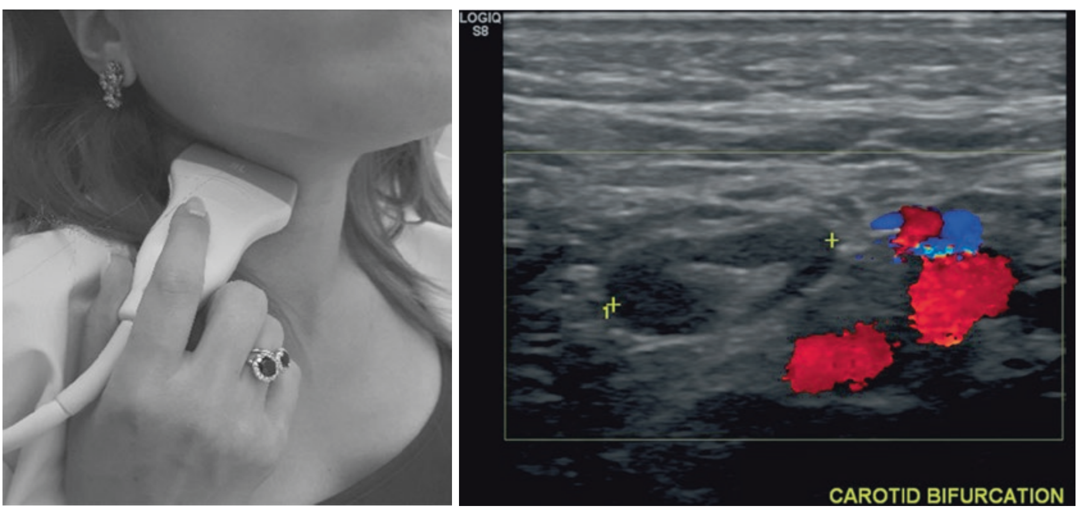


Fig. 10.18 Jugulodigastric lymph node above the carotid bifurcation. Characteristic location at the junction of the internal jugular vein with the posterior belly of the digastric muscle. Benign lymph nodes are bordered smoothly and move freely on ultrasound and palpation

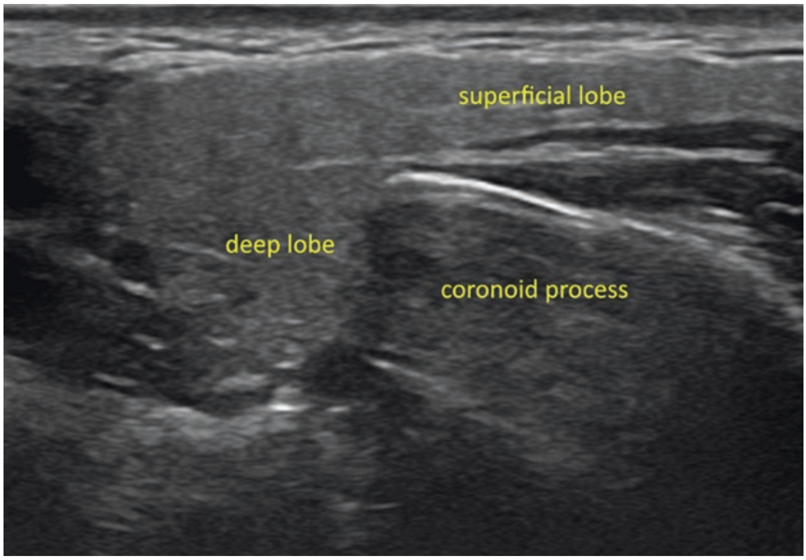


Fig. 10.19 Cross section of the parotid gland at the height of the coronoid process. The gland is homogeneous, with increased echogenicity and smooth margin

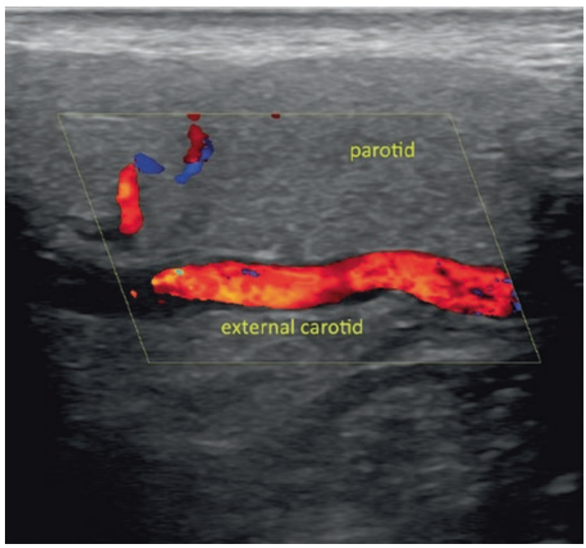



Fig. 10.20 Presence of a color signal in the intraparotid part of the external carotid artery during Doppler control. Each parotid should be evaluated for both transverse and sagittal scans

The Stensen secretory duct emerges from the upper part of the anterior rim of the base and travels forward onto the masseter muscle. After that, it pierces the buccinator muscle and the mucosa of the cheek, erupting into the pore opposite the second upper molar. Except in the case of dilation, it is not visible on the ultrasound examination (Fig. 10.21).

(b) The submandibular gland is the second largest salivary gland after the parotid gland. The superior exterior surface of the submandibular gland comes in relation to the homonymous cavity of the mandible. The lower-outer surface is covered by the skin, the muscular plate and the cervical fascia. The posterior end of the gland exhibits a groove through which the external maxillary artery travels and is separated from the parotid by the insertion of a fibrous band. The anterior part comes in direct contact with the anterior belly of the digastric muscle (Fig. 10.22).

Wharton's submandibular excretory pore starts from the middle of the inner surface of the submandibular gland and after passing between the maxillohyoid muscle and the sublingual salivary gland, it eventually flows to the top of the sublingual mucosa. As in the case of the parotid gland, the normal submandibular canal and endoparenchymal branches are subtle and usually do not show upon normal ultrasonographic examination (Figs. 10.23 and 10.24).

(c) The sublingual gland is the smallest of the salivary glands, is located below the sublingual fold, and comes in direct contact with the sublingual groove of the lower jaw. It has a flattened form, a major pore flowing into the sublingual mucosa, and many minor pores flowing into the free edge of the sublingual fold (Fig. 10.25).

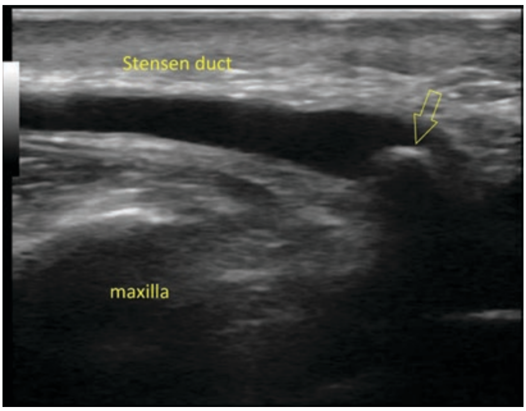


Fig. 10.21 Enlarged parotid duct with anechoic content due to obstruction of its final section by a calcified stone (arrow)

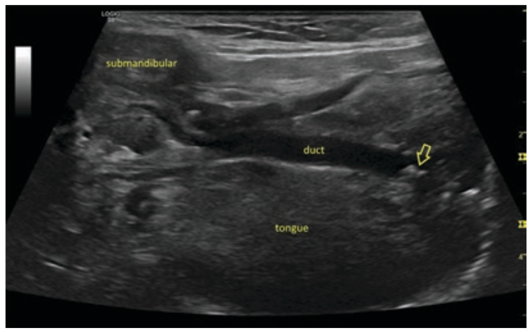


Fig. 10.23 Presence of a stone (arrow) in the sublingual area that causes stretching of the Wharton pore

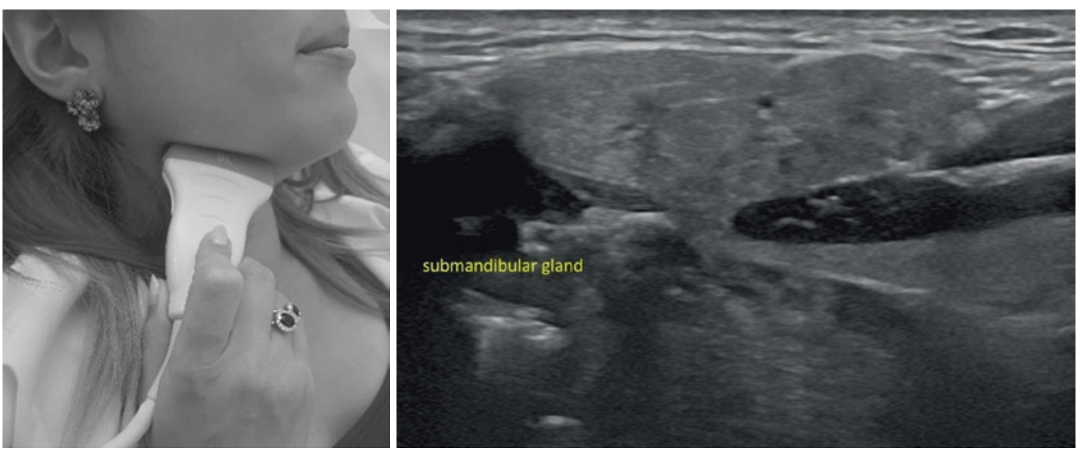


Fig. 10.22 The parenchyma of the submandibular gland is of medium echogenicity, with a relatively homogeneous texture and with a clear border

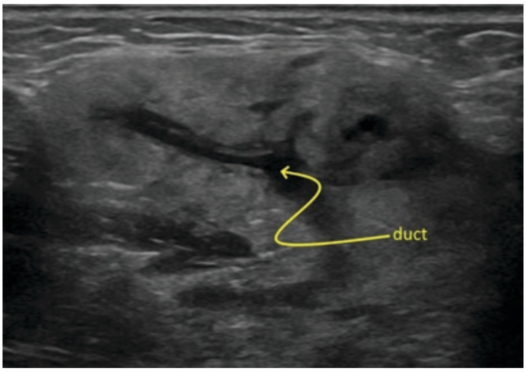


Fig. 10.24 Dilatation of the intermediate pores branches (arrow) in the case of sialadenitis

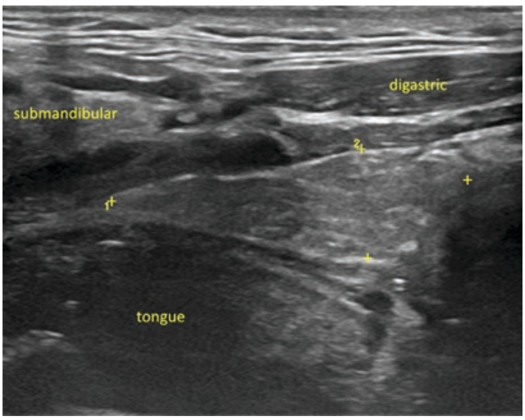


Fig. 10.25 Elongated transverse section of the sublingual gland by placing the transducer in front of the submandibular gland and parallel to the body of the mandible. Spindle morphology of the sublingual gland, in contact with the base of the tongue is observed

References

1. Standring S, editor. Gray's anatomy. 41st ed. London: Elsevier; 2016.
2. Moore KL, Dalley AF, Argus AMR. Clinically oriented anatomy. 7th ed. Philadelphia: Lippincott Williams & Wilkins; 2006.
3. Orhan K. Ultrasonography in maxillofacial diagnosis. Berlin: Springer; 2021.
4. Naqvi J, Yap KH, Ahmad G, Ghosh J. Transcranial Doppler ultrasound: a review of the physical principles and major applications in critical care. Int J Vasc Med. 2013;2013:629378.
5. Rasulo FA, De Peri E, Lavinio A. Transcranial Doppler ultrasonography in intensive care. Eur J Anaesthesiol Suppl. 2008;42:167–73.
6. Feigl G, Hammer GP, Litz R, Kachlik D. The inter carotid or alar fascia, other cervical fascias, and their adjacent spaces—a plea for clarification of cervical fascia and spaces terminology. J Anat. 2020;237:197.
7. Guidera AK, Dawes PJ, Fong A, Stringer MD. Head and neck fascia and compartments: no space for spaces. Head Neck. 2014;36:1058–68.
8. Kulzer MH, Branstetter BF 4th. Chapter 1 neck anatomy, imaging-based level nodal classification and impact of primary tumor site on patterns of nodal metastasis. Semin Ultrasound CT MR. 2017;38:454–65.
9. Som PM, Curtin HD, Mancuso AA. Imaging-based nodal classifcation for evaluation of neck metastatic adenopathy. AJR Am J Roentgenol. 2000;174:837–44.
10. Delantoni A, Sarafopoulos A. Sonographic anatomy and pathology: cervical lymph nodes in ultrasonography in dentomaxillofacial diagnostics. p. 77–87.