ELECTRON MICROSCOPIC STUDY OF THE RUDIMENTARY CILIA IN ODONTOBLASTS OF THE MOUSE DENTAL PULP

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造象牙細胞內 나타나는 原形纖毛의 微細構造에 관한 硏究

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》 국문초록 《

생쥐 치수내 조상아세포의 미세구조연구 중에 종종 보게되는 원형섬모의 미세구조와 이들의 가능한 기능을 다음과 같이 추정하였다.

1. 상아질형성물질을 분비하는 기능을 가진 조상아세포내 2가지 다른 형태의 원형섬모가 발견된다.
2. 조상아세포내 2개의 Basal Centriole을 가지고 있으면서 아마 중앙에는 쌍으로된 microtuble이 없고 쌍으로 된 9개의 말초섬유를 가진 형태의 원형섬모는 조상아세포와 치수내 말초신경 사이에 일어나는 지각 기능에 관여하는것으로 추측된다.
3. 다른 한형태의 섬모, 즉 한개의 Centriole을 가지고 있으면서 쌍으로된 9개의 말초섬유를 가진 섬모는 조상아세포에서 분비된 상아질 형성물질을 움직이게 하는 이동기능에 관여하는것으로 사료된다.

INTRODUCTION

In the course of a general study of the fine structure of odontoblasts of the mouse dental pulp, occasional occurence of cilia were observed. Since Munger (1958)[22] and Barnes (1961)[8] reported on the ultrastructure of rudimentary cilia and their possible roles, many investigators [1-9] have been observed rudimentary cilia in a great varieties of vertebrates including human gingiva and oral mucosa, periodontal ligaments and pulp of mouse, and speculated their functions.

Despite a lot of general fine structural studies [10-17] of the pulp, so far little attention has been paid to the frequent occurrence of cilia and their possible roles in odontoblasts.

In functional points, the odontoblasts secrete the dentin forming substances and add amounts of carbohydrates to the predentin matrix before calcification takes place. [10-11] It is valuable to consider the multiple function of the secretory cells of mesenchyme origin.

Among them the intradental sensory mechanism remain in the arguments. The transduction

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mechanism between the odontoblasts and pulpal nerve endings might include these areas.

The cilium with a circumciliary invagination of the cell membrane appears frequently in the pulp, periodontal membrane and gingiva. There are two kind of the fibril patterns in the cilium. The first group contains the nine peripheral plus two central fibrils with one basal centriole. [18-21] The other group is a pattern of nine peripheral with no central fibrils.[3-8), 11, 22, 23] The former structure suggests a motile function and for the latter, there are only numerous speculations regarding their function. Among them it has been speculated that they are either rudimentary structures and products of specialization, or degenerate and functionally modified [4, 6, 8), 22-25] structures. Barnes[8] tentatively assigned a sensory function to such cilia, and Munger[22] suggests a chemoreceptoral function for the rudimentary cilia of the beta cells in the pancreas. Other investigators foresee a possible relationship between solitary cilia and mitotic activity.[26-28] On the basis of these references, the cilia in odontoblasts may be assigned to perform the sensory function. The significance of ciliated odontoblasts is discussed.

MATERIALS AND METHODS

Tissue for this study was obtained from normal, sexually mature mouse of both sexes. After the tissue was perfused with Half Strength Karnovsky fixative, the blocks of tissues containing the mandibular 1st molars and alveolar bone were dissected from the adult mice and split into two part of the tooth. The tissue samples were fixed in 1% ossmium tetroxide with 0.1m cacodylate buffer for another two hours. The specimens were washed in the same buffer, dehydrated in graded ethanols and embedded in a mixture of Epon resin in a routine manner.[29]

Following polymerization, sections 1 micron in thickness were made on an LKB ultrome with diamond knives and stained with 1% toluidine blue to select proper area of the tissue for observation. From selected blocks ultrathin sections of 700 Å were made with diamond knives on the same ultramicrotome. They were collected on 200-mesh grids, stained with uranyl acetate and lead citrate.

The sections were then observed in a Hitachi 8 electron microscope.

OBSERVATIONS

The cilia with a circumciliary invagination of the cell membrane frequently appears in the odontoblasts of the pulp and the cilium with various shapes extend into extracellular space. There are two kinds of the basal centriole structures orienting the different angulation to each other.

The two centriole structures of the cilia. (Fig. 1, 2):

The basal body consists of the distal and proximal centrioles and the orientation of two centrioles shows the parallel or sharp angles to each other. The cilia of the odontoblast in longitudinal-section with various shape and length project into the extracellular space. The tips are bulbous brush shapes and almost point to the pulpal direction. The bulbous cilium with the axes of two centriole being at the right angle to one another contains the ciliary vesicles and one of them shows the round shape with the central dense core, but the other is not clear in its central structure.

One of the brush shaped structures of cilium has a long irregular shaft and two basal bodies being at angles to each other. The fibrilar structures in the ciliary shaft are not clear in our observation.

One basal structure of the cilia. (Fig. 3, 4):

The brush shape of the cilium also occur in the odontoblasts with one basal structure. One of the cilium projects into the intercellular space near the nerve ending

DISCUSSION

The observation presented in this study may profitably be discussed in relation to the two questions, namely, the structure and the possible role of cilia in the odontoblasts and odontoblastic process, and pain mechanism of pulp.

Barnes[8] classified the cilia on the basis of basal bodies and the fibril arrangement in cilium. On the basis of the basal organization of cilia, they divided these structure into two general types: Cilia whose organization involves only one centriole, and those whose basal organization involves two discrete centrioles, the proximal centriole and the distal centriole.

According to the fibril pattern in the cilium, cilia was grouped two general categories. The first category includes those which show the characteristics 9+2 pattern of fibril. The second category of cilia includes those cilia modified from the basic 9+2 pattern by the loss of the two central fibrils, 9+0 pattern of fibril. In recent year Scherft and Daemz[9] described some remarkable exception to their classification of the cilia classified with respect to their single or multiple occurrence, internal structure, and number of associate centriole from their review of literature. The exceptions are the 9+0 fibril pattern and only one basal body, and slight variations on the 9+0 fibril pattern associated with two basal organization, such as 8+1. In ultrastructural studies on the odontoblasts and fibroblasts of the pulp. Garant[10] and Han[16] described that the rudimentary cilium arising from one of the pair of centriole was frequently encountered within the odontoblasts and adjacent mesenchyme cells of the pulp. The cilia often projected into the extracellular space but occasionally they were observed within a ciliary sheath enclosed by surrounding cytoplasm. The fibril of the ciliary shaft were arranged in nine doublet configurations and central fibril were not observed within them.

Thus their results of the fine structural studies on cilia in the odontoblasts and fibroblasts of the pulp were almost same as our findings except that in our study we found another group of cilia whose a basal organization consisting of only one centriole that are classified by Sherft[9] as one of remarkable exceptional groups. As Sherft[9] pointed out that the number of specimens observed was always small, it is not too bold to assume that this is a matter of chance, and that a second centriole might have been found in other sections. However cilia in the odontoblasts might belong to either the group whose a diplosomal basal structure or one of the exceptional group whose a basal organization consisting of only one centriole possessing 9+0 fibril pattern. The study of the pain mechanism in the pulp have performed in many ways but whether the dentin is innervated or whether the odontolblasts are transducer for nerve impulse is still controversial.[30-34] Rapp et

al.,[35] have claimed that the nerve fibers terminated about the cell bodies of the odontoblast. But Fearnhead[31] could find not synaptic or other special forms of connection between odontoblast and nerve. In ultrastructural studies of the dentin innervation Frank[15,32] (1966a and b) and Arwill (1967)[36] described that nonmyelinated nerve fibers lied in close relation to the odontoblastic process in human adult predentin and inner dentin. Roane et al.,[37] observed several examples of cellular structures resembling small nerve fibers associated with odontoblastic process. However there is no clear-cut explanation of how a stimulus applied to the dentin can influence nerve fibers that apparently don't penetrate all the dentinal tubules or even the bulk of the dentin.

Among it's explanations the odontoblasts and their process act as dentinal receptor mechanism whereby they participate in the innervation and transmission of sensory stimuli in dentin,[15,35] and the odontoblasts with their process are similar to the hair follicles with their hair extension. Every time the odontoblastic process is violated an impulse is sent to the terminal nerve endings situated on or near the odontoblastic body.[30] Moreover no one have paid their attention of how odontoblastic process can conduct the impulse to the nerve endings.

Mammarian receptor organs perceiving various type of stimuli are frequently ciliated or possess cilia derivatives. The 9+0 fibrils organization with two basal bodies strongly suggest that they are performing a sensory or conducting functions.

Example of such patterns are the connecting cilium in retinal rods,[23] Schwann cell in automatic nerve system,[4] the tip of a dentrite in the sensory cell of the locus ear,[38] the secretory cells in the pars distalis of the mouse hypophysis,[8] the myoepithelium in the female breast,[5] the cells from differentiating fibroblast and smooth muscle cells from neonatal chicken,[6] the neurons of the inner nuclear and ganglion cell layers of human and guinea pig retinas,[2] olfactory organs acoustic vestibular.[39]

Our findings of 9+0 fibril pattern of cilia in odontoblast and particularly in odontoblastic process would be reasonable to explain that the pulp pain may be conducted to the nerve endings either in dentin or in pulp through the ciliated odontoblast that might be an indicative of sensory function.

But the existence of the cilia in every odontoblast and odontoblastic process needs further investigation.

SUMMARY

Two different types of cilia appeared in the odontoblasts with secretory function of the dentin forming substances.

The cilia possessing the double nine peripheral fibrils and probably no central pairs of microtubules with two basal centrioles in odontoblasts and odontoblastic process is speculated to be an indicative of sensory function.

The other cilia with a single centriole may be associated with the motile function i agitating the extracellular dentin forming materials secreted from the odontoblast.

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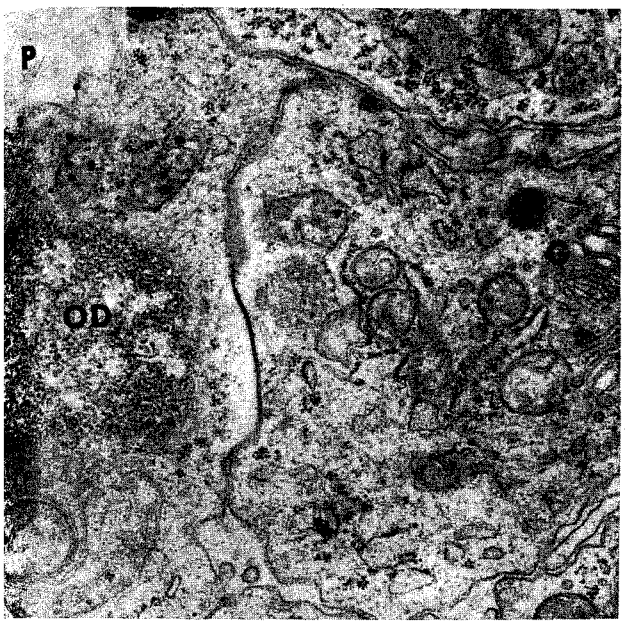

Fig. 1. Longitudinal section of a basal body: P: Predentin. G: Golgiaparatus. OD: Odontoblast X 37500

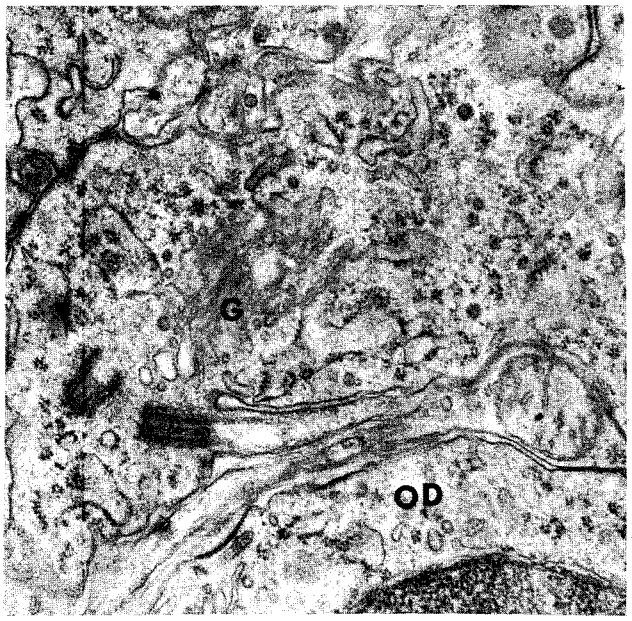

Fig. 2. Cilium of the odontoblast in longitudinal section. X 880

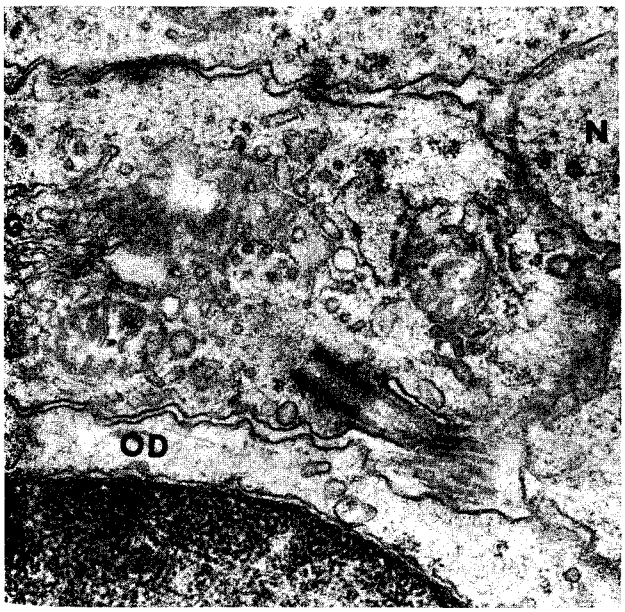

Fig. 3. One basal structure of the Cilia. X 14300

Fig. 4. Brush shape of the Cilium. X 20400.