On the Form and Vascular Supply of the Newt Teeth

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Introduction

There have been many researchers on the histology of the newt teeth. Hertwig (1874) was the first researcher on the histology of amphibian teeth, and Oltmanns ('51) particularly reported an extensive work in this field using most kinds of the amphibia. Subsequently Gillette ('55) observed the frog teeth and Parsons and Williams ('62) studied the amphibian teeth in the phylogeny. In Japan, Asatani ('56) reported the histology of the amphibian teeth and his report is representative. From these reports, the so-called tooth pedicle was the most interesting subject in respect to its structure and origin.

On the other hand, the vascular supply of the newt teeth was only described by Hada ('62) using many kinds of vertebrate from the view point of comparative anatomy.

Recently, the scanning electron microscope became a useful instrument for the morphology, especially, the hard tissue, but the so-called soft tissue can be also observed under this instrument.

In this paper, the vascular supply of the teeth, from the view point of tooth development of the newt will be described. Generally the newt shows the most simple vascular supply in its tissues or organs among various vertebrates, and therefore the principle type of the vascular supply of the teeth can be expected and the continuous succession of tooth development in this vertebrate is also useful for this study.

Materials and Methods

Thirty adult newts (*Triturus pyrrhogaster*) were prepared for this study and fifteen of them were infused with 10% gelatine solution added india ink through the left ventricle. Noninfused newts were used for ordinary celloidin and epon sections, and the scanning electron microscopy. All of these infused or non-infused newts were decapitated. Most of the infused heads were cut into 500—300 μ serial transparent sections. Two of infused heads were also cut into 15 μ H. E. stained serial sections. From one of the non-infused heads, small blocks of the teeth were taken and embedded in the epon to be cut into 1 μ sections, which were stained with toluidine blue.

For the scanning electron microscopy, fourteen non-infused heads were used and they were dripped in the 1—1/10 N NaOH solutions to remove the soft tissue in various grades. The infused heads as mentioned above were used mostly for the celloidin section but a few were for the scanning electron microscopy, that is, they were kept in a refrigerator and then washed to remove the soft tissue, leaving the semihard infused vessels. These

hard or semihard tissues were dried with alcohol and acetone for the microscopy.

Observation

The maxillary and mandibular teeth are numbered ca. twenty respectively, and they make single row differing from fish teeth. Most part of a mature tooth is situated under the oral mucous epithelium and only its apex protrudes from the epithelium having large lingual and small buccal cuspids.

This bicuspid tooth has a curved conical crown ($60 \times 150 \mu$) and it connects with a cylindrical dental pedicle ($90 \times 150 \mu$) which has a large triangular or oval dental porta ($60 \times 130 \mu$) at the lingual side. However, size of the porta depends on the succeeding tooth germ. The dental pedicle connects with the basal bone in the mature tooth. The so-called anular sulcus can be recognized in the H. E. stained sections or dehydrated materials for the scanning electron microscopy. The anular sulcus of the dehydrated tooth shows granular structure under the electron microscope. Asatani ('56) pointed that the anular sulcus became evident by advancement of drying the tooth.

The lingual side of the mature pedicle has a thick wall in contrast to thinner buccal wall and is perforated by the connective tissue and vessels, where is the dental porta.

In area of the connective tissue between the dental lamina and basal bone there is a large sinusoidal plexus, and sinusoidal net can be recognized around the tooth germs or mature teeth. The celloidin section is so thick that the relation of the tooth germ and dental lamina to the sinusoids is not clarified, but in the epon section, relation of these structures can be distinctly shown. Hada ('62) reported some teeth having no capillary in the dental pulp in some kinds of fish, but in this vertebrate only the mature tooth has the capillary loop in its pulp.

The internal maxillary and internal mandibular arteries are main source of the tooth vascular supply, and external maxillary and external mandibular arteries are the accessory arteries for the teeth of mandibula and maxilla. Two internal arteries run along dental ridge and make the sinusoidal plexus in the groove of basal bone.

The sinusoidal plexus on the basal bone is arranged along the dental ridge and sends many vertical branches in direction to the mature teeth passing along the succession of the tooth development. In other words, two of these vertical branch ; medial and distal branches ascend along with the tooth germs and reach the mature tooth. At the first place, they ascend along the medial and distal margins of the lingual surface of the tooth germ in the last generation, and then ascend obliquely on the medial and distal surfaces of this tooth germ to reach the mesial and distal margin of the lingual surface of the tooth germ next to the last generation and so on. These vertical sinusoidal branches running along the succession of the tooth development like the side rails of the ladder. One of the side rails of the sinusoidal ladder is surrounded by four tooth germs, or two tooth germs and two mature teeth, that is, these vertical sinusoidal branches pass in a space between not only the successions of the tooth development but also between tooth germs in the succe-

ssion. The side rails of the sinusoidal ladder show a wavy course and they communicate each other by the horizontal communicating branches which resemble to the rungs of the ladder. These rungs are in the space between tooth germs, or between tooth germ and the mature tooth, and therefore every tooth germ is surrounded by the square sinusoidal net.

Fig. 1. Capillary plexus of the mature tooth and tooth germs in the newt.

Fig. 2. The vascular supply of the mandibular mature tooth and tooth germs in the nuwt.

In the dental papilla has no capillary but the mature tooth has a capillary loop in its pulp and the square sinusoidal net surrounds the dental crown. In addition to this sinusoidal net, the older sinusoidal net surrounds the dental pedicle which was newly built along with the elongation of the dental pedicle. The capillary loop entering the dental pulp originates from this new deeper sinusoidal net. The superficial and deeper sinusoidal nets connect with the side rails of the ladder, and the superficial net comes from the sinusoidal net around the dental crown in its previous stage. Hada ('62) described the capillary loop which sprouted from the side rails of the sinusoidal ladder buccal to the mature tooth, but the dental porta opens at the lingual wall of the dental pedicle and therefore the capillary loop sprouts from the lingual two side rails.

In some case a full-mature tooth shows a clot of the infusion material in the dental pulp and in other case this clot has small radial projections. They may show a degeneration of the capillary loop and also show tooth shedding.

The sinusoidal plexus on the surface of the basal bone receives the venous roots vertically from the tooth regions and then run to the distal part along the surface of the bone and becomes the internal maxillary or internal mandibular veins.

The connection between these capillaries or sinusoids with the other capillaries in the submucous tissue is also interest. Both of the submucous tissue of buccal and lingual mucous membrane have the capillary net and the sinusoidal net surrounding the mature tooth connect with the capillary net of the buccal submucous capillary net. However the capillary net in the lingual submucous tissue does not connect with the sinusoidal net surrounding the tooth or tooth germ, because the dental lamina protrudes between them. At the base of the dental lamina the sinusoidal plexus widely protrudes between and connects with the

buccal or lingual deep capillary net in a few parts. The buccal capillary net is a terminal of the external mandibular or external maxillary artery and the lingual capillary net is a terminal of the mucous branches of the internal mandibular or internal maxillary artery and these arteries or branches branch off from their stem at the distal part of the maxilla or mandible. On the buccal surface of the mature tooth or shedding tooth, there are two sinusoidal channels ; superficial and deeper and the superficial net connects with the buccal capillaries at its ends, that is to say, at the terminal of the rails of the ladder. As shown in Fig 14, form of the buccal capillary net is different from the sinusoidal net surrounding the tooth, but in some case the sinusoidal net which has no tooth intervenes between buccal capillary net and sinusoidal net showing mature tooth. Therefore the sinusoidal net will disappear at the time of tooth shedding and the connection between buccal capillary net and superficial sinusoidal net show that the degeneration of the deeper sinusoidal net prior to the degeneration of the superficial sinusoidal net.

Discussion

1. Form of the mature tooth. The bicuspid newt teeth have already been mentioned by many workers and their form and histology were clarified, but the three dimensional observation was not done. The interesting point is the so-called anular sulcus at which the crown is removed from the dental pedicle by 1 N NaOH. This weakly calcified tissue shows irregular margin showing granular structure on its surface. The H. E. stained section showed light red in the pedicle, in corresponding to the dental crown which shows deep red. The osseous connection between two neighbouring pedicles is quite few in this vertebrate, but sometimes the foramina at the lingual surface could be recognized. This foramina may be for nerves and vessels. The dental pedicle is long as it needs its own sinusoidal net around it. The large dental porta is for the capillaries and the nerves passing through it. Asatani ('56) described the connection between the dental pulp and the bone marrow but the authors could not find out such a connection including the capillary connection between them.

2. Vascular supply of the tooth. Hada ('62) described that the maxillary and mandibular arteries and veins run along surface of the basal bones, however the intramandibular or intramaxillary vessels could be observed in the authors' sections. Asatani said the source of the dental sinusoidal plexus was these intra-mandibular or intramaxillary vessels, Gaupp (1896) showed the internal and external arteries of the mandible and maxilla and reported the external mandibular artery branching off the submandibular artery. The internal arteries run along the ridge of the bone and make the arterial plexus which terminates in the sinusoidal plexus in a groove of the bone in the authors' sections. This sinusoidal plexus plays role of the stem for vascular supply of the teeth. Hada described that the capillary loop originates from lingual and buccal sinusoid but the author could not find out such a sinusoid sending the capillary loop at the buccal surface and the authors' result is acceptable from view point of the dental development.

3. Tooth development and its vascular organization. The dental lamina has ordinarily three tooth generations including the mature tooth. When the dental germ appears at the base of the dental lamina, the sinusoidal plexus sends vertical branches around it and these branches connect with preceding sinusoidal net at the mesial and distal margin of the tooth germ and these vertical branches communicate each other with horizontal sinusoidal branches. At this time, this dental germ is surrounded by square sinusoidal net. According to the tooth development, the sinusoidal net surrounding the dental germ may move together with the dental germ along the curved surface of the basal bone. In the tooth maturation, the sinusoidal net around the germ develops and surrounds the dental crown, and the elongated dental pedicle is surrounded by a new sinusoidal net, that is, the mature tooth is surrounded by two sinusoidal nets; superficial and deeper ones. This deeper sinusoid sends a capillary loop in the dental pulp. At the shedding of the tooth, the dental crown degenerates and fall out and then dental pedicle is resorbed together with the deeper sinusoidal plexus but the superficial sinusoidal plexus which connect with the buccal submucous capillaries remains in a short time after tooth shedding and finally will be resorbed in the buccal submucous capillary net.

Summary

Thirty adult newts (*Triturus pyrrhogaster*) were prepared for this study and fifteen newts were infused with 10% gelatine solution added india ink through the left ventricle. The remaining non-infused newts were used for the ordinal celloidin sections, epon sections or for the scanning electron microscopy. A few of the infused newt and most of the non-infused newts were dripped in solution of 1—1/10N NaOH to be removed the soft tissue completely or to leave the vessels and the hard tissue for the electron microscopy. The infused newts were mostly cut into the serial and transparent celloidin sections

The obtained results are as follows;

1. The stem vessels of the teeth come out from the internal mandibular and internal maxillary vessels and they run along the base of the dental lamina and terminate in the sinusoidal plexus.
2. The sinusoidal plexus sends many vertical sinusoidal branches to respective mature teeth along the succession of tooth development. These vertical sinusoidal branches communicate each other with the horizontal sinusoidal branch which situates between tooth germs in succeeding generation.
3. All of the dental germs and dental crown of the mature teeth are surrounded by the single sinusoidal net. When the tooth germ grows, the germ moves with the sinusoidal net and the mature tooth as fixed with the basal bone and elongated pedicle is surrounded by new deeper sinusoidal net which sends a capillary loop into the dental pulp.
4. At the time of tooth shedding, the sinusoidal nets around the mature tooth degenerate and the deeper net will disappear and the superficial net will be resorbed into the capillary net of the submucous buccal tissue.

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イモリの歯牙の形態と血管分布について

長谷川 一 夫・林 宏 文・石 田 雅 男

両棲類の歯牙の組織学的研究は Hertwig (1874), Oltmanns ('51), Gillete ('55), Parsons と Willams ('62), 浅谷 ('56) らによる報告がみられるが, その血管分布についてはわづかに波田 ('62) の記載をみるのみである. イモリは脊椎動物の中では比較的単純な血管分布を示すことが知られており, 更に歯牙の連続的発生が見られるので, 歯牙発生に伴う血管分布の変化あるいは歯牙発生と血管分布事情の相関を知り得るであろう事は推測に難くない所であろう. 本研究には30例のイモリを使用し, その半数は血管注入標本とし, 他の半数は無注入のまま, セロイジン連続切片, エボン切片として観察するか又は2例の注入標本と共に走査電顕の試料とした. 大部分の注入標本は500 μ 連続透明切片として観察した. 走査電顕試料は0.1~1 NのNaOHで処理し, 硬組織と血管, 又は硬組織のみとした. 上下顎歯の主幹血管は内上, 下顎血管であり基底骨上を歯板に平行に走る類洞血管叢となり, これより, 多数の枝が歯胚に沿って完成歯に向かい, 各歯胚をとりまく洞様毛細血管網となる. 完成歯では歯冠と歯台をとりまく深淺2層の網となる. 浅層のものは外上, 下顎血管と連絡している. すなわち歯胚の発生とともにそれをとりまく毛細管網が出来, 歯胚の移動と共に移動, 歯足の完成とともに深層の毛細管網を形成し, 歯牙脱落とともに変性吸収されるものである.

Explanation of photographs

- Fig. 3 : A scanning electron microscopic photograph of mature tooth crown treated by 1/10 N NaOH overnight (800 ×).
- Fig. 4 : An epon embedded thick section stained with toluidin blue. G ; mature tooth and dental germs. Around the mature tooth and dental germs, there are sinusoidal branches, and on the basal bone there is a sinusoidal plexus. (270 ×).
- Fig. 5 : A scanning electron microscopic photograph of tooth line of the mandibule treated by 1 N NaOH overnight. PO : porta of the dental pedicle (100 ×).
- Fig. 6 : A scanning electron microscopic photograph of the mandibular teeth and sinusoidal nets. The sinusoidal net was infused with 10% gelatine solution added india ink and then epithelium was removed (240 ×).
- Fig. 7 : A scanning electron microscopic photograph of a mature tooth surrounded by the sinusoidal net, and it was treated by 1/10 N NaOH overnight (240 ×). CR : dental crown, P : dental pedicle.
- Fig. 8 : A scanning electron microscopic photograph of the sinusoidal net and teeth infused with 10% gelatine solution added india ink and then epithelium was removed (240 ×). D : tooth, S : sinusoidal net.
- Fig. 9 : A light microscopic photograph of the stem vessels of mandibule. Horizontal section 500 μ (30×). A : internal mandibular artery, SP : sinusoidal plexus. V : internal mandibular vein.
- Fig. 10 : A light microscopic photograph of the sinusoidal plexus. Horizontal section of the mandibule 500 μ (30×). B. : buccal submucous capillary net. L : lingual submucous capillary net. SP : sinusoidal plexus. In this section there is no communication among those capillary net or plexus.
- Fig. 11 : A light microscopic photograph of the sinusoidal net around the teeth and dental germs. Horizontal section 500 μ (45 ×). In this section there is no communication among these sinusoidal nets and buccal or lingual capillary net. B : buccal capillary net. L : Lingual capillary net.
- Fig. 12 : A light microscopic photograph of the sinusoidal net around the mature teeth and dental germs. Horizontal section 500 μ (75 ×). D : dental germ. R : Clot of the infused material in the dental pulp.
- Fig. 13 : A light microscopic photograph of H. E. stained celloidin section. Frontal section of the mandibule 20 μ (82 ×). G : mature tooth. SP : sinusoidal plexus on the basal bone.
- Fig. 14 : A light microscopic photograph showing communication between buccal capillary net and superficial sinusoidal net around the mature teeth (100 ×). BC : buccal capillary net. D : mature tooth.
- Fig. 9—12 and 14 are transparent thick section infused with 10% gelatine solution added india ink into the vascular channels.