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SOME REMARKS ON THE STRUCTURE OF DENTIN AS REVEALED BY THE ELECTRON MICROSCOPE

by

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The structure of dentin has been the object of close examinations for a long time. Various light microscopical investigations have resulted in a number of different opinions on the fine structure of the dentinal canals and the fibers of Tomes. Their appearance is dependent of their origin and here several theories have been forwarded. It is mostly assumed that these elements are differentiated from the connective tissue cells of the pulp. An interesting hypothesis, however, has been presented by *Westin* (1931) who regards the odontoblasts as being derived from the endothelium of the vessels. Through the development of the electron microscope with its high resolving power compared to that of the light microscope, the hope was cherished that the problem would possibly be solved. In a study of the present literature on the subject it is evident that there is still quite a great divergency of opinion.

It is almost generally accepted among electron microscopists that the dentinal fiber is a thin-walled protoplasmic process from the odontoblasts, the latter which are arranged on the wall of the pulp cavity and send their processes into the dentinal tubules (*Scott & Wyckoff*, 1947, 1950, *Syrrist*, 1949, *Syrrist & Gustafson*, 1951, *Helmcke & Jahn*, 1952 a, 1952 b, *Scott*, 1952, 1953, *Scott et al.*, 1952, *Kennedy et al.*, 1953, *Helmcke*, 1953, and *Schroff, Williamson & Bertaud*, 1954).

Helwig and *Menke* (1949) and *Menke* (1950) are of a different opinion. They regard the dentinal fibers as a bundle of true

fibers, showing a periodicity of the same type as collagen. *Helmcke* (1953) believes that these authors have mistaken some of the components in the organic ground substance for dentinal fibers.

A matter of great dispute is the question of the existence of the so called sheath of Neumann. The opinions for and against are rather equally divided. *Helmcke* (1953) in his excellent atlas on the ultra structure of teeth gives a good review of the electron microscopical works on this subject. He draws the conclusion that the sheath of Neumann in its original sense does not exist, which means that the cell membrane of the odontoblastic process lies in direct contact with the dentinal ground substance. He states, possibly correctly, that the differences of meaning as to this structure probably are due to an uncertainty of terminology.

The different appearance that the fibers of Tomes show in various investigations is probably due to the influence of different fixatives and decalcifying fluids on the protoplasm of the fibers (*Schroff et al.* 1954, a.o.). Often pictures presented show an empty space between the wall of the dentinal tubule and the odontoblastic process. This space has been looked upon by many as being an artefact due to shrinkage. An altogether different opinion is presented by *Schroff et al.* (1954). They postulate that the dentinal fiber has not originally filled out this space but that the latter has appeared after decalcification. This decalcifying effect, according to these authors, is due to the stronger mineralization of these parts and thus they have been more readily dissolved by the action of the acid of the decalcifying fluid. These workers present pictures on replica studies as well as thin sections.

MATERIAL AND METHODS

The investigations presented in this paper have been carried out on homoteeth, molars and pre-molars. Immediately after extraction, the tooth has been split and fixed in a veronal buffered osmic acid solution according to *Palade* (1952). After fixation, the tooth has been decalcified by 40 % formic acid, buffered with 7 % sodium formiate after first eliminating the enamel to accelerate the decalcification. As soon as this latter process has been completed, which has been controlled by x-ray examination,

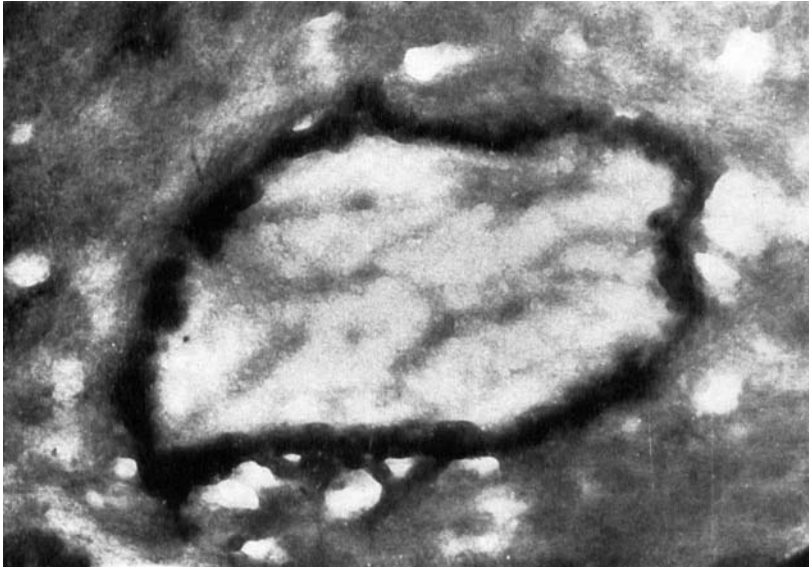


Fig. 1. Section from dentin. Homo tooth. Dentinal tubule completely filled by a fiber of Tomes. A distinct border structure is seen, apparently composed of small rounded elements and a linear structure. Electron micrograph. Fix.: buffered osmic acid. Magnification: 50 000 \times .

the preparations have been embedded in a mixture of n-butyl and methyl methacrylate according to *Newman, Borysko and Swerdlow* (1949). Sectioning for electron microscopy has been performed on a *Sjöstrand* ultra microtome (*Sjöstrand*, 1953) using polished *Schick* rezor blades (*Sjöstrand*, 1954).

RESULTS

In a number of sections, the contents of the dentinal canals, that is the odontoblastic processes, completely fill the lumen of the tubules. (Fig. 1.) Measurements on the diameter of the tubules show these to vary in our preparations between 1.0—1.6 microns. A surrounding empty space can not be seen here. The structure of the dentinal fiber shows in the fixation used a rather homogeneous appearance. A central bundle of fibers has not been seen.

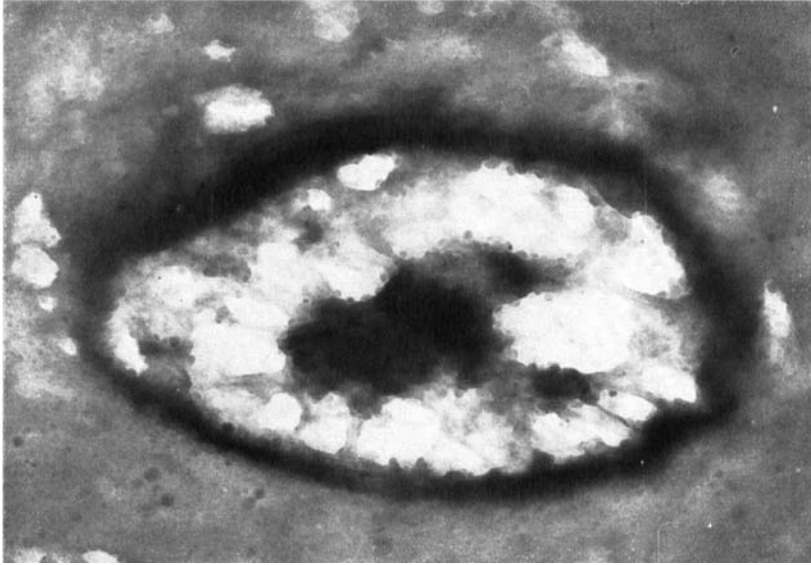


Fig. 2. Section from dentin. Homo tooth. Dentinal tubule with its contents. Appearance due to shrinkage. A surrounding border structure can be seen. Granular appearance probably due to fixation. Electron micrograph. Fix.: buffered osmic acid. Magnification: 50 000 \times .

The border between the odontoblastic process and the surrounding dentin shows an increased electron microscopical density, probably indicating a specialized border structure. It is difficult to determine, whether this structure in reality belongs to the fiber of Tomes, or to the wall of the dentinal tubule, as the lumen is completely filled by the fiber. The rather great density of this border structure makes it difficult to observe finer details. However it is possible here and there to study a minute structure, which has the character of on one hand, a number of closely lying rounded elements with a diameter of 400—800 A, on the other hand, a somewhat denser linear structure. The latter has a measureable thickness of around 200 A. In some sections it appears to be double contoured. The border zone as a whole has a thickness of around 0.1 micron.

In preparations not so well fixed, an obvious shrinkage of the dentinal fiber has occurred. (Fig. 2.) Here the above-mentioned

border structure can still be seen, surrounding the lumen of the tubules. The shrunken odontoblastic process can be seen lying in the center of the tubule but it is attached to the walls by thin bridges of protoplasm.

The fibers of the dentinal matrix, especially in the predentin show a periodicity similar to that of collagen fibers.

DISCUSSION

As *Schroff et al.* (1954) a.o. point out, the pictures of the dentinal tubules and their contents are dependent upon the quality of the fixation and the influence of different decalcifying agents. In our material, in spite of decalcification, spaces surrounding the fiber of Tomes have not appeared. This may be due to the degree of decalcification. The assumption of the above-mentioned authors that the fiber of Tomes is surrounded by a stronger mineralized zone can not be verified from our investigations, but need not therefore be incorrect. It is possible too, that the dentine in our preparations was situated closer to the predentin zone and thus less mineralized. The different pictures shown in various papers may also indicate a structural difference in the ground substance surrounding the dentinal tubules located in various places.

The importance of fixation for the appearance of the preparations is proved by the differences between well fixed and poorly fixed material. Due to the slow rate of penetration of many fixatives, osmium not excepted, those parts of the preparations, which do not lie close to the fixative are poorly fixed. The pictures here shown represent a section from the innermost dentinal layer, which has been in close contact with the fixing fluid (Fig. 1), and another section from a more distant layer (Fig. 2).

Of interest is the dense area between the tubule and the dentinal fiber. The small rounded elements which seem to form a part of this border zone may be cross-sectioned fibrils and the double-contoured linear structure has the appearance of a cell membrane.

SUMMARY

In an electron microscopical investigation of the dentinal tubules and their contents, it is shown that in well fixed material the odontoblastic processes completely fill the tubules. A border zone between the wall of the tubules and the fibers has been observed. Its structure has been discussed.

ZUSAMMENFASSUNG

EINIGE BEMERKUNGEN ZUR STRUKTUR DES ZAHNBEINES MIT
ELEKTRONENMIKROSKOP BETRACHTET

In einer elektronenmikroskopischen Untersuchung von den Dentinkanälchen und ihrem Inhalt wird gezeigt, dass in gut fixiertem Material die Odontoblastenfortsätze die Dentinkanälchen ganz und gar ausfüllen. Eine Grenzzone zwischen der Wand der Dentinkanälchen und den Tomes'schen Fasern ist beobachtet worden. Die Struktur dieser Zone ist diskutiert worden.

RÉSUMÉ

QUELQUES REMARQUES SUR LA STRUCTURE DE LA DENTINE
OBSERVÉE AVEC LE MICROSCOPE ÉLECTRONIQUE

Dans une étude ultramicroscopique sur les tubes dentinaires et leur contenu est indiqué, que dans une substance bien fixée les prolongements odontoblastiques remplissent complètement les canalicules dentinaires. Une zone limite entre la paroi des canalicules dentinaires et les fibres dentinaires est observée. La structure de cette zone est discutée.

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