

Anatomy of the Trigeminal Nerve

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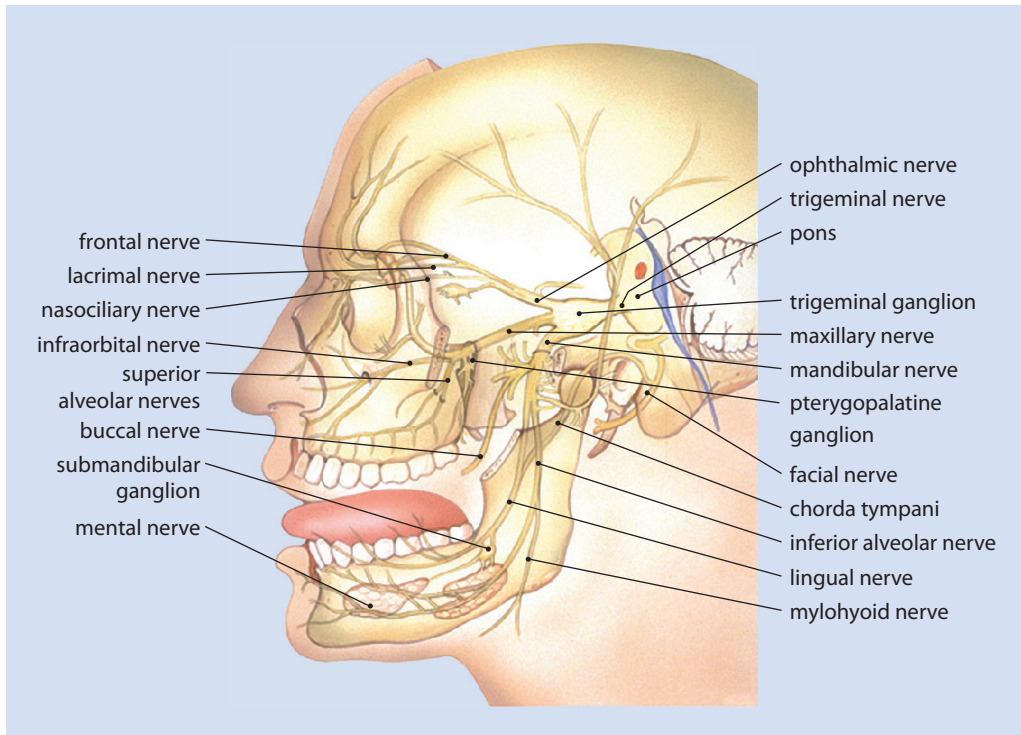
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The trigeminal nerve is the fifth cranial nerve (n. V), which plays an important role in the innervation of the head and neck area, together with other cranial and spinal nerves. Knowledge of the nerve's anatomy is very important for the correct application of local anaesthetics.

2.1 Introduction

The trigeminal nerve contains a large number of sensory (afferent) and motor (efferent) neurons. The sensory fibres carry nerve impulses towards the central nervous system, while the motor fibres carry impulses away from the central nervous system. The trigeminal nerve has a wide innervation area (■ Fig. 2.1). The nerve provides the sensitivity of the dentition, the mucosa of the mouth, nose and paranasal sinuses and the facial skin. The nerve also contains motor fibres that innervate, among others, the masticatory muscles. Although the trigeminal nerve is the most important nerve for the sensory and motor innervation of the oral system, the facial (n. VII), glossopharyngeal (n. IX), vagus (n. X) and hypoglossal (n. XII) nerves are also of significance. The n. VII, n. IX and n. X, for example, take care of the taste sense, and the n. IX and n. X provide the general sensation (pain, touch and temperature) of



■ Fig. 2.1 Overview of the trigeminal nerve (lateral view)

the pharynx, soft palate and the back of the tongue, while the n. XII is responsible for the motor innervation of the tongue. Although these latter nerves do play an important role in innervating the oral cavity, they will only be mentioned marginally in this book.

2.2 The Central Part of the Trigeminal Nerve

2.2.1 Origin

The trigeminal nerve emerges from the middle of the pons, at the lateral surface of the brainstem. The nerve consists of two parts here: the sensory fibres form a thick root and the motor fibres form the much thinner motor root. These two roots run to the front of the petrous part of the temporal bone where the large sensory trigeminal ganglion (semilunar or Gasserian ganglion) lies in a shallow groove surrounded by dura mater.

The trigeminal ganglion is formed by the aggregation of cell bodies of sensory neurons. After the ganglion, three branches of the trigeminal nerve can be distinguished: the ophthalmic nerve (n. V₁), the maxillary nerve (n. V₂) and the mandibular nerve (n. V₃). The motor root joins the mandibular nerve only, once it has exited the skull via the foramen ovale. The sensory areas covered by the three main branches are generally as follows:

- The ophthalmic nerve carries sensory information from the skin of the forehead, the upper eyelids and the nose ridge and the mucosa of the nasal septum and some paranasal sinuses.
- The maxillary nerve innervates the skin of the middle facial area, the side of the nose and the lower eyelids, the maxillary dentition, the mucosa of the upper lip, the palate, the nasal conchae and the maxillary sinus.
- The mandibular nerve innervates the skin of the lower facial area, the mandibular dentition, the mucosa of the lower lip, cheeks and floor of the mouth, part of the tongue and part of the external ear.

Of all the areas that the trigeminal nerve innervates, the oral cavity is the most enriched with sensory neurons. The density of sensory neurons in the mouth is much larger than in any other area, e.g. the facial skin. This density of sensory neurons increases from the back to the frontal area of the mouth.

Most of the trigeminal ganglion neurons are pseudo-unipolar. This means that each neuron in the ganglion has a peripheral and a central process. The peripheral process (axon) is relatively long and carries the impulses coming from sensory receptors (■ Box 2.1). The central process (dendrite) is short and enters the pons and synapses with the sensory trigeminal nucleus situated in the

Box 2.1 Receptors

Sensory nerves are capable of picking up impulses from the external world and the body. The ends of the fibres themselves function as receptors, or there are special receptors (e.g. taste receptors, muscle spindles). Each receptor type is the most sensitive to one specific sensation. There are, for example, mechanoreceptors (reacting to touch and mild pressure), thermoreceptors (reacting to temperature) and nociceptors (reacting to tissue damage). Nociceptors serve pain sensation. There are also so-called proprioceptors. These are mostly found in muscles (muscle spindles and Golgi tendon organs) and in the joint capsules. They supply information on the position of the jaw and the speed and direction of movement. This form of sensation is called proprioceptive sensibility or proprioception.

There are a great number of receptors present in the facial skin and lips, in the mucosa of the oral cavity and tongue, in the teeth and the periodontium and in the masticatory muscles and temporomandibular joint.

brainstem. The proprioceptive fibres in the trigeminal ganglion are an exception. Their cell bodies are not situated in this ganglion but in the mesencephalic nucleus of the trigeminal nerve. The proprioceptive fibres are found in the motor root of the trigeminal nerve and carry impulses from, among others, muscle spindles of the masticatory muscles.

The trigeminal ganglion has somatotopy. This means that the neurons in the ganglion are arranged in the same order as the areas that are innervated by the three main branches of the trigeminal nerve. The cell bodies of the ophthalmic nerve are grouped medially in the ganglion, while those of the mandibular nerve are grouped laterally. In the middle of these two groups, the cell bodies of the maxillary nerve can be found.

2.2.2 Trigeminal Nuclei

The trigeminal nerve has a sensory and motor nucleus within the brainstem (■ Fig. 2.2). The sensory nucleus lies laterally, and most of the sensory neurons of the trigeminal nerve contact (synapse) with the neurons in this nucleus. The nucleus forms a long column that extends from the midbrain to the spinal cord. It consists of (from cranial to caudal) the mesencephalic, the principal and the spinal trigeminal nuclei.

Proprioceptive information from, for example, the masticatory muscles is managed in the mesencephalic nucleus. The principal trigeminal nucleus mainly receives touch and pressure impulses from the entire oral area, whereas the spinal trigeminal nucleus

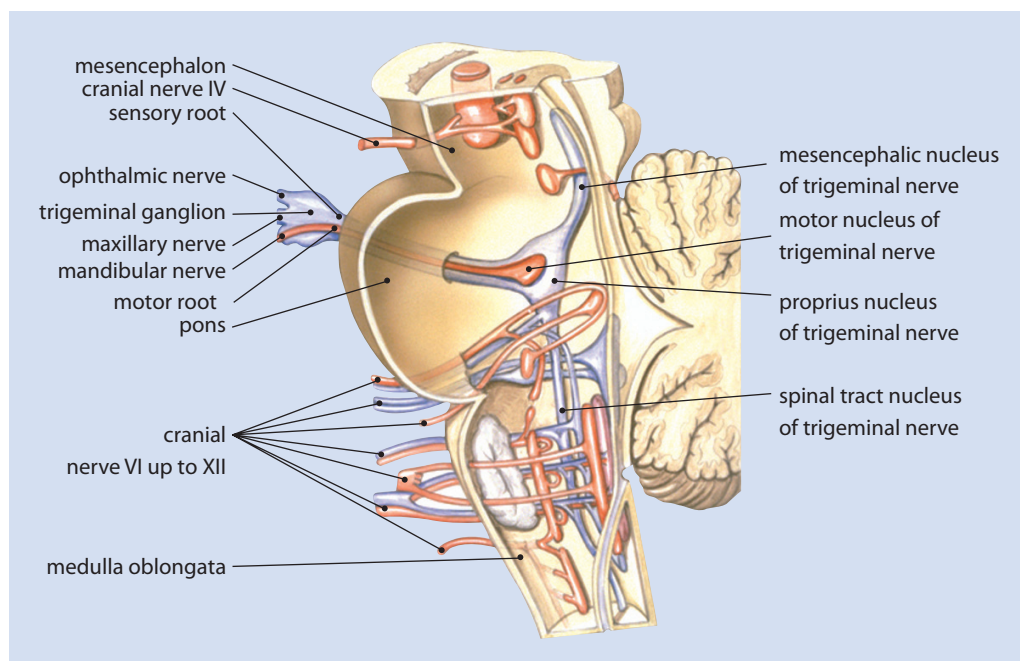
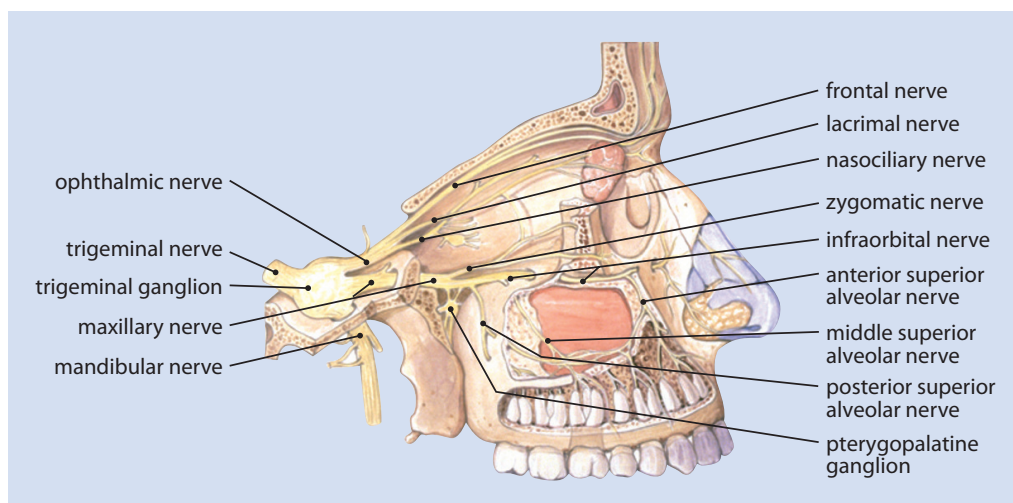


Fig. 2.2 The motor and sensory nuclei in the brainstem (medial view). The sensory nuclei are shown in *blue* and the motor nuclei in *red*

receives information on pain, temperature and pressure from the entire trigeminal area. All information received via the sensory trigeminal nuclei is managed and integrated in, among others, the thalamus via ascending paths. After this the information is brought to various areas of the cerebral cortex, where perception occurs.

The motor neurons of the trigeminal nerve are grouped in a motor nucleus that lies medially to the sensory nucleus in the centre of the pons. The axons of these motor neurons run to (among others) the masticatory muscles. As previously described, these axons pass the trigeminal ganglion as an independent bundle (motor root), without synapsing within it. Similar to the motor neurons in the spinal column, the motor neurons in the motor trigeminal nucleus are directly stimulated via the corticobulbar tract, originating from the contralateral cerebral cortex. Within the motor nucleus, there is a large amount of somatotopy, i.e. the motor neurons that innervate (parts of) the different muscles are grouped together. Via fibres coming from the sensory mesencephalic nucleus, the motor trigeminal nucleus receives proprioceptive information from the masticatory muscles, temporomandibular joint and periodontium.



■ Fig. 2.3 The branching of the ophthalmic and maxillary nerves (lateral view)

2.3 The Peripheral Part of the Trigeminal Nerve

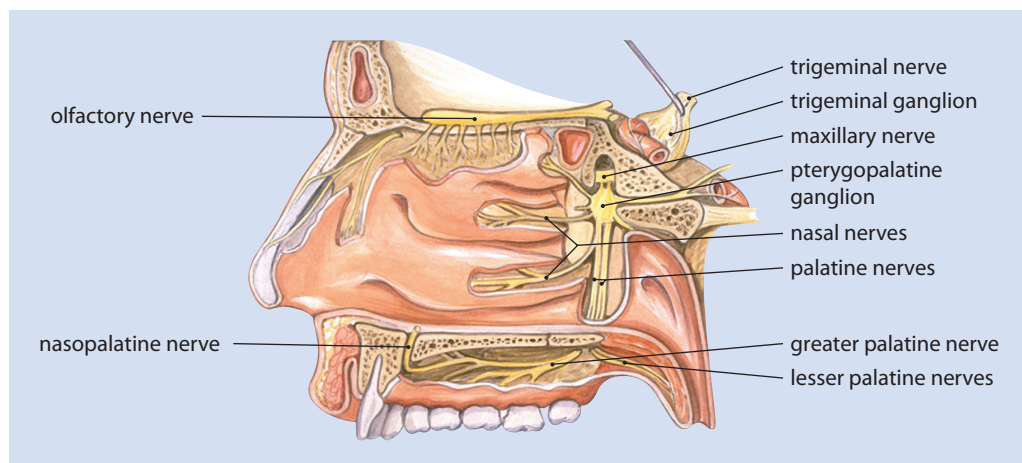
2.3.1 Ophthalmic Nerve

The ophthalmic nerve (n. V_1) enters the cranial part of the orbit (■ Fig. 2.3). This nerve carries only sensory fibres, and, just before leaving the cranial cavity through the superior orbital fissure, it branches off into three: the nasociliary, frontal and lacrimal nerves. These nerves run in the roof of the orbit and are involved in the sensory innervation of a large number of structures, such as the mucosa of the frontal, sphenoid and ethmoid sinus, the mucosa of the nasal cavity and nasal septum, the skin of the nose ridge, the upper eyelid and forehead till the hairline and the mucosa that covers the eyeball and inside of the eyelids.

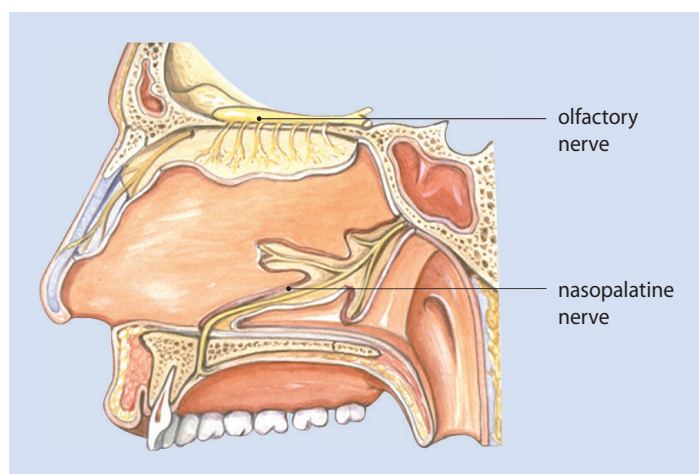
2.3.2 Maxillary Nerve

The maxillary nerve (n. V_2), too, is solely sensory. It enters the pterygopalatine fossa (► see Sect. 2.4.1) via the foramen rotundum (■ Fig. 2.3). Through the inferior orbital fissure, it reaches the floor of the orbit and proceeds there as the infraorbital nerve, first in the infraorbital sulcus and then in the infraorbital canal. It then reaches the face via the infraorbital foramen.

Within the pterygopalatine fossa, the maxillary nerve is connected via a number of branches to the upper side of the parasympathetic pterygopalatine ganglion. Sensory fibres run through these branches which exit on the lower side of the



■ Fig. 2.4 The maxillary nerve (medial view)



■ Fig. 2.5 The path of the nasopalatine nerve along the nasal septum

ganglion (■ Figs. 2.4 and 2.5) and form, among others, the following nerves:

- The nasal nerves and nasopalatine nerve that run through the sphenopalatine foramen to the nasal mucosa. The nasal nerves innervate the back part of the nasal mucosa. The nasopalatine nerve, which runs forwards along the nasal septum and reaches the oral cavity through the incisive canal, innervates the mucosa and bone of the nasal septum, frontal two-thirds of the palate and the palatal gingiva of the maxillary teeth.
- The greater palatine nerve that runs via the greater palatine canal to the mucosa of the hard palate where it subsequently innervates the palatal gingiva of the maxillary alveolar process and the pulp of the palatal first molar and premolar.

- The lesser palatine nerves that run to the mucosa of the soft palate via the lesser palatine canals.

Together with the palatine nerves, there are also parasympathetic and orthosympathetic fibres that run from the pterygopalatine ganglion to the salivary glands in the palatal mucosa.

In the pterygopalatine fossa, the maxillary nerve also branches into the posterior superior alveolar nerve and the zygomatic nerve (■ Fig. 2.3). The posterior superior alveolar nerve exits the pterygopalatine fossa through the pterygomaxillary fissure and runs over the maxillary tuberosity. The nerve divides into a large number of little branches, the posterior superior alveolar rami, which enter the wall of the maxilla through small openings and innervate the maxillary molars and corresponding buccal gingiva. The zygomatic nerve arrives in the orbit via the inferior orbital fissure and branches into the zygomaticotemporal and zygomaticofacial nerves. These exit the lateral orbital wall through small canals in the zygomatic bone and innervate the skin above. The zygomatic nerve also contains postganglionic parasympathetic fibres that come from the pterygopalatine ganglion and that join the lacrimal nerve (branch of n. V_1) for the lacrimal gland.

As it runs along the orbital floor, the infraorbital nerve branches in two: the middle superior alveolar nerve, for the innervation of the maxillary premolars and the corresponding buccal gingiva, and the anterior superior alveolar nerve, for the maxillary canine and incisors and the corresponding buccal gingiva. These nerves usually run between the mucosa and outer wall of the maxillary sinus. There they divide into a number of small branches, the medial and anterior superior alveolar rami that penetrate into the maxillary alveolar process via small openings. Inside the bone, they form together with the posterior superior alveolar rami, right above the apices, an extensive nervous network – the superior alveolar plexus – from which short little branches are sent to the dentition and gingiva.

Once the infraorbital nerve reaches the face via the infraorbital foramen, it splits into a large number of branches for the sensory innervation of the skin of the lower eyelid (palpebral rami), the infraorbital region, the side of the nose (nasal rami) and the skin and mucosa of the upper lip (labial rami).

2.3.3 Mandibular Nerve

The mandibular nerve (n. V_3) contains both sensory and motor fibres. This nerve exits the skull through the foramen ovale and ends in the infratemporal fossa (► see Sect. 2.4.2; ■ Fig. 2.6). The mandibular nerve is located just below this foramen between the

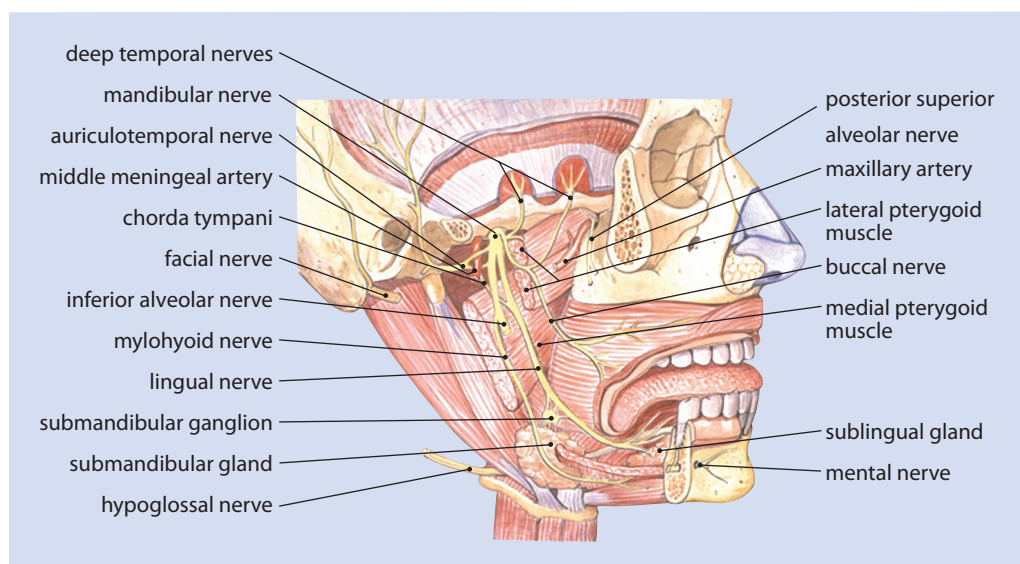


Fig. 2.6 The mandibular nerve (lateral view)

lateral pterygoid muscle and the tensor veli palatini muscle. The nerve sends a motor branch to the latter muscle.

The mandibular nerve splits into two main branches, the anterior and posterior trunks. From the anterior trunk, a sensory nerve emerges, the buccal nerve, and a number of motor nerves, i.e. the pterygoid nerves, the deep temporal nerves and the masseteric nerve. Three branches emerge from the posterior trunk: the auriculotemporal nerve (sensory), the lingual nerve (sensory) and the inferior alveolar nerve (mixed sensory and motor).

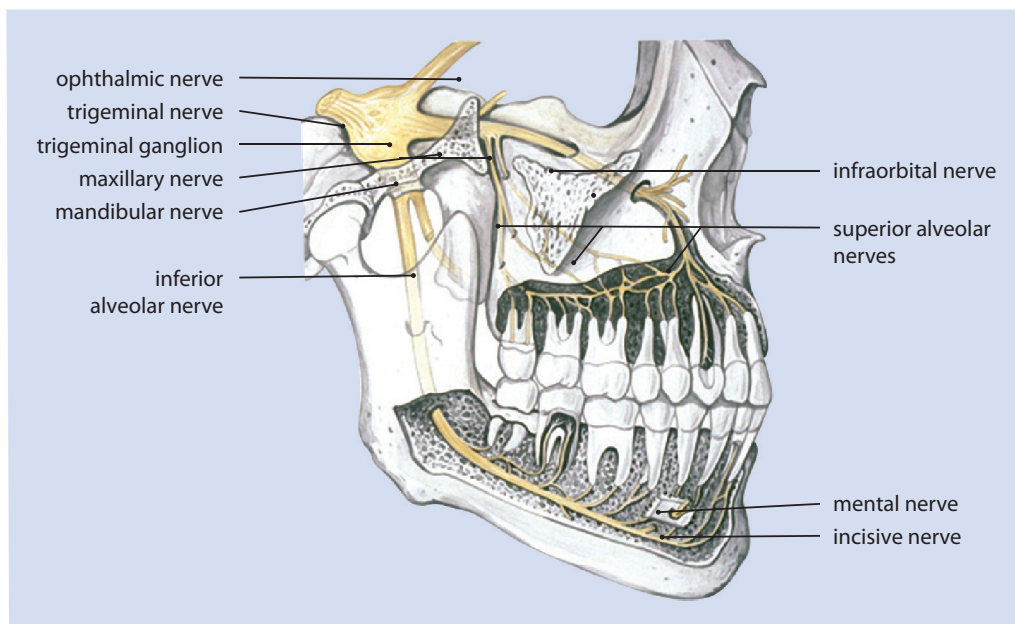
The buccal nerve runs along the medial surface of the upper head of the lateral pterygoid muscle and moves laterally between the two heads of the muscle. The nerve contains postganglionic parasympathetic fibres, coming from the otic ganglion, for the salivary glands in the buccal mucosa. The nerve innervates the skin and mucosa of the cheek and the buccal gingiva of the mandibular alveolar process at the level of the molars and premolars. The course of the nerve on the anterior side of the ramus shows a great variation.

The pterygoid nerves are short motor branches for the medial and lateral pterygoid muscles. The masseteric nerve runs laterally along the top of the upper head of the lateral pterygoid muscle and reaches the deep surface of the masseter muscle via the mandibular notch. The deep temporal nerves also run high along the lateral pterygoid muscle and penetrate the medial side of the temporal muscle.

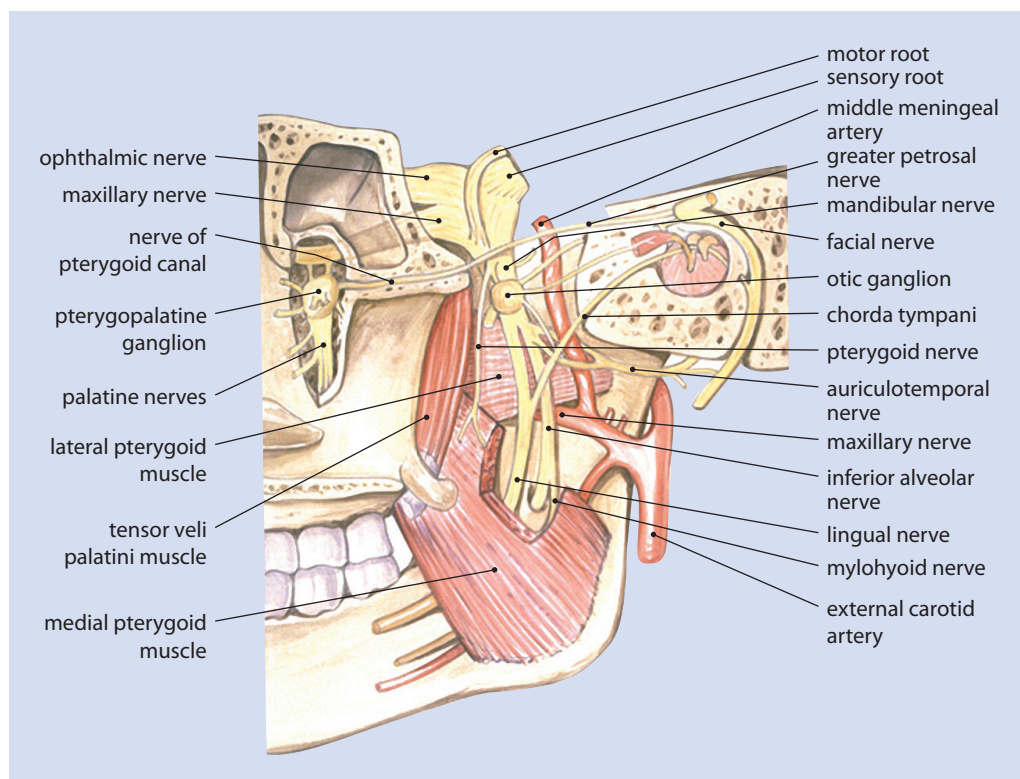
The auriculotemporal nerve arises as two roots encircling the middle meningeal artery. After the roots have merged to a single nerve, this nerve first runs laterally behind the mandibular neck

and then bends upwards in front of the ear. It is involved in the sensory innervation of the temporomandibular joint and the skin of the temporal and auricle region. The nerve also contains postganglionic parasympathetic fibres for the parotid gland from the otic ganglion. This parasympathetic ganglion lies between the mandibular nerve and the tensor veli palatini.

At its origin, the inferior alveolar nerve contains motor and sensory fibres. It runs deep to the lateral pterygoid muscle. Emerging from beneath this muscle, it directs to the mandibular foramen. Just before it enters the mandibular canal, it gives off its motor mylohyoid branch for the mylohyoid muscle and for the anterior belly of the digastric muscle. Inside the mandibular canal, the inferior alveolar nerve contains only sensory fibres. Here, under the apices, a network is formed, the inferior alveolar plexus, from which little branches are sent to the dentition and gingiva of the inferior alveolar process (■ Fig. 2.7). Anteriorly, the inferior alveolar nerve gives off the mental nerve. This emerges from the mental foramen, located between and just below the apices of P_1 and P_{2inf} and innervates the skin of the chin, the skin and mucosa of the lower lip and the buccal gingiva of the inferior alveolar process at the level of the canine and incisors. The last stretch of the inferior alveolar nerve inside the mandibular canal that runs in the direction of the symphysis is not located in a canal. This part of the inferior alveolar nerve is usually named as a separate nerve, the incisive nerve.



■ Fig. 2.7 The innervation of the dentition by the superior alveolar nerves and the inferior alveolar nerve

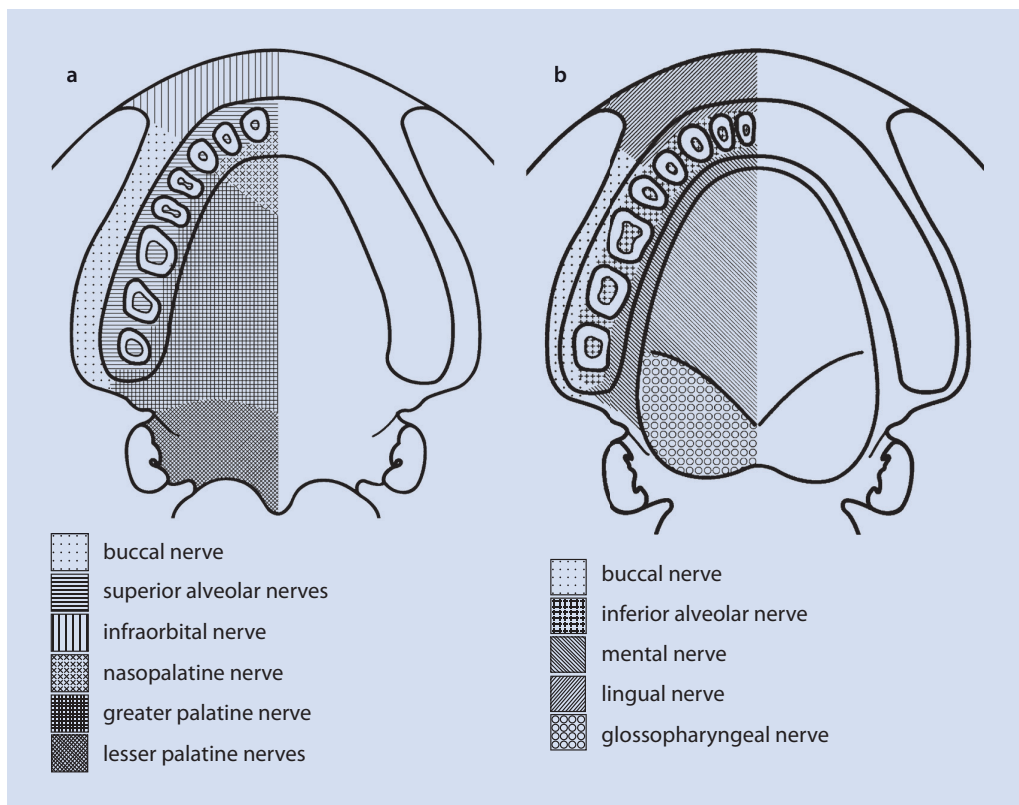


■ Fig. 2.8 The mandibular nerve (medial view)

Box 2.2 Innervation of the Tongue

Various nerves are involved in the sensory and motor innervation of the tongue. The general sensitivity (pain, touch, temperature) of the anterior two-thirds of the tongue is supplied by the lingual nerve (branch of the n. V₃). The specific sensitivity (taste) of the anterior two-thirds is supplied by the chorda tympani (branch of the n. VII) that has joined with the lingual nerve. The sensitivity, general and specific, of the posterior third of the tongue is supplied by the glossopharyngeal nerve (n. IX). The motor innervation of the tongue takes place through the hypoglossal nerve (n. XII).

The lingual nerve is joined, directly after its separation of n. V₃, by the chorda tympani (■ Fig. 2.8). This is a branch of the facial nerve with preganglionic parasympathetic fibres from the brainstem and sensory nerves for the taste of the anterior two-thirds of the tongue (■ Box 2.2). The lingual nerve runs deep to the lateral pterygoid muscle and forwards over the lateral surface of the medial pterygoid muscle. At the level of the apices of the third mandibular molar, it lies immediately beneath the mucosa



■ **Fig. 2.9** The sensory innervation of the oral cavity. **a** The palate, the superior alveolar process, the cheek and the upper lip. **b** The tongue, the inferior alveolar process, the cheek and the lower lip

against the inner side of the mandible. It continues superiorly to the mylohyoid muscle, passing under the submandibular duct, and then ascends in the tongue. The section of the lingual nerve that comes from n. V_3 supplies the general sensitivity (pain, touch, temperature) of the anterior two-thirds of the tongue, the mucosa of the floor of the mouth and the lingual gingiva of the inferior alveolar process. The submandibular parasympathetic ganglion is closely related to the lingual nerve. This ganglion is connected by a number of small branches to the underside of the nerve. Preganglionic parasympathetic fibres from the chorda tympani reach the ganglion via these branches. The postganglionic parasympathetic fibres run to the submandibular and sublingual glands.

A schematic summary of the sensory innervation of the oral cavity with the areas supplied by the various branches of the maxillary and mandibular nerves is given in ■ Fig. 2.9.

2.4 Deep Areas

The pterygopalatine fossa and the infratemporal fossa (including the pterygomandibular space) are deep areas in the head that are of great significance for block anaesthesia of (branches of) the maxillary and mandibular nerves, respectively.

2.4.1 Pterygopalatine Fossa

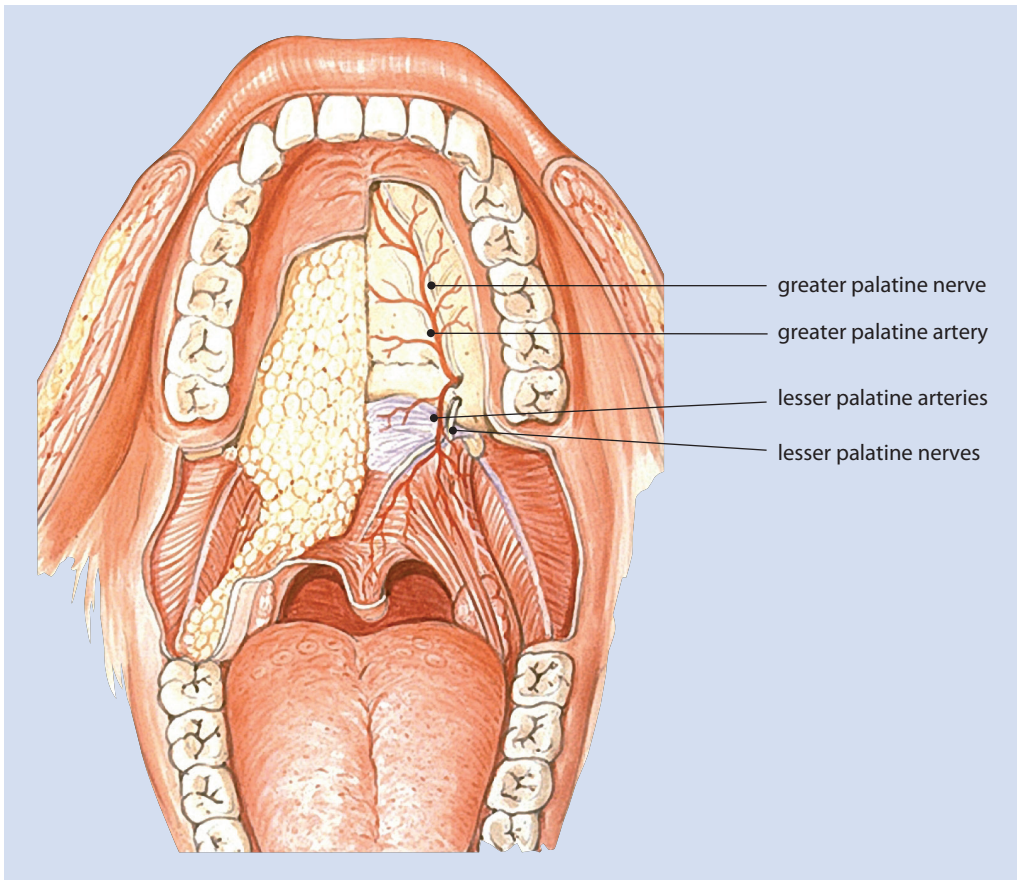
The pterygopalatine fossa is a small pyramid-shaped space that lies medially to the infratemporal fossa. The tip of the pyramid is directed downwards. The fossa is found behind the orbit and the maxillary tuberosity and also lateral to the posterior part of the nasal cavity. The posterior wall is formed by the pterygoid process of the sphenoid bone, the medial wall by the perpendicular plate of the palatine bone and the anterior wall by the maxillary tuberosity.

The pterygopalatine fossa has a large number of openings and forms an important junction for blood vessels and nerves. In the top of the fossa, the cranial cavity can be accessed posteriorly via the foramen rotundum, and it is connected anteriorly via the medial part of the inferior orbital fissure to the orbit. Laterally the infratemporal fossa can be reached via the triangular pterygomaxillary fissure. Medially the sphenopalatine foramen forms the connection with the nasal cavity. The downward-directed tip of the fossa runs narrowly to the greater palatine canals, thus reaching the palate.

The maxillary artery reaches the pterygopalatine fossa through the pterygomaxillary fissure. Within the fossa, the artery gives off various branches:

- The posterior superior alveolar artery and the infraorbital artery that run alongside the veins and nerves of the same name.
- The descending palatine artery that runs downwards through the greater palatine canal and splits into the greater palatine artery and the lesser palatine arteries. The greater palatine artery runs forwards over the hard palate, whereas the lesser palatine arteries serve the soft palate (■ Fig. 2.10).
- The sphenopalatine artery that runs through the sphenopalatine foramen to the mucosa of the nasal cavity.

Veins, which drain regions supplied by these arteries, connect with the pterygoid plexus. This area can be approached by an injection dorsolateral of the M_{2sup} with the needle point directed medially. Aspiration is essential.



■ Fig. 2.10 The palate from below

As mentioned previously, the maxillary nerve enters the pterygopalatine fossa via the foramen rotundum. The nerve runs forwards along the top side of the fossa and enters the orbit via the inferior orbital fissure. From this point, the nerve is called the infraorbital nerve. In the fossa, the maxillary nerve gives off the posterior superior alveolar nerve that leaves the fossa through the pterygomaxillary fissure and uses the surface of the maxillary tuberosity to reach the maxillary molars. Immediately beneath the maxillary nerve lies the pterygopalatine ganglion, which serves the parasympathetic innervation of, among others, the lacrimal gland, salivary glands of the palate and mucous glands in the nasal cavity, using the various branches of the maxillary nerve. The orthosympathetic innervation of these structures originates from the superior cervical ganglion which branches into a network around the arteries of the head region. The maxillary nerve also branches off caudally in the greater and lesser palatine nerves for the sensory innervation of the hard and soft palate,

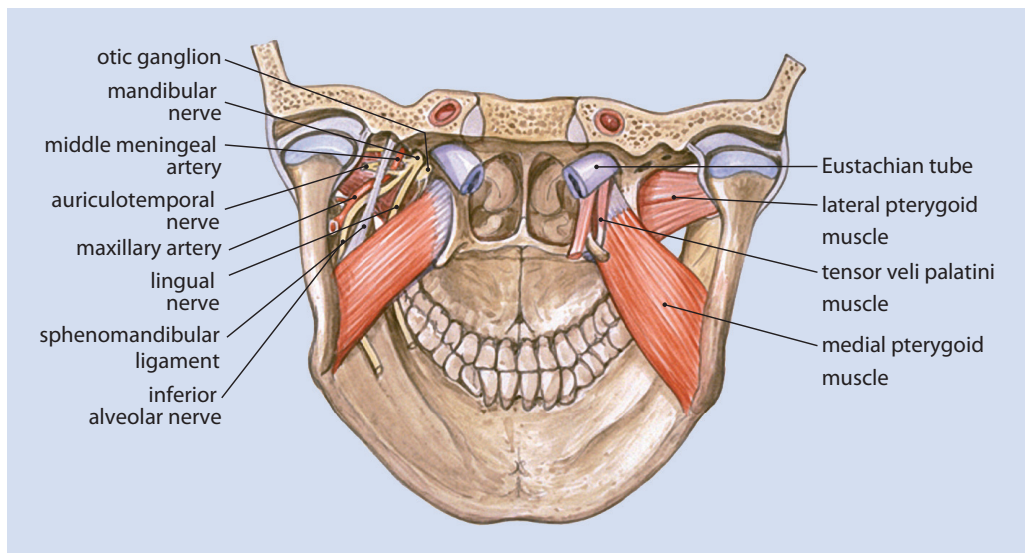
respectively; they leave the pterygopalatine fossa via the greater palatine foramen and the lesser palatine foramina. Ventrally and medially, the maxillary nerve branches off into the nasopalatine nerve, for the innervation of the nasal cavity via the sphenopalatine foramen. This nerve eventually also reaches the anterior part of the palate via the nasal septum and the incisive canal.

2.4.2 Infratemporal Fossa and Pterygomandibular Space

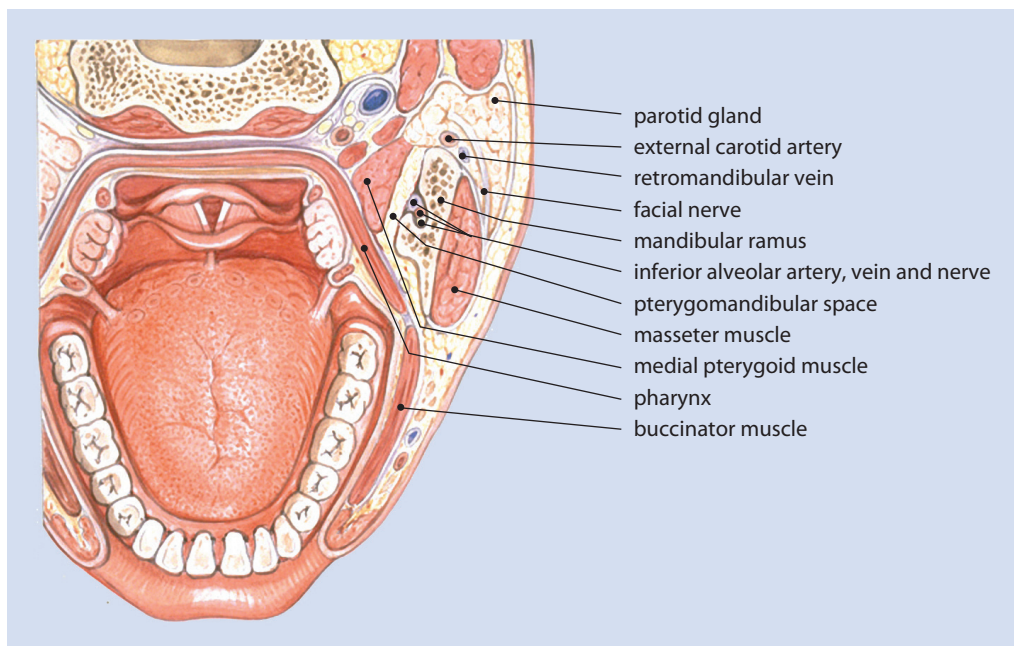
The infratemporal fossa is an area on the inner side of the zygomatic arch and the mandibular ramus. The other bony boundaries of the fossa are the greater wing of the sphenoid bone on the upper side, the maxillary tuberosity on the anterior side and the lateral plate of the pterygoid process (sphenoid bone) on the medial side. The pharynx wall provides a soft tissue boundary, medially and ventrally.

On the posterior side, the infratemporal fossa changes, without a clear border, into the parapharyngeal and retropharyngeal space. Medially the fossa provides access to the pterygopalatine fossa via the pterygomaxillary fissure. The fossa is connected via the foramen ovale and the foramen spinosum to the cranial cavity, and via the lateral part of the inferior orbital fissure, it is connected to the orbit.

The lateral pterygoid muscle and the medial pterygoid muscle are situated within this fossa (■ Fig. 2.11). Besides these muscles, the infratemporal fossa is filled to a large extent by a fat body that



■ Fig. 2.11 The infratemporal fossa viewed from behind

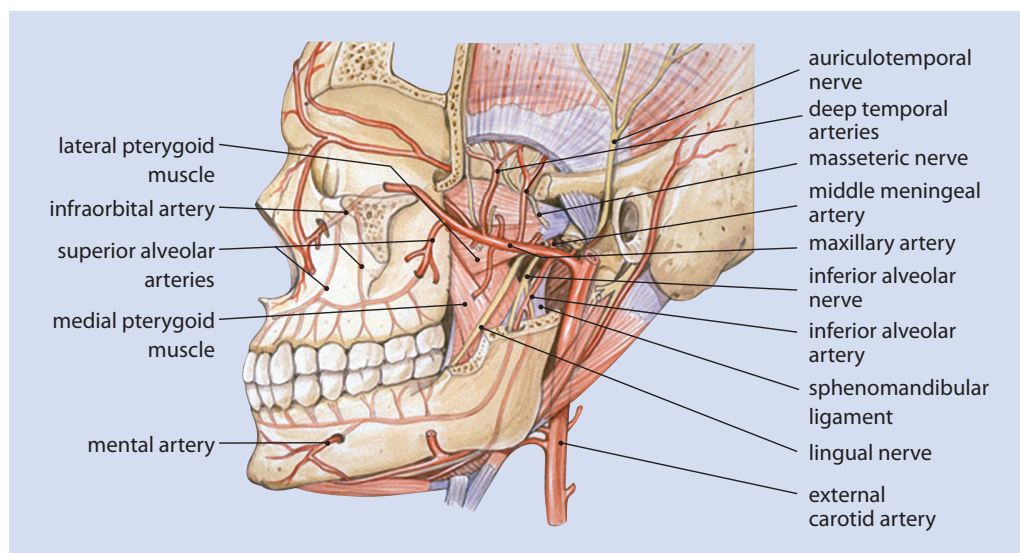


■ Fig. 2.12 Horizontal cross-section of the oral cavity and of the pterygomandibular space

is an extenuation of the buccal fat pad (of Bichat). Blood vessels and nerves are embedded within this fat, i.e. the maxillary artery, the pterygoid venous plexus and branches of the mandibular nerve.

The lateral and medial pterygoid muscles, together with the mandibular ramus, border a separate space within the infratemporal fossa, the so-called pterygomandibular space. In a frontal cross-section, the pterygomandibular space is triangular in shape (resembling a paper cornet), enclosed medially by the medial pterygoid muscle, cranially by the lateral pterygoid muscle and laterally by the mandibular ramus. The space is bordered ventrally by the pharynx wall and dorsally by the deep section of the parotid gland (■ Fig. 2.12). The space merges into the submandibular space ventro-caudally, and more medially and caudo-cranially, it merges into the parapharyngeal and retropharyngeal spaces, which eventually convert into the mediastinum and the pericard.

The most important artery in the infratemporal fossa is the maxillary artery (■ Fig. 2.13). This artery supplies blood to the nasal cavity, the palate, the maxilla and mandible and the masticatory muscles. The artery enters the fossa between the mandibular neck and the sphenomandibular ligament. It subsequently runs to the lower margin of the lateral pterygoid muscle and continues medially or laterally from this muscle to the pterygopalatine fossa. Besides



■ **Fig. 2.13** The maxillary artery (lateral view)

giving off a large number of branches to masticatory muscles (masseteric artery, deep temporal arteries, pterygoid arteries), the maxillary artery also branches off, among others, the middle meningeal artery, which reaches the cranial cavity via the foramen spinosum, and the inferior alveolar artery. The latter nerve enters, together with the inferior alveolar vein and nerve, the mandibular canal via the mandibular foramen and supplies blood to the lower jaw. The mental artery, which branches off from the inferior alveolar artery at the end of the mandibular canal, exits with the mental vein and nerve through the mental foramen and supplies blood to the chin and lower lip. Within the infratemporal fossa, the veins continue to follow the path of the arteries. These veins lead into the extensive pterygoid venous plexus, which lies laterally of the lateral pterygoid muscle. The pterygoid plexus connects posteriorly, via the short maxillary vein, with the retromandibular vein and anteriorly with the facial vein.

The mandibular nerve reaches the infratemporal fossa via the foramen ovale. The parasympathetic otic ganglion, which innervates, among others, the parotid gland and the salivary glands in the cheek, lies directly under the foramen ovale, on the medial side of the nerve. This nerve initially runs between the medial side of the lateral pterygoid muscle and the medial pterygoid muscle and gives off motor branches here for the innervation of the lateral and medial pterygoid muscles (pterygoid nerves), the temporalis muscle (deep temporal nerves), the masseter muscle (masseteric nerve) and the tensor tympani and tensor veli palatini muscles. Sensory branches are the buccal, lingual, inferior alveolar and auriculotemporal nerves. The buccal

nerve runs laterally between the two heads of the lateral pterygoid muscle and then continues to the cheek. This nerve also contains parasympathetic fibres for the innervation of the salivary glands. The auriculotemporal nerve initially consists of two roots, which pass around the medial meningeal artery. The auriculotemporal nerve runs in a dorsolateral direction to the mandibular neck, continues behind it and innervates, among others, the temporomandibular joint, the skin behind this joint and the skin in front of the ear. This nerve also contains parasympathetic fibres for the parotid gland, which originate from the otic ganglion. The two largest branches of the mandibular nerve are the inferior alveolar nerve and the lingual nerve. These two nerves initially run medially from the lateral pterygoid muscle. On the medial side of this muscle, the chorda tympani also joins the lingual nerve. The two nerves enter the pterygomandibular space at the lower margin of the lateral pterygoid muscle.

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