Light and Electron Microscopy of Human Nails

by

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The common histologic features shared by the claw, hoof, horn, hair, feather, scale and nail are that they are all an appendage of the skin. These keratinized hard tissues are derivates of the epidermis. In common with these tissues, enamel is a mineralized hard tissue also derived from the epidermis. The protein of the enamel has the keratin property in that the enamel is of epithelial origin, and it appears to have structural features of the β-keratins, as determined by X-ray diffraction (PIEZ [2] 1962). On the other hand, however, histochemical reactions of the enamel demonstrated that its protein may be different from keratins (BARNETT and SOGNNAES [3] 1962).

Based upon the fact that the protein of the above cutic derivates belongs to keratins, that of the enamel has been widely regarded as coming under the same kind.

The nail described in this paper is a hard tissue composed of cornified cells of the nail matrix. Enamel, however, is a highly mineralized hard tissue formed by the secretion of the ameloblasts of the enamel organ which is in turn derived from the basal layer of the epidermis. Consequently, a great difference is found in their respective formations.

As already stated, the enamel is a tissue related to the nail from the viewpoint of histogenesis. Therefore, we have interest in the nail as much as in the enamel in spite of differences in their histochemistry and formation processes. The light and electron microscope aspects obtained from the nail tissue are described below, accompanied with their micrographs.

Material and Method

As material, there were collected the human nails of a normal appearance obtained from a male, aged 42, and two females, aged 34 and 39.

The replicas were obtained from the natural exterior surface of the nails and cross-sectioned surface near their free borders. Some of the nail cross-sectioned surfaces were etched with a solution of 4 percent NaOH at 50°C for 10 minutes.

Prior to electron microscopy, acetylcellulose film replicas from the nails had been examined under the light microscope. After this, for the purpose of their electron microscopy, the evaporated chrome-carbon film was obtained from the acetylcellulose film replica, where methyl acetate was used as a solvent agent of acetylcellulose film.

Descriptions of Individual Micrographs

In the first place, light microscopic aspects of the nail natural exterior surfaces are to be dealt with.

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Figs. 1–4 display light microscopic images of nail surface replicas. The pictures are shown in the negative presentation but the concavities and convexities in the photos are so given as to correspond to those of actual nail surfaces. Notably the cornified cells of the nail matrix are seen in the elevated manner, the intercellular regions being in the manner of depression.

As regards the light microscopic histology, it is evident that the nail is composed of cornified cells, flat and polygonal in shape, arrayed in the strata. The cornified nail cells retain residues of cell nuclei, abounding in fibrils. Also in this light microscopy, flat and polygonal cornified nail cells of very close contact are revealed in detail to have abundant fibrils. Some of these cornified cell fibrils consist of fibrous keratins, the other belonging to tonofibrils in the cells. Complicated fibrils of fibrous keratins are visible very densely distributed in the cells. The fully-keratinized nail cells contain the typical keratin pattern of filaments embedded in an amorphous matrix, which seems to be made up of γ-keratins. On the other hand, fibrous keratins of the cornified cells seem to belong to α-keratins.

Figs. 5–8 display electron microscopic aspects of human nail.

Frequent fine furrows visible on the exterior surface of the nail represent themselves between the fibril bundles of fibrous keratins embedded in an amorphous matrix. A remarkably intimate contact exists among the keratinized cells. Frequent cornified cells are found partially interdigitated closely with its neighboring cells.

Figs. 9–12 display an image from the exterior surface of ungual cornified cells fairly differing from the cases of Figs. 5–8.

As shown in Figs. 9–12, such an image is found here and there on the exterior surface of the nail. The structural concavities and convexities appear on the ungual exterior surface owing to the distribution of fibril bundles of fibrous keratins embedded in the amorphous matrix as given also in Figs. 5–7.

Fig. 13 portrays an exterior surface etched with a solution of caustic soda. Clear tissue structures are observed as the result of NaOH etching. In other words, the distribution behavior of fibril bundles composed of fibrous keratins is apparent there. The fibrils are seen embedded in the amorphous matrix in the shape of bundles, with various orientations. Since the orientations of fibril bundles are different, boundaries clearly appear between them on the cornified cells.

Fig. 14 is a photomontage displaying transversely cut surface neighboring its free border. Fibrous keratin fibrils are represented embedded in an amorphous matrix. Furrows are seen between fibril bundles. We can observe that this cut surface is poor of fibrous keratin fibrils but is abundant in the amorphous matrix. Roughly speaking, a longitudinal rod-like structure lying vertically in the picture merits our attention.

Considerations

Such tissues having the functions of skin appendages as scale, horn, claw, nail, hoof, feather and hair are without exception the derivates of the epidermis. These tissues contain abundant keratins. Keratins are usually divided into soft and hard keratins according to their hardness. The above tissues belong to hard keratins, to use customary distinction between "soft" keratins (the epidermis itself) and the "hard" keratins, feather, hair, horn, etc. The classification was put on a well-defined basis by GIROUD, BULLIARD and LEDBOND (1934[3]). The distinction is primarily based on the im-
mediate sensation of hardness or softness, and the fact that soft keratins (epidermis) desquamate while the hard keratins (hair, nail, etc.) persist. These properties are linked with other differences appearing in the course of keratinization and with the chemical composition of the final product. These are tabulated in the following table:

<table>
<thead>
<tr>
<th>Properties of &quot;soft&quot; and &quot;hard&quot; keratins</th>
</tr>
</thead>
<tbody>
<tr>
<td>Soft keratin</td>
</tr>
<tr>
<td>soft and pliable</td>
</tr>
<tr>
<td>desquamating</td>
</tr>
<tr>
<td>in course of development cells pass through a keratothyalin layer</td>
</tr>
<tr>
<td>higher lipid content</td>
</tr>
<tr>
<td>lower sulfur content (&lt;3%)</td>
</tr>
<tr>
<td>lower thermal stability</td>
</tr>
<tr>
<td>ratio of basic amino acids histidine, lysine and arginine = 1:4:4</td>
</tr>
<tr>
<td>less perfect ordering</td>
</tr>
</tbody>
</table>

This table is cited from “Keratin and Keratinization” by MERCER [1], Pergamon Press, 1961.

Fine intracellular fibrils in the epithel and epidermis usually end on desmosomes. The geometrical arrangement of these fibrils and their attachment to studs (desmosomes) on the cell membranes suggests a mechanical role in maintaining cell shape and rigidity, i.e. they are literally "tonofibrils". The tonofibrils are similar to the first formed fibrils in keratinizing systems and occur in enhanced amounts in precisely the situation where support is demanded. Similarly tonofibrils and keratinizing behavior are also found in the nails derived from the epidermis.

 α-keratin contains tonofibrils. Basic similarities were seen by GIROUD and LEBLOND (1951[3]) in both forms of keratinization by assuming the universal presence of tonofibrils in structures undergoing keratinization. They observed that tonofibrils are existent not only in Malpighian cells but also in all other keratinizing cells, including cornified cells. A resistant keratin is formed by the tonofibrils which are stabilized by disulfide bonds extending between adjacent polypeptide chains. BIRBECK and MERCER (1957[4]) demonstrated that keratin is a complex substance and besides tonofibrils other cytoplasmic constituents also play an important role in formation of the horny substance residing in terminal cells of keratinizing tissues.

ALEXANDER and HUDSON (1954[1, 4]) divided the keratin into a fiber-forming α-component (fibrous keratin) and a non-fibrous sulfur-rich γ-component (amorphous keratin) in which a fiber-forming α-component is embedded.

BIRBECK and MERCER (1957[4]) recognized the existence of a system of filaments (α-keratin) embedded in a sulfur-rich matrix (γ-keratin). BRODY (1959[1, 4]) demonstrated a similar pattern in the epidermis also in the case of nails. The proteins of nails consist of both fibril bundles of α-keratin and amorphous matrix of γ-keratin in which α-keratin fibrils are embedded. In keratinized tissues with their special requirements of strength,
cell surfaces become very convoluted, deeply interdigitated and heavily studded with desmosomes. Further the intercellular cement becomes modified in its solubility and chemical stability and forms dense intercellular sheets between the surfaces. As are with the above cases, the cornified cells of the nails also possess their intercellular intimacy of contact.

Summary

Human nails of the fingers and toes have been investigated by means of the light and electron microscopes. Most components of the nails are revealed to be composed of fibrous keratin (α-keratin), amorphous keratin (suspected γ-keratin) and tonofibrils. The α-keratin and tonofibrils are seen emdedded in the amorphous keratin (γ-keratin).

References

Figs. 1 and 2.

The photos display replica aspects of human nail surfaces under the light microscope.

×1600.
Figs. 3 and 4.
The pictures represent images similar to Figs. 1 and 2.
$\times 1600$. 
Figs. 5 and 6.
These electron micrographs are taken of the nail surface of the left ring finger of a 42 year old male person.
Figs. 7 and 8.

Fig. 7 is an electron microscopic image exhibiting nail surface of the left ring finger of 42 year old male person, while Fig. 8 portraying nail surface of the left middle finger of 34 year old female.
Figs. 9-12.

The electron micrographs represent portions of nail surfaces. Fig. 9 is taken of manicured nail of the thumb of 39 year old female. Manicure paint had been removed and nail surface replica was taken for the purpose of electron microscopy. Figs. 10-12 are taken of nail surface of the left little finger of 42 year old male.
Fig. 13.
An electron micrograph showing the nail surface of the left thumb of 42 year old male. The nail surface was etched with a 50°C solution of 4 percent NaOH for 10 minutes.
Fig. 14.
An electron microscopic photomontage depicts a transversely sectioned surface of the nail neighboring its free border. This image is taken from the left thumb of 42 year old male.