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Autonomic and sensory innervation of cat molar gland and blood vessels in the lower lip, gingiva and cheek

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Abstract

Innervation of the molar gland and blood vessels in the lower lip, gingiva and cheek mucous membrane was investigated in the cat with the aid of whole mount acetylthiocholinesterase (WATChE) histochemistry and retrograde neuronal tracing methods with horseradish peroxidase (HRP) and HRP-conjugated wheat germ agglutinin (WGA-HRP). The molar gland was found to be supplied from the buccal nerve and branches of the mylohyoid nerve on the basis of microdissection of WATChE-stained mandibular preparations under a dissecting microscope. The rostral half of the lower lip-gingiva was innervated by mental branches from the inferior alveolar nerve. The caudal half of the lower lip-gingiva and cheek mucous membrane were observed to be supplied from the buccal nerve. Following injections of HRP/WGA–HRP into the molar gland, lower lip-gingiva and cheek, many retrogradely labeled ganglion neurons were observed in the ipsilateral main and accessory otic ganglia, superior cervical ganglion and mandibular division of the trigeminal ganglion. In the pterygopalatine ganglion, a small number of positive neurons were found, but in a few cases in which the injected tracer was restricted to the lower lip-gingiva and anterior half of the molar gland, labeled neurons were not detected in the main ganglion nor in its accessory microganglia. These findings indicate that the cat molar gland receives a postganglionic parasympathetic supply from the otic ganglia, postganglionic sympathetic input from the superior cervical ganglion and sensory innervation from the trigeminal ganglion by way of the buccal nerve and mylohyoid nerve. Vessels in the rostral half of the lower lip-gingiva receive the same inputs from the inferior alveolar nerve, and vessels in the caudal half receive inputs from the buccal nerve. The vessels in the cheek mucous membrane receive dual parasympathetic supplies from the otic ganglia and the pterygopalatine ganglion by way of the buccal nerve.

Keywords: Parasympathetic outflow; Blood flow; Otic ganglion; Pterygopalatine ganglion; Circulation; Trigeminal ganglion; Sympathetic ganglion; Ganglia

1. Introduction

It has been reported that stimulation of the trigeminal ganglion or nerve could elicit at least three different vasodilatation responses simultaneously: parasympathetic (Gonzalez et al., 1975), antidromic (Lundblad et al., 1982; Couture and Cuello, 1984; Izumi and Karita, 1991) and reflex vasodilatation (Lambert et al., 1984). Parasympathetic innervation of blood vessels in the mandibular area has been partially investigated by several researchers (Izumi and Karita, 1991, Izumi and Karita, 1992, Izumi and Karita, 1993; Kuchiiwa et al., 1992, Kaji et al., 1991). Izumi and Karita (1991) reported that intracranial electrical stimulation of the facial or glossopharyngeal nerve caused blood flow to increase in the rostral portion of the cat lower lip-gingiva. (In the cat, there were no sharp boundaries between the lip and gingiva except in the vibrissal portion.) We examined the origin of the postganglionic parasympathetic fibers supplying the blood vessels in the rostral portion of the lower lip-gingiva on the basis of a retrograde axonal tracing method by injection of a tracer into the portion in which we had observed facial or glossopharyngeal nerve stimulation-induced vasodilatation (Kuchiiwa et al., 1992). In this experiment, retrogradely labeled neurons were observed in the otic ganglion but not in the pterygopalatine ganglion. These findings raise the possibility that both facial and glossopharyngeal preganglionic vasodilator fibers are mediated in the otic ganglion. Since the vasodilator response was abolished by sectioning of the inferior alveolar nerve, it is considered that the

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vasodilator fibers pass to the lower lip-gingiva by way of the inferior alveolar nerve (Izumi and Karita, 1993). As will be shown below, the inferior alveolar nerve emerges through the mental foramina and distributes to the rostral half of the lower lip-gingiva, but not the caudal half. The origin and pathway of innervation of blood vessels in the whole lip-gingiva region are not yet fully understood. The nerve supply to the blood vessels in the cheek mucous membrane is also unknown.

It has long been known that parasympathetic fibers originating in the otic ganglion innervate the parotid gland, and those originating in the submandibular ganglion supply the submandibular and sublingual glands (see Sicher, 1965; Gabella, 1976). Besides these main salivary glands, many other microscopic salivary glands exist in man: some in the tongue, others around and in the palatine tonsil between its crypts, with large numbers in the soft palate, posterior part of the hard palate, the lips and cheeks (Bannister, 1995). In the cat, in addition to the microscopic glands, there are four pairs of prominent accessory salivary glands: molar, palatine, zygomatic and lingual (Crouch, 1969). However, the origin and pathway of autonomic and sensory innervation of these accessory oral glands have not yet been elucidated.

The cat molar gland lies on the lateral side of the mandible. It has ducts (several to over ten in number) that open directly through the mucosa into the oral cavity. The molar gland is similar in structure to the main salivary glands, and is mainly of the mucous type. Although it makes an important contribution to the saliva of the mouth, there is no information available concerning the innervation of this gland.

With recent developments in histochemistry, small clusters of autonomic ganglion cells and fine bundles of autonomic fibers can be detected in whole mount preparations under a dissecting microscope (Kuchiiwa, 1990). The purpose of this study was to clarify the nerves supplying the cat molar gland and vessels in the mandibular areas including the lower lip-gingiva and cheek mucous membrane by employing newly developed whole mount acetylthiocholinesterase (WATChE) histochemistry, and to investigate the origin of the postganglionic parasympathetic fibers innervating the gland and vessels by means of the horseradish peroxidase (HRP) and HRP-conjugated wheat germ agglutinin (WGA–HRP) methods. An additional aim of this study is to confirm the origins and trajectories of the sensory fibers and postganglionic sympathetic fibers innervating this gland and the vessels in these areas.

2. Materials and methods

2.1. WATChE histochemistry

A total of 8 adult cats (b.w. = 1.5–3.5 kg) were dissected to trace nerves associated with the molar gland, lip-gingiva and cheek mucous membrane. The cats were deeply anesthetized with an intramuscular injection of ketamine hydrochloride (30–50 mg/kg) and an intraperitoneal injection of Nembutal (sodium pentobarbital: 20–30 mg/kg), and perfused through the ascending aorta with physiological saline followed by 10% sodium phosphate buffered formalin (pH 7.4). In two cases the cranial vascular system was injected with a 1% Berlin blue solution. A preliminary dissection was performed to expose the appropriate nerves in the lower part of the face. Skin was resected without damage to the underlying nerves and adipose tissue was removed under a binocular dissecting microscope.

The tissue was treated by WATChE histochemistry (slightly modified from Kuchiiwa, 1990) to facilitate observation of the fine autonomic nerve connections. The WATChE staining was as follows. The tissue was immersed in a 20% phosphate-buffered sodium sulfate solution (pH 7.4) at 37°C for 2 h and incubated in a 0.05 M acetate buffer solution (pH 5.0) containing 4 mM of acetylthiocholine iodide, 75 mM of glycine, and 15 mM of copper sulfate at 37°C for 90–120 min. It was then rinsed 5–10 times in distilled water, transferred to 1.25% sodium sulfite solution for 15–20 min, and again rinsed 5–10 times. The specimen was then placed in a solution of 1% silver nitrate for 5 to 10 min depending upon the degree of staining desired. It was subsequently rinsed in distilled water 5 times and treated in 1% sodium thiosulfate for approximately 10 min. Finally the preparation was thoroughly rinsed. These incubating steps were carried out at room temperature and the solutions were well stirred during the procedure. The stained preparation was stored in 0.2% phosphate buffered (pH 7.4) sodium azide solution at 4°C. The selectively stained preparations were dissected under a binocular dissecting microscope with special attention to the course of the fine autonomic nerves supplying the molar gland, lower lip-gingiva and cheek mucous membrane. When necessary, fine nerves and vessels were dissected out, dehydrated in graded alcohol, cleared in xylene, mounted on slides, and small parts of the tissue were mounted on slides with 30–40% polyvinylpyrrolidone (Sigma Chemical) dissolved in 30% acetic acid (Gienc, 1977), and observed with a light microscope. Some nerves were removed and sectioned on a freezing microtome at 40 μm thickness.

2.2. Tracer injection

Experiments were carried out on 10 adult cats weighing 1.6–3.2 kg. The animals were anesthetized with an intramuscular injection of ketamine hydrochloride (30–50 mg/kg) and with an intraperitoneal injection of Nembutal (sodium pentobarbital: 20–30 mg/kg), and 20 μl of 30% HRP and 5% WGA–HRP (Toyobo) mixture dissolved in saline was injected into the molar gland, lip-gingiva and cheek mucous membrane with a Hamilton microsyringe. After a 45–51 h post-injection survival period, the cats

were re-anesthetized and perfused through the ascending aorta with 1 l of saline followed by 2 l of 1.0% formalin and 1.25% glutaraldehyde in 0.1 M sodium phosphate buffer at pH 7.4. The otic ganglion, accessory otic ganglia, pterygopalatine ganglion, accessory pterygopalatine ganglia, submandibular ganglion, superior cervical ganglion, nodose ganglion, trigeminal ganglion and injected tissue were removed. These tissues were immersed in cold buffer containing 30% sucrose, and 40 μm-thick sections were cut on a freezing microtome. All sections of the ganglia and every 5th section of the injected tissue were prepared for peroxidase histochemistry by the tetramethylbenzidine reaction method (Mesulam, 1978) and treated with a 5% ammonium molybdate solution adjusted to pH 3.5 with 1 N hydrochloric acid (slightly modified from Fujii and Kusama, 1984). Parts of the sections of the ganglia were counterstained with neutral red and the neighboring sections of the injected tissue were stained with hematoxylin–eosin.

3. Results

3.1. WATChE histochemistry

In the WATChE-preparations, autonomic ganglia, postganglionic autonomic nerves, exocrine glands and muscles were stained dark brown, somatic motor and sensory nerves pale brown; connective tissues and fasciae remained unstained. In dehydrated microscopic preparations, the postganglionic autonomic fibers were observed to be stained intensely, but the preganglionic, sensory and motor fibers were not stained. This technique facilitated the demonstration of fine autonomic nervous connections and permitted photomicrographic recording of anatomical detail (Kuchiiwa, 1990).

The molar gland of the cat lay on the lateral surface of the mandible (Figs. 1 and 2). It extended anteroposteriorly from the lower lip opposite the first premolar to the rostral margin of the masseter. The anterior half was situated

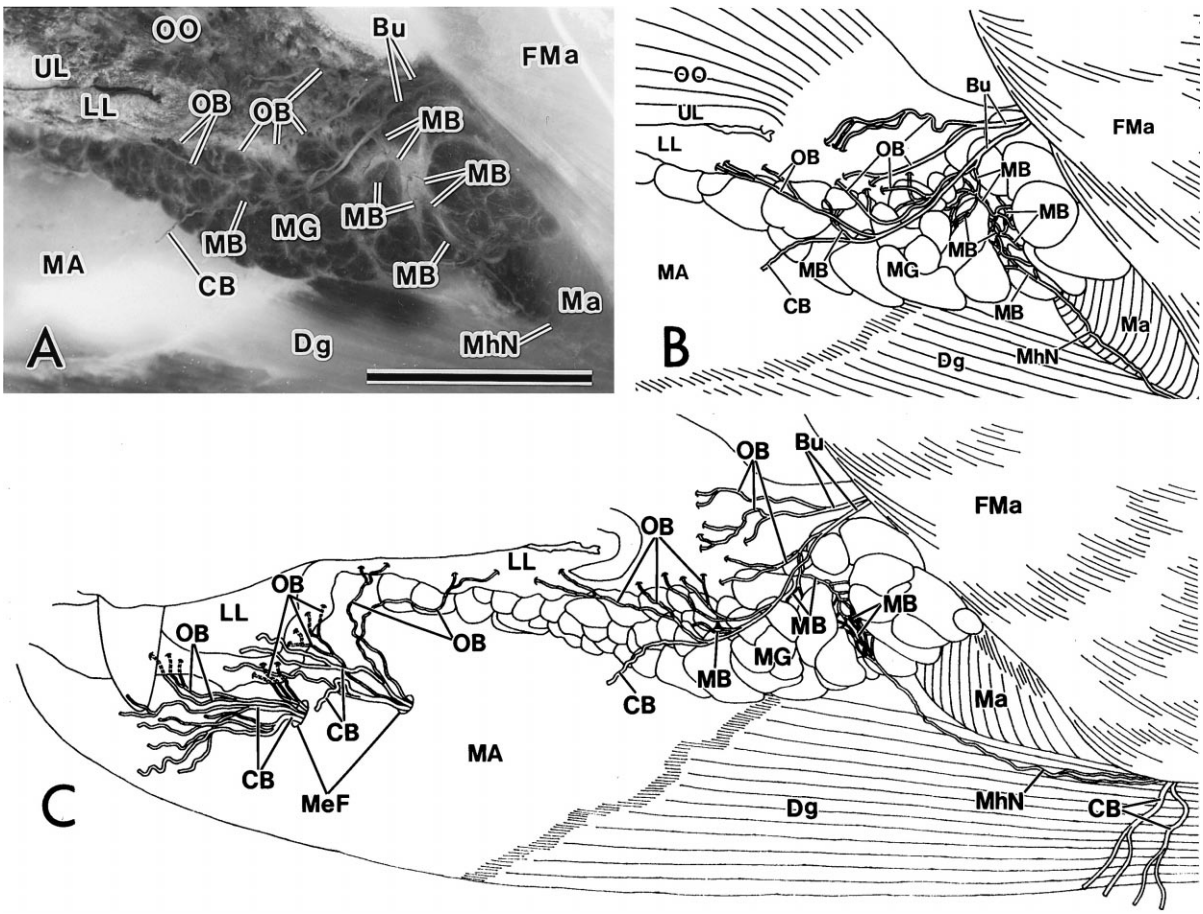

Fig. 1. (A and B) Photomicrograph (A) and sketch of same portion (B) of the WATChE-preparation showing the cat molar gland (MG), the branches to the molar gland (MB) and the branches to the oral mucous membrane (OB) derived from the buccal nerve (Bu) and the mylohyoid nerve (MhN). The cat molar gland lies on the lateral surface of the mandible (MA). The weakly stained buccal nerve passes between the Orbicularis oris (OO: partly removed) and the rostral border of the masseter (Ma) where intensely labeled MB and weakly labeled OB emerge. MB from the mylohyoid nerve is also stained intensely. In this WATChE-preparation, postganglionic autonomic fibers, molar gland and muscles are stained dark brown, and connective tissue and fascia remained unstained. Bar = 10 mm. (C) Sketch of nerves supplying the molar gland and the oral mucous membrane of the lower lip-gingiva and cheek. The same preparation as A and B. Abbreviations: CB, cutaneous branch; Dg, digastric muscle; FMa, fascia of masseter; LL, lower lip; MeF, mental foramen; UL, upper lip.

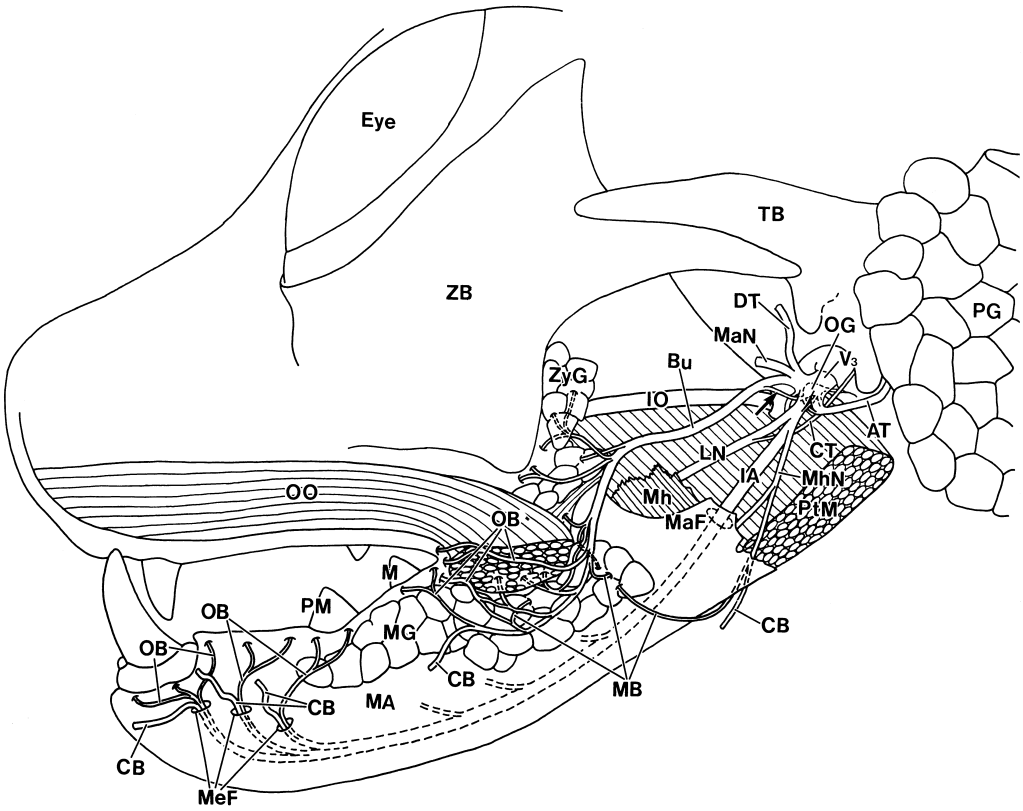

Fig. 2. Drawing showing the nerves supplying the molar gland (MG), lower lip-gingiva and cheek mucous membrane. The buccal nerve (Bu) emerges from the mandibular nerve (V_3) and passes forwards producing branches to the zygomatic gland (ZyG), the oral mucous membrane (OB) and the molar gland (MB). The otic ganglion (OG) is on the inferior surface of the origin of the mandibular nerve and several fine nerves emerge from this to connect with each branch of the mandibular nerve. The connection between the otic ganglion and the buccal nerve is indicated by an arrow. Abbreviations: AT, auriculotemporal nerve; CB, cutaneous branch; CT, Chorda tympani; DT, deep temporal nerve; IA, inferior alveolar nerve; IO, inferior orbital nerve; LN, lingual nerve; M, molar tooth; MA, mandible; MaF, mandibular foramen; MaN, masseteric nerve; MeF, mental foramen; Mh, mylohyoid; MhN, mylohyoid nerve; OO, Orbicularis oris; PG, parotid gland; PM, premolar; PtM, Pterygoideus medialis; TB, temporal bone; ZB, zygomatic bone.

between the oral mucous membrane and the Orbicularis oris, and the posterior half was situated between the mandible and the platysma. The gland was 25–30 mm long and 4–9 mm high. In some cases, it consisted of two lobes about equal in size. Each was long-ellipsoid in shape, with the longest diameter directed rostrocaudally, measuring 13 by 4 mm to 16 by 7 mm.

In the WATChE-preparations, a few WATChE-positive fine nerves derived from the buccal nerve were found to enter the molar gland, and several weakly stained nerves were distributed round the oral mucous membrane (Figs. 1 and 2). The buccal nerve separated from the mandibular nerve and passed forwards between the external pterygoid muscle and temporal muscle, where darkly stained fine branches emerged to innervate the zygomatic gland, and weakly labeled branches to innervate the mucous membrane of the cheek. The buccal nerve then coursed obliquely downwards and outwards between the Orbicularis oris and the rostral border of the masseter where it distributed unstained branches to the Orbicularis oris, then to the molar gland, and forwards over the lateral surface of the gland to supply it and the mucous membrane of the oral angle and the caudal half of the lower lip-gingiva (Fig. 2).

A weakly labeled branch from the mylohyoid nerve was observed to travel between the masseter and the digastric muscle, and intensely labeled fine branches from this nerve were found to enter the molar gland from its infero-lateral aspect (Figs. 1 and 2). The branches to the mucous membrane from the nerve were weakly stained in the WATChE-preparations.

Weakly stained mental branches of the inferior alveolar nerve were observed to emerge from the mental foramina and distribute to the rostral half of the lower lip-gingiva. No molar gland connection with these nerves was found under the dissecting microscope (Fig. 1C).

The darkly stained main otic ganglion was observed to connect with the mandibular nerve at the point where the auriculotemporal nerve separated from the primary trunk (Fig. 2). The main otic ganglion distributed several fine WATChE-positive nerves to connect with each branch of the mandibular nerve. In some cases, an intensely stained communicating branch to the buccal nerve was prominent in the vicinity of its origin (Fig. 2, arrow).

Several darkly stained accessory otic ganglia were found around the mandibular trunk and near the origins of the lingual nerve and the inferior alveolar nerve. The chorda

tympani nerve was observed to be stained weakly. Two fine weakly stained branches derived from the chorda tympani nerve were found to enter the accessory otic ganglia, and several to over ten intensely stained postganglionic fine branches from the ganglia were observed to join the mandibular nerve and the inferior alveolar nerve at the portion proximal to the entrance of the mandibular canal.

It has been reported that small groups of ganglion cells were scattered along the ducts of the submandibular and sublingual glands of the guinea-pig, especially in the regions of the ducts closest to the glands (Gibbins, 1990). Such microganglia were also observed in the present WATChE-study in the cat. The postganglionic fine branches from these microganglia were observed to be distributed to the floor of the oral cavity, not to the lip-gingival nor buccal areas. Besides these microganglia, a very prominent single ganglion was found associated with the lingual nerve at the origin of the branch to the submandibular gland (oromandibular gland), and 2–4 small microganglia on the branches of the lingual nerve at the floor of the oral cavity inferolateral to the body of the tongue (perilingual ganglia). The postganglionic nerves from the 'oromandibular ganglion' or 'perilingual ganglia' were observed to be distributed to the floor of the oral cavity or to the tongue, not to the lip-gingival nor buccal areas.

The superior cervical ganglion and its postganglionic nerves were also darkly stained in the WATChE histochemistry. In line with earlier observations of Barlow and Root (1949), several postganglionic branches emerged from the upper side of the superior cervical ganglion. The nerves passed upwards to enter the tympanic cavity and join the tympanic plexus. Three to five darkly stained nerves deriving from the tympanic plexus passed forwards and below the trigeminal ganglion in a fan-like arrangement, and then a single WATChE-positive postganglionic branch joined the mandibular nerve at the point where the motor root joined the sensory portion.

In the dehydrated WATChE-preparations, darkly stained

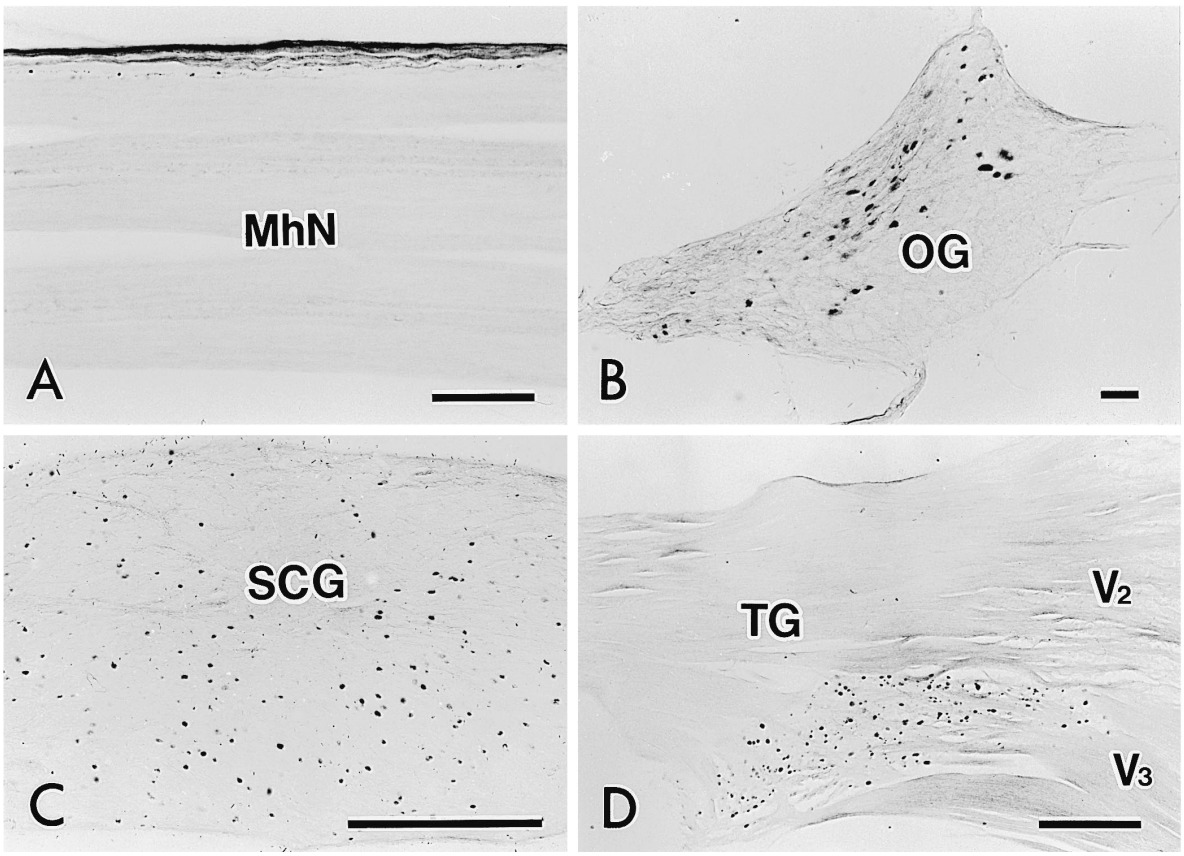

Fig. 3. (A) Photomicrograph showing the darkly stained WATChE-positive nerve fibers in the longitudinal section through the mylohyoid nerve (MhN). Note that the positive fibers run on the surface of the nerve in a bundle. 40 μm-thick frozen section. Bar = 100 μm. (B) Photomicrograph of a section showing the labeled ganglion neurons in the otic ganglion (OG) after injections of HRP/WGA–HRP into the ipsilateral molar gland, lower lip-gingiva and cheek. Tetramethylbenzidine method; 40 μm-thick frozen section without counterstain. Bar = 100 μm. (C) Photomicrograph showing the distribution of labeled neurons in the superior cervical ganglion (SCG) after the same injections of the tracer. Labeled neurons are distributed throughout the ganglion. Tetramethylbenzidine method; 40 μm-thick longitudinal frozen section without counterstain. Bar = 1 mm. (D) Photomicrograph of a longitudinal section through the trigeminal ganglion (TG) showing the distribution of labeled cells in the ganglion after the same injections. The majority of labeled neurons are distributed in the mandibular division of the ganglion. Tetramethylbenzidine method; 40 μm-thick frozen section without counterstain. Bar = 1 mm. Abbreviations: V2, maxillary nerve; V3, mandibular nerve.

nerve fibers were observed on the surface of the buccal nerve, mylohyoid nerve and the other mandibular branches under a light microscope (Fig. 3A).

3.2. Tracer injection study

In the sections of the HRP/WGA–HRP injected tissues from 7 of 10 cases, injected enzyme filled most of the molar gland and the surrounding lip-gingiva, buccal connective tissue and mucous membrane. In 3 cases, however, the tracer was observed restricted more or less to the anterior half of the molar gland and the whole lower lip-gingiva.

In all cases, many ganglion neurons were labeled in the ipsilateral main and accessory otic ganglia. The labeled cells ranged from 20 to 48 μm in diameter, with an average of 38.4 μm. The total number of labeled cells in the ganglia ranged from 155 to 582, with an average of 335.1, and they were arranged in a localized manner in the main ganglion (Fig. 3B).

In the pterygopalatine ganglion ipsilateral to the injections, a small number of neurons was retrogradely labeled in 7 of 10 cases in which the buccal tissue was filled with the injected enzyme. The total number of labeled cells ranged from 4 to 19, with an average of 9.5. In the 3 cases in which the tracer was restricted to the lower lip-gingiva and anterior half of the molar gland, application of HRP/WGA–HRP did not result in retrograde labeling of cells in the pterygopalatine ganglion or its accessory microganglia.

Numerous labeled neurons were observed in all cases throughout the superior cervical ganglion ipsilateral to the injections (Fig. 3C). The same injections labeled many neurons in the mandibular division of the trigeminal ganglion, ipsilaterally (Fig. 3D). No labeled neurons were identified in the submandibular ganglion or nodose ganglion following injections of the tracer to the molar gland, lip-gingiva and cheek.

4. Discussion

After injections of HRP/WGA–HRP into the cat molar gland, the lower lip-gingiva and cheek mucous membrane, most retrogradely labeled neurons in the parasympathetic ganglia were observed in the ipsilateral main and accessory otic ganglia. This indicates that all these mandibular areas chiefly receive parasympathetic input from the otic ganglia. Since there are no structures except glands and vessels which are known to receive parasympathetic innervation in the injected area (Gabella, 1976), it is conceivable that the retrogradely labeled cells in the otic ganglia observed in this study play a role in the secreto-motor function of the molar gland and in the vasomotor function in this gland and in the lower lip-gingiva and buccal tissues.

In the cases in which the tracer filled the posterior lobe of the molar gland and surrounding buccal tissue, a small number of labeled neurons was found in the pterygopalatine ganglion and its accessory microganglia. Since our previous study showed that blood vessels in this portion receive dual parasympathetic supplies from the otic ganglion and the pterygopalatine ganglion (Kuchiiwa et al., 1992) and the number of the labeled cells in the present study was very small, it is conceivable that uptake of the enzyme from vessels in the cheek mucous membrane labeled the neurons in the pterygopalatine ganglia. These findings strongly suggest that the secreto-motor supply to the cat molar gland originates almost exclusively in the otic ganglia, and also that the blood vessels in the lower lip-gingiva receive vasomotor fibers from the otic ganglia, and the vessels in the cheek mucous membrane receive fibers from both the otic and the pterygopalatine ganglia.

In the present WATChE-preparations, darkly stained roots originating in the otic ganglia were found to join each branch of the mandibular nerve including the buccal nerve and the mylohyoid nerve. A few WATChE-positive branches distributed from these nerves were observed to enter the molar gland, and several weakly labeled branches innervated the lower lip-gingiva and cheek mucous membrane. Autonomic postganglionic fibers are selectively stained in the WATChE-preparations, indicating that the intensely stained nerves mainly consisted of autonomic postganglionic fibers, and weakly stained ones contain sensory and motor fibers in addition to the postganglionic fibers. This indicates that the cat molar gland receives many postganglionic fibers and the lip-gingival and buccal mucous membrane receive fewer postganglionic fibers by way of the buccal nerve and the mylohyoid nerve. Segade et al. (1987) demonstrated that each branch of the guinea-pig mandibular nerve receives postganglionic fibers from the otic ganglion. This is borne out by our observations that several fine WATChE-positive nerves emerged from the otic ganglia to connect with each branch of the mandibular nerve.

In the present WATChE-preparations, the inferior alveolar nerve was observed to distribute to the rostral half of the lip-gingiva. Izumi and Karita (1992) reported that vasodilator response was elicited in the rostral portion of the cat mandibular lip-gingiva by electrical stimulation of the intracranial facial nerve as well as of the intracranial glossopharyngeal nerve, and that this response was completely abolished by sectioning of the ipsilateral inferior alveolar nerve. This indicates that the vasodilator fibers travelling both in the facial and in the glossopharyngeal nerves join the inferior alveolar nerve and reach the rostral half of the lip-gingiva. They also reported (Izumi and Karita, 1991) that pretreatment with hexamethonium, an autonomic ganglionic blocker, reduced the increase in blood flow elicited by electrical stimulation of the facial and glossopharyngeal nerves, but had no effect on that elicited by stimulation of the trigeminal nerve, suggesting

the presence of parasympathetic vasodilatation mechanisms as well as antidromic vasodilatation mediated by sensory nerves in the lip-gingiva.

The vasodilator response evoked in this area by stimulation of the facial nerve is never affected by lesion of the ipsilateral pterygopalatine ganglion (Izumi and Karita, 1992). This is consistent with our present results that no labeled neurons were observed in the pterygopalatine ganglion nor in its accessory microganglia when the tracer was restricted to the rostral half of the lower lip-gingiva. This indicates that the parasympathetic vasodilator fibers travelling by way of the facial nerve are not mediated in the pterygopalatine nor accessory pterygopalatine ganglia.

Izumi and Karita (1993) also reported that electrical stimulation of the peripheral cut ends of the chorda tympani nerve and the chorda lingual nerve elicited a blood flow increase in the ipsilateral lower lip. The response was significantly reduced by pretreatment with hexamethonium and was abolished by section of the inferior alveolar nerve. Izumi and Karita suggested that the parasympathetic vasodilator fibers running in the chorda tympani nerve pass to the inferior alveolar nerve by way of a presumptive communicating branch derived from the lingual nerve, and are mediated in unlocated microganglia on that communicating branch but not in the otic ganglia. In our present WATChE-preparations, however, we could not find any such 'communicating branch' nor any 'unlocated microganglia'. It is, of course, difficult to consider that the vasodilator fibers are mediated in peripherally located ganglia such as the oromandibular, perilingual, or microganglia scattered along the ducts of the submandibular and sublingual glands.

The discrepancies between our anatomical data and Izumi and Karita's physiological data cannot be accurately explained at the present time. However, it is certain that the rostral half of the lip-gingiva is supplied by the postganglionic fibers of the otic ganglion neurons by way of the inferior alveolar nerve. Since, in our WATChE-preparations, constant communicating branches from the chorda tympani nerve were observed to pass to the inferior alveolar nerve via the accessory otic ganglia, and no other autonomic ganglia could be found along the inferior alveolar nerve, it is conceivable that some of the facial preganglionic vasodilator fibers may reach the otic ganglia by way of the communicating branch from the chorda tympani, and be mediated in the otic ganglia as well as the glossopharyngeal preganglionic vasodilator fibers.

The trigeminally mediated reflex vasodilatation in the

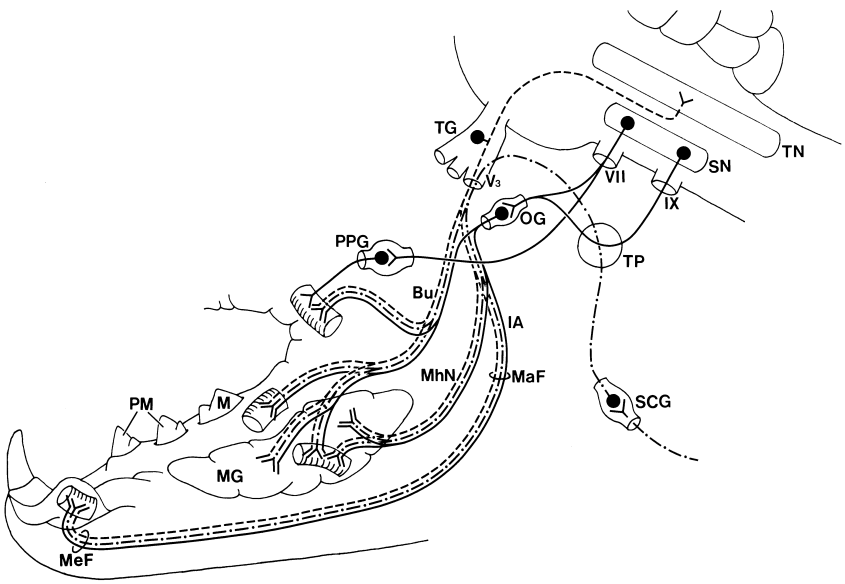

Fig. 4. Schematic drawing showing the parasympathetic (solid line), sympathetic (chain line) and sensory (dashed line) innervation of the cat molar gland (MG) and the blood vessels in the gland, lip-gingiva and cheek mucous membrane. The secreto-motor and vasomotor preganglionic parasympathetic fibers to the molar gland and the vasomotor fibers to the gland, lower lip-gingiva and cheek mucous membrane are considered to originate in the salivatory nucleus (SN) in the medulla and pass to the otic ganglion (OG) by way of both the facial (VII) and the glossopharyngeal nerve (IX). The postganglionic outflow from the otic ganglion to the molar gland and the vessels in the gland runs by way of the buccal nerve (Bu) and the mylohyoid nerve (MhN). The vasomotor fibers to the caudal half of the lip-gingiva pass by way of the buccal nerve and the vasomotor fibers to the rostral half of the lower lip-gingiva by way of the inferior alveolar nerve (IA). The vessels in the cheek mucous membrane receive facial and glossopharyngeal inputs both from the otic ganglion and the pterygopalatine ganglion (PPG). The molar gland and the blood vessels in the caudal half of the lower lip-gingiva and cheek also receive sympathetic supply from the superior cervical ganglion (SCG) and sensory input from the mandibular division of the trigeminal ganglion (TG) by way of the Bu and/or MhN. The rostral half of the lower lip-gingiva receives the same inputs by way of the inferior alveolar nerve. Bifurcated lines do not indicate bifurcation of axons. Abbreviations: V_3, mandibular nerve; M, Molar; MaF, mandibular foramen; MeF, mental foramina; PM, premolar; TN, trigeminal nuclei; TP, tympanic plexus.

lower lip-gingiva was abolished by section of the glossopharyngeal nerve root but not of the facial nerve root (Izumi and Karita, 1992). This indicates that a somato-autonomic reflex vasodilator response is mediated in the otic ganglia, and suggests that there is a functional difference between the two groups of parasympathetic vasodilator fibers supplying the lower lip-gingiva.

In this study, many labeled cells were observed in the trigeminal ganglion and the superior cervical ganglion after the injections of tracers, and it was found that WATChE-positive postganglionic sympathetic branches derived from the tympanic plexus joined the mandibular nerve at its origin. These findings indicate that the cat molar gland receives sensory supply chiefly from the trigeminal ganglion and sympathetic supply mainly from the superior cervical ganglion by way of the buccal nerve and the mylohyoid nerve, and also indicate that the vessels in the rostral half of the lip-gingiva receive the same inputs by way of the inferior alveolar nerve, and that the vessels in the caudal half of the lower lip-gingiva and the cheek mucous membrane receive inputs by way of the buccal nerve.

In conclusion, this study provides the following anatomical evidence on the modes of innervation of the cat molar gland and blood vessels in the lip-gingiva and cheek mucous membrane (Fig. 4). (1) The cat molar gland receives secreto-motor parasympathetic supply from the otic ganglia, sympathetic supply from the superior cervical ganglion, and sensory supply from the trigeminal ganglion, by way of the buccal nerve and mylohyoid nerve. (2) Blood vessels in the rostral half of the lower lip-gingiva receive vasomotor inputs from the otic ganglia by way of the inferior alveolar nerve. (3) Blood vessels in the caudal half of the lower lip-gingiva and those in the anterior half of the molar gland receive possible dual parasympathetic supply from the facial and the glossopharyngeal nerve by way of the otic ganglia and the buccal nerve. (4) Blood vessels in the cheek mucous membrane and those in the caudal half of the molar gland receive dual parasympathetic supplies from the facial nerve and glossopharyngeal nerve by way of both the otic ganglia and the pterygopalatine ganglia. (5) The cat lower lip-gingiva and cheek mucous membrane have no relation with the submandibular ganglion or nodose ganglion.

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