The Fine Structure of Lamellated Nerve Endings Found in the Rat Gingiva

Ii-sei WATANABE and Eichi YAMADA

Department of Anatomy (Prof. E. YAMADA), University of Tokyo Faculty of Medicine, Japan

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Summary. The fine structure of lamellated nerve endings found in the rat gingiva (Sprague Dowly) was examined by electron microscopy.

The lamellar corpuscles are localized in the subepithelial portion of the dermal papillae and are circular or oval in shape.

The lamellar cells surrounding the nerve terminals demonstrate several modifications in their configuration due to the variable number of cytoplasmic sheets. All the sheets are characterized by the presence of numerous caveolae, small mitochondria, a few cisterns of rough endoplasmic reticulum, microfilaments and microtubules.

Serial sections clearly showed that the nerve terminal is subdivided into two or four branches, each of which terminates at different levels of the corpuscle.

The laminae branch several times, ultimately connecting with those of neighboring laminae through desmosomes, and are separated from similar processes by an interlaminar substance. The nerve endings contain many mitochondria, neurotubules and small clear vesicles. Cytoplasmic protrusions extend from the nerve terminal into the clefts between the lamellar cells. Small clear vesicles are found in the basal area of the protrusion. The interlaminar spaces are occupied by an amorphous material though collagenous fibrils are conspicuous in some regions.

Several different types of nerve endings have been known to occur in the gingiva, serving for the sensory transmission of the oral mucosa.

PEASE and QUILLIAN (1957), CAUNA (1953, 1958), PEASE and PAILLIE (1959), CAUNA and ROSS (1960), CHOUCHKOV (1971), HASHIMOTO (1973), SPENCER and SCHAUMBURG (1973) and IDE (1976) all reported on the fine structure of the Meissner corpuscles and Pacinian corpuscles. They described a complex arrangement of axons surrounded by many cytoplasmic laminae of lamellar cells. On the other hand, PATRIZI and MUNGER (1965) depicted some details of the encapsulated nerve endings in the rat penis and MacDONALD and SCHMITT (1979) studied the ultrastructure of the human mucocutaneous end organ of the glans penis.

As far as could be noted in literature, however, only MARTINEZ and PEKARTHY (1974) have reported on some of the ultrastructural characteristics of encapsulated nerve endings in the rat gingiva. In this paper, we will demonstrate more details gained through electron microscopic observation of the sensory corpuscles in the rat gingiva,

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with special reference to the peculiar relationship of the axon terminal and lamellar cells. The preliminary results of this study have been previously presented (Watanabe and Yamada, 1979).

MATERIAL AND METHODS

About 20 Sprague Dowly rats weighing 200 g were anesthetized with an intraperitoneal injection of Nembutal. The rats were perfused via the left ventricle with about 15 ml of modified Karnovsky's fixative containing 2.5% glutaraldehyde, 2% paraformaldehyde in a 0.1 M phosphate buffer (pH=7.4). The gingiva was dissected out and cut into small segments and immersed in the above fixative for 3 hrs at room temperature. Afterwards, the tissues were washed in a 0.1 M phosphate buffer for about 10 min and postfixed with 1% osmium tetroxide in the same buffer (pH=7.4) for 2 hrs at 4°C. The tissues were washed in the buffer for a few minutes and then dehydrated in graded alcohols after "en bloc" staining by 5% aqueous uranyl acetate solution and embedded in Epon 812.

The thin sections were cut on a Porter-Blum 11 or LKB ultramicrotome. The sections were stained by uranyl acetate and lead citrate, and examined in Hitachi-12A electron microscope.

Fig. 1 and 2. Photomicrograph of an encapsulated corpuscle in the rat gingival mucosa. Epon-embedded semi-thin sections are stained with toluidin blue. Fig. 1: single corpuscle and Fig. 2: two corpuscles within a common capsule. The corpuscle contains an axon in the center and a lamellated cell nucleus at the periphery. ×900
Thick sections (approximately $2\mu m$ thick) were made on the same ultramicrotome, mounted on glass slides and stained by toluidine blue for light microscopy.

**OBSERVATIONS**

**Light microscopy**

The lamellar corpuscles are found in the subepithelial portion of the dermal papillae. They are circular or oval in shape, and may be seen as a single corpuscle (Fig. 1) or two corpuscles surrounded by a capsule (Fig. 2).

As noted in Figures 1 and 2, the axon terminal is located in the center and an inner core may be observed around the axon. The nucleus is generally found at the periphery of the corpuscle, which belongs to the lamellar cell. Several capillaries are usually noticed near the corpuscle.

**Electron microscopy**

In the serial sections it was confirmed that a single fiber completely loses its myelin sheath before its entry to the inner core of the corpuscle (Fig. 3).

![Fig. 3. Transverse section of an encapsulated lamellar corpuscle of rat gingiva. The terminal axon (A) and a bundle of unmyelinated axons (Al) are seen. The outermost lamina of the lamellar cells (C) is relatively rich in cytoplasm, indicating its perikaryal nature. Flat capsular cells show denser cytoplasm and accompanies collagenous fibers. ×11,000](image-url)
The serial sections also showed that the nerve terminal may arborize two times in the inner core. It subdivides in two or four branches, each of which terminates at different levels of the corpuscle (Fig. 3, 5, 6).

The lamellar cells surrounding the nerve terminals show various modifications in their configurations with a variable number of cytoplasmic sheets (Fig. 4-6). The cytoplasmic sheets (laminae) of the lamellar cells contain small mitochondria, a few cisterns of rough endoplasmic reticulum, microfilaments and microtubules. All the sheets are characterized by the presence of numerous caveolae along their surfaces (Fig. 7-9).

The nucleus of the lamellar cells is generally located at the periphery of the corpuscle. The perikaryon shows a relatively large amount of cytoplasm which contains a moderate number of mitochondria, rough endoplasmic reticulum, free ribosomes and Golgi bodies in addition to microfilaments and microtubules (Fig. 3, 4). The laminae branch several times, connecting with those of neighboring laminae through desmosomes as shown in Figures 5 and 8, and are separated from similar processes by an interlaminar substance. The nerve endings contain many mitochondria, neurotubules and small clear vesicles (Fig. 5-7). The short cytoplasmic protrusions extend from the nerve terminal into the clefts between the lamellar cells where the lamellar cell covering

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**Fig. 4.** The axon (A) in the lamellar corpuscle is subdivided into two branches, causing an irregular disposition of lamellae. ×16,000

**Fig. 5.** Four branches in one lamellar corpuscle are identified. Accordingly, the arrangement of lamellae is also modified. ×15,000

**Fig. 6.** At this level, each of the four branches of the terminal axon is enclosed by several irregular laminae of lamellar cells, while the whole corpuscle is surrounded by a common lamellar structure. ×11,000
Fig. 5 and 6. Legends on the opposite page.
Fig. 7 and 8. Legends on the opposite page.
is lacking (Fig. 5-8). Small clear vesicles tend to accumulate in the basal area of these protrusions.

The transverse sections of the inner core at different levels show that the structures are relatively modified compared to those of the Pacinian corpuscle, because both two-pronged and four-pronged branches of lamellar cells are present at the same time. Therefore, the organization of the bilateral distribution of the lamellar cells is slightly irregular (Fig. 8).

The interlaminar spaces are occupied by an amorphous material, though collagenous fibrils are conspicuous in some regions (Fig. 3-8). In those regions where a wider interlaminar space is present, the lamellar cell is usually covered by a basement membrane. It becomes indistinct, however, as the interlaminar space becomes smaller. The terminal portion of the laminar process covers the axon surface directly.

The capsule consists of a few layers of flattened cells which are arranged in a concentric and overlapping manner (Fig. 1, 2, 4, 6). The fine structural feature of these flattened cells resembles that of the fibroblasts. The cells accompany collagenous fibrils and no basement membrane is seen along their surface. A small bundle of unmyelinated nerve fibers may be observed near the capsule (Fig. 1-3).

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**Fig. 9.** Higher magnification of laminae showing microtubule (MT), 10 nm filaments, a few mitochondria (M) and numerous caveolae (small arrows) along their surface. Note the desmosome-type junctions (large arrows) between neighboring laminae. ×50,000

**Fig. 7.** High magnification of the terminal axon showing many mitochondria (M), neurofilaments (NF), and clear vesicles (V). The laminae of lamellar cells present many caveolae along their surfaces. ×17,000

**Fig. 8.** Cross section of a terminal axon characterized by numerous mitochondria. The axon extends several irregular projections towards the clefts on its opposite sides (arrows). ×14,000
DISCUSSION

The present study demonstrates the morphological and ultrastructural features of the axon terminal and its relationship to the cytoplasmic laminae of the encapsulated lamellar corpuscle of the rat gingiva.

As mentioned before, only Martinez and Pekarthy (1974) have previously reported on certain aspects of the encapsulated nerve endings in the rat gingiva. They mentioned that a single axon possesses microvesicles and microtubules, and is surrounded by lamellar cells and capsular cells. The encapsulated corpuscle described in the present paper differs in several aspects from that in their findings. Namely, the axon terminal was found to divide several times and generally forms an irregular disposition at successive levels of lamellar cells in the inner core. On the other hand, the cytoplasmic organelles of the lamellar cells seem to be the same, presenting mitochondria, microtubules, rough endoplasmic reticulum and microfilaments.

Suzuki and Kurosuni (1972) reported on the encapsulated nerve endings in the dermis of the mole snout. They mentioned that the axon is surround by closely packed cytoplasmic laminae of the lamellar cells. Their findings are somewhat similar to the present observations.

The bilateral organization of the lamellar cells in the inner core of the Pacinian corpuscles has been described by Pease and Quillian (1957), Quillian and Armstrong (1963) and Spencer and Schaumburg (1973). Quillian and Armstrong (1963), Andres (1969), Saxod (1970), Nafastad and Andersen (1970), Halata (1971), Halata and Mungur (1980), Andres and During (1973) reported similar ultrastructural characteristics in the Herbst corpuscles.

Since there is a bilateral organization of lamellar cells, the corpuscles present the longitudinal clefts in the core region, which might serve as a route for metabolic exchange or for the transportation of nutritive substances from extracellular connective tissue to the axon terminal (Pease and Quillian, 1957; Suzuki and Kurosuni, 1972). The encapsulated corpuscle of the rat gingiva described in the present paper also showed similar bilateral clefts, although the organization of lamellar cells was somewhat irregular in arrangement.

In this connection, it is interesting to note that the present observations demonstrated that the axon terminal extends several complicated small processes towards the clefts. Spencer and Schaumburg (1973) suggested that those axon processes are purposefully arranged to detect any stimuli of mechanical deformations transmitted from the surface of the receptor. Nakai and Kawasaki (1959) assumed that similar processes found in the growth cone subserve a tactile function.

Rice et al. (1973) postulated that the receptor membrane in insect mechanoreceptors may be stretched over a microtubular cytoskeleton and that the displacement of sensory hairs provides a change in the shape of elliptical membrane pores resulting in an increased ionic conductance and membrane depolarization. The microfilaments impart elastic properties to the axon process; a displacement of the process would be quickly restored. A similar phenomenon may occur at the axon processes of the encapsulated corpuscle. On the other hand, Spencer and Schaumburg (1973) confirmed that the clear vesicles in sensory axon terminals contain a substance which is released during the mechanical distortion of an axon process and is then able to effect the ionic conductance of the axolemma.

The encapsulated sensory corpuscle described in this paper presents two or four
axon terminals at different levels. This finding suggests that they must have a complicated system in order to conduct the delicate impulses of the gingival mucosa.

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Prof. Hi-sei Watanabe
Chairman of the Department of Morphology
Faculty of Dentistry, State University
16100–Araçatuba—São Paulo, Brazil