Fine Structure of Probable Sensory Nerve Endings in Human Periodontal Ligaments

By

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Summary: In the present study, the special features of the nerve endings in human periodontal ligaments were examined ultrastructurally. They were found to be located in close proximity to nerve bundles and were distributed chiefly in the apical region. Each nerve ending was round or oval in shape, and 10 µm to 25 µm in diameter. They were surrounded by thin Schwann cell cytoplasm, and their axons contained mitochondria, dense bodies, and myelin figures. Their features were similar to those of sensory nerve receptors.

The distribution of nerve endings in human periodontal ligaments has been the subject of histological and ultrastructural studies for several decades. Lewinsky and Stewart (1937) described the presence of two types of nerve endings in human periodontal ligaments: free nerve endings, and knob-like swellings. Other histological reports have described still other shapes of nerve endings: unencapsulated Ruffini-like endings (Rapp et al., 1957) and elongated spindle-like endings (Bernick, 1959). Simpson (1966) observed the knob-like enlarged ending by means of the apoxestic technique employing light microscopy.

In recent ultrastructural studies, Griffin and Harris (1974) noted that the nerve endings formed three types of mechnoreceptors in human periodontal ligaments: simple, compound, and complex. Nakamura et al. (1982) confirmed the presence of encapsulated nerve endings and indicated that this type of ending probably represents the sensory mechanoreceptor in human periodontal ligaments.

From the results of histological observations of human periodontal ligaments, Brashear (1936) and Lewinsky and Stewart (1937) suggested that the large-diameter unmyelinated fibers which lost their myelin sheath constitute the receptors of touch sensation, whereas the small-diameter unmyelinated ones are concerned with pain. However, the precise structure of the nerve endings in the periodontal ligaments still remains to be elucidated.

The purpose of this study was to examine the nerve-ending organs in human periodontal ligaments by means of electron microscopy.

Materials and Methods

The materials used in this study were
non-carious premolar teeth extracted for orthodontic reasons from 20 patients, 8-16 years old. The premolars with surrounding periodontal tissues were cut out and fixed in 0.1 M cacodylate buffer (pH 7.4) containing 2% glutaraldehyde. After dehydration through a graded series of ethanol, followed by propylene oxide, they were embedded in Araldite 502. Blocks were cut horizontally with glass knives. The sections were examined under a JSM 100-cx electron microscope after staining.

Results

Nerve bundles of various diameters were observed in the human periodontal ligaments studied. Some of the nerve bundles were ensheathed with perineurium, while others were not ensheathed. In some cases, nerve bundles near the apical region of the ligaments contained special features of swollen oval-shaped unmyelinated nerve fibers. However, such cases were not abundant. These bundles were not located in close proximity to blood vessels and were distributed in the central area of the periodontal ligaments, although they were positioned slightly in the direction of the alveolar bone. These nerve bundles were surrounded only by collagen fibers. In the present study, the occurrence of two swollen nerve fibers was detected. Each nerve fiber was located peripherally in a nerve bundle. Each fiber measured 10 μm (termed a small fiber) to 25 μm (termed a large fiber) in diameter. The small fiber contained neurotubules in irregular arrays, neurofilaments, scattered mitochondria, multivesicular bodies, and myelin figures. The fiber was surrounded by thin Schwann cell cytoplasm, and partly surrounded with basal lamina. This type of fiber was separated from other nerve fibers by about 4 μm (Figs. 1 and 2). The large fiber contained an accumulation of mitochondria which were of nearly the same shape and size, neurofilaments, neurotubules, dense bodies, and myelin figures. The fiber was surrounded completely by thin Schwann cell cytoplasm. The large type of fiber was separated from other fibers by a space of 140 μm which contained fibroblast processes and collagen fibers (Fig. 3).

Discussion

In the present study, the special features of nerve fibers in human periodontal ligaments were observed by means of electron microscopy.

According to Chouchkov (1978), some of the specialized nerve endings such as Pacinian-, Ruffini-, and Krause endbulbous corpuscles contain accumulations of lysosomes and some mitochondria, as well as myelin figures. Moreover, Cauna (1966) suggested that nerve endings contain numerous mitochondria in order to satisfy the energy demands for re-setting after stimulation; and dense bodies and myelin figures appear as a result of continuous turnover of the endings. In the present study, we found that the nerve fibers contained organella similar to those seen in the nerve endings reported previously. Accordingly, such fibers would appear to be a type of nerve endings to their cytoplasmic components. The nerve fibers observed in the present study resembled the knob-like endings (Lewinsky and Stewart, 1937; Simpson, 1966) and elongated spindle-like endings (Bernick, 1959) which appeared in previous reports.

The nerve endings, the terminal axons described here, were similar in their cytoplasmic components to those reported by Schoultz and Swett (1974) in the Golgi tendon organ of the cat, and by Byers (1985) as Ruffini-like mechanoreceptors in the periodontal ligaments of the rat.

Based on physiological studies, it is
generally agreed that both rapidly and slowly adapting mechanoreceptors are present in the periodontal ligaments (Anderson et al., 1970, Hannam, 1976; Mei et al., 1977; Cash and Linden, 1982). It seems probable that these two physiological types correspond to two morphologically distinctive mechanoreceptors: capsulated and uncapsulated organized endings (Hannam, 1976). Cash and Linden (1982) suggested that in the canine teeth of the cat, the distributions of the two types of receptors are different: slowly adapting receptors are situated near the root apex, and rapidly adapting receptors are situated near the center of the periodontal ligaments. Burstone (1962) undertook a calculation of the theoretical stress in a single rooted tooth, and suggested that the force occurs with the highest stress at the root apex and next highest at the alveolar crest. Catton (1970) inferred certain relationships between mechanoreceptors and their surrounding tissues: rapidly adapting receptors tend to be loosely attached to the surrounding tissues, while slowly adapting ones are firmly fixed to them.

Well known anatomical and functional designations have been given for receptors in joints (Schoultz and Sweet, 1974, Story, 1976; Halata, 1977; Sathian and Devanandan, 1983), skin (Knibestöl, 1975; Biemesderfer et al., 1978) and other organs (Karuh, 1984). The Pacinian corpuscles are rapidly adapting receptors, while the Ruffini corpuscles and Golgi tendon organ are slowly adapting receptors. The Ruffini corpuscles and Golgi tendon organ appear to play a role in the relaxation of pressure in the joints. The special features of the nerve endings observed in this study seem to indicate a similar role to that of joint mechanoreceptors.

The overall results suggest that the special features of the nerve endings in this study probably represent a kind of sensory receptor in the human periodontal ligaments.

References


PLATES
Explanation of Figures

Plate I

Fig. 1. Special features of the swollen nerve ending (NE, small type). The ending is surrounded by a thin layer of Schwann cell cytoplasm (SC). The axon contains neurotubules arranged in irregular arrays, neurofilaments, multivesicular bodies, and mitochondria. x 8,000.

Fig. 2. Higher magnification of part of the swollen nerve ending (NE, small type), showing the detailed axoplasm containing multivesicular bodies and myelin figure (Hy). x 20,000.

Fig. 3. Another swollen nerve ending (NE, large type) separated from other nerve fibers by a fibroblast process (F) and collagen fibers. The nerve ending contains an accumulation of mitochondria, scattered dense bodies, and myelin figures. The nerve ending is surrounded by a thin layer of Schwann cell cytoplasm (SC). x 5,400.