The Tooth Development of the Parrot Perch,
*Oplegnathus fasciatus*,
(family Oplegnathidae, Teleostei)

by
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Introduction
The parrot perch, *Oplegnathus fasciatus*, Temminck et Schlegel (Teleostei) has a set of characteristic beak-like tooth-plates which consists of small teeth and tooth germs layered on the jaw bone. We call it here "jaw-tooth".

As various developmental stages of the teeth and tooth germs are available from a single individual of this fish, many light and electron microscopical observations of them have been made in our laboratory[1–7].

So far, the development of the teeth and the correlation between the change in mode of feeding and that of the shape of the jaw-tooth have been reported by Hiyama[8] and Joh[9].

Examination by light microscopy of the development of small teeth made during 1977, 1978 and 1979 have revealed several new facts which are reported here.

Materials and Methods
The jaw-teeth were obtained from four specimens of each of the following three size-groups of the fish; the young measuring ca. 3 cm in total length, the juvenile[10] measuring ca. 8 cm in total length and the adult measuring ca. 30 cm in total length.

The jaw-teeth were immediately fixed with 10 percent neutral formalin for 24 hours. After fixation they were demineralized in 5 percent nitric acid in distilled water, 5 percent trichloroacetic acid in distilled water and 10 percent EDTA (pH 7.4) solutions, and were embedded in paraffin and celloidin.

Sagittal, frontal and horizontal sections were made to a thickness of ca. 8 μ in paraffin and ca. 15 μ in celloidin, and were then stained with Hematoxylin and Eosin, Azan, Aldehydefuchsin-Masson Goldner and Bielschowsky-Gömöri stain.

Results
A. The correlation between the change in mode of feeding and that of the shape of the jaw-tooth

The external appearances of jaw-tooth in each stage (young, juvenile and adult) are shown in Fig. 1.
1. The young stage measuring ca. 3 cm in total length
   The upper and lower jaw-teeth are both rectangular in shape. The jaw-tooth is not so mineralized as in the adult that it is easy to section.
   The maximum replacement dentition in a mesial plane of jaw-tooth has one functional tooth and five prefunctional teeth. Replacement teeth are scattered on the jaw bone.
   The young fishes of this stage live under drifting seaweeds and eat small crustaceans.
2. The juvenile stage measuring ca. 8 cm in total length
   The shape of the jaw-tooth resembles that of the adult. Replacement teeth are larger and more densely ordered than in the young.
   The maximum replacement dentition has one functional tooth and seven prefunctional teeth.
   The juvenile fishes of this stage live in the shade of a fish preserve and eat much larger crustaceans.
   After this stage, the fish shows an increasing inclination for polyphagia.
3. The adult stage measuring ca. 30 cm in total length
   The jaw-tooth assumes a characteristic beak-like shape. The jaw-tooth becomes very hard.
   The form of the outer teeth built on the outer surface of the jaw bone becomes increasingly distinguishable from that of the inner teeth.
   The maximum replacement dentition has one functional tooth and fourteen prefunctional teeth.
   The adult lives over rocky bottom and eats hard echinoderms and barnacles by pecking at them.

B. The development mode of replacement teeth in each of the three stages
1. The young stage measuring ca. 3 cm in total length
It has been reported that the tooth germ begins to appear when the total length of 11.5 mm is attained[8].

In this young stage, a replacement dentition has 4 to 5 prefunctional teeth. Figs. 2, 3 and 4 show each developmental stage of prefunctional teeth in a replacement dentition. Only a tapered tooth (A) is a functional tooth and the leftmost tooth germ (B) is in an early developmental stage. Prefunctional teeth move on to

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**Fig. 2** Replacement dentition in young stage

**Fig. 3** Replacement dentition in young stage - sagittal section (H-E stain)
the direction shown by the arrow (Fig. 2). The tooth germ begins to develope at the point of dental laminas which are formed by the penetration of both oral vestibule epithelium and oral cavity proper epithelium into the mesodermal region like a sac (Figs. 5, 6).

When the future outline of the enameloid matrix is completed and its mineralization begins to occur, the tooth germ begins to depart from the dental lamina and changes its direction.

When the development of the tooth germ proceeds to the early enameloid mineralization stage, the dental lamina that will form the next tooth germ begins to penetrate (Fig. 7). At the enameloid hyper-mineralization stage, the next succes-sional tooth germ attains the development stage of enameloid formation (Fig. 3-1).

The tooth germ of enameloid hyper-mineralization stage comes to possess longer
ameloblasts and odontoblasts and increases in volume. This is characteristic of this stage.

The inner tooth (Fig. 4-C) is observed sporadically in the mesodermal region. The development of the bone is uncompleted and active osteoblasts are observed around the bone (Fig. 8).

2. The juvenile stage measuring ca. 8 cm in total length
   In this stage, the shape of jaw-tooth markedly differs from that in the previous stage.

   Fig. 9 shows outer teeth of a mesial plane and a labial distal edge as well as inner teeth which do not appear in the same visual field on sections.

   Fig. 10 shows the replacement dentition of the outer teeth. When the development of the tooth germ proceeds to the enameloid formation stage, the dental lamina forming the next tooth germ bulges at the top.
Fig. 8 Osteoblast around bone (arrow)
-sagittal section (H-E stain)

Fig. 9 Replacement dentition in juvenile stage

Fig. 10 Replacement dentition in juvenile stage
-sagittal section (H-E stain)
In a replacement dentition, teeth of enameloid formation stage, enameloid mineralization stage, enameloid hyper-mineralization stage and dentin formation stage are recognizable in this order.

It has been confirmed by us that in this juvenile stage, teeth of various develop-
mental stages appear simultaneously, which is not the case with the young stage. This means that the penetration of the dental lamina is more frequent.

The outer teeth of the labial distal edge are smaller in size and there are a smaller number of teeth in a replacement dentition (Fig. 11).

The inner teeth become layered and there are three to four prefunctional teeth in a replacement dentition (Fig. 12).

3. The adult stage measuring ca. 30 cm in total length

Fig. 13 shows the outer teeth of a mesial plane and a labial distal edge as well as the inner teeth which are not visible in the same visual field on sections.

The maximum replacement dentition has one functional tooth and fourteen prefunctional teeth. Teeth of enameloid formation stage, enameloid mineralization stage, enameloid hyper-mineralization stage and dentin formation stage are recog-

![Fig. 13 Replacement dentition in adult stage](image)

![Fig. 14 Replacement dentition in adult stage -sagittal section (AF-MG stain)](image)
When the development of the tooth germ further proceeds to the later enameloid formation stage, the dental lamina of the next tooth germ is extended (Fig. 16).

Fig. 17 shows the outer teeth of the labial distal edge and Fig. 18 shows the outer and inner teeth in a horizontal section. The shape of the outer teeth of the labial distal edge and inner teeth which are formed by the penetration of the dental lamina of the oral cavity proper epithelium is characteristically round in shape in comparison with the outer teeth of the mesial plane.

Fig. 19 shows the correlation of the outer teeth of replacement dentition in a horizontal section.

Fig. 20 shows the development and relationship between the teeth of each replacement dentition in a sagittal continuous section illustratively. The maximum replace-
ment dentition is row-I and the next is row-II, and each tooth in one row is numbered according to its developmental stage one, two, three, and the tooth germ is numbered zero.

There are developmental lag in tooth maturation between corresponding teeth of row-I and those of row-II. The tooth germ is formed after the dental lamina has

Fig. 17 Replacement dentition of outer teeth in labial distal edge -sagittal section (H-E stain)

Fig. 18. Outer teeth and inner teeth of adult -horizontal section (H-E stain)
been extended backward and penetrated expanding its top. The developing tooth germ moves forward and enters each replacement dentition that has already been formed and becomes a successional tooth.

The movement of the tooth and bone in the adult is considered to happen in the following sequences: the tooth in replacement dentition departs from the dental lamina at the enameloid mineralization stage, and from this stage to the enameloid hyper-mineralization stage the volume of the tooth germ increases and so does the height of ameloblasts. Further, after the dental papilla is absorbed, invasion of newly formed bone takes place (Fig. 21) and the outer dentin extends in one direction (Fig. 14) and is anchylosed with the bone. Thus, these result in the movement of teeth and bone, and the front prefunctional tooth becomes an eruptive tooth.

The shedding of the tooth is thought to happen by physical erosion, for no part resorbed by osteoclast is seen.
Fig. 22 shows abrasion of the outer tooth in a sagittal section and Fig. 23 shows erosion of bone in a horizontal section. After the eruptive tooth is shed, a successional tooth appears and becomes an eruptive tooth.

**Discussion**

It is known that the teeth of fishes are polyphyodontia and that the oral teeth of lower vertebrates such as fishes reflect the function of feeding mechanism. So the shape of the oral teeth varies greatly.

The jaw-tooth of the parrot perch, Oplegnathus fasciatus, which is composed of many small layered teeth is a remarkably specialized tooth.

It has been reported that only a few fishes such as Pseudoscarus muricatus[11], Callvodon ouifrons, Calotomus japonicus[12], and Sphoeroides niphobies[13] have
similar jaw-teeth, but there have been no reports about its developmental process and its formation mechanism of layered teeth which compose the jaw-tooth.

Specialities and generalities of formation process of jaw-tooth of *Oplegnathus fasciatus* will be discussed below on the basis of the results of our research.

1. The correlation between tooth and dental lamina

   The tooth germ of *Oplegnathus fasciatus* are formed at the top of the dental lamina which is formed by the penetration of the oral epithelium into the bottom of the mesodermal region as in *Pagrosomus unicolor*[14], and one dental lamina forms one tooth germ of the replacement dentition as in flat-fishes[15] and scombroid fishes[16].

   Besides, it is characteristic of *Oplegnathus fasciatus* that the penetration of dental lamina occurs from two directions; namely, from the epithelium of oral vestibulum and from that of the oral cavity proper. This and increase in frequency of penetration numbers of the dental lamina are thought to be the cause of the formation of many tooth germs.

2. The increase in tooth numbers

   In *Oplegnathus fasciatus*, it was observed that the tooth germ was formed quickly and the developing process of matrix formation and tooth mineralization occurred in the same pattern in young, juvenile and adult fishes. In other words, it is considered that the speed of enameloid and dentin matrix formation and mineralization are uniform in this species.

   Then it is thought that the rapid increase of tooth numbers after the juvenile stage of this fish is caused by increase in frequency of penetration numbers of dental lamina.

   Because, in juvenile fish tooth germs of an early developmental stage which are not observed in young fish (like the enameloid formation stage and early mineralization stage) are observed in a replacement dentition and the penetration of dental lamina of the next successional tooth happens at the time of enameloid formation.

Fig. 23 Erosion of bone
-horizontal section (H-E stain)
stage, not at the enameloid mineralization stage in young fish.

3. The movement of teeth and bone

As for the movement of teeth, Kirino[17] suggested that there are two cases of being pushed upward by newly formed epithelium and by directions of argentophil fibers.

In Oplegnathus fasciatus, the increase of tooth volume in enameloid formation stage and enameloid mineralization stage, especially the extension of ameloblasts' length and the absorption of dental papilla and newly formed bone invading among teeth are thought to make possible the movement of teeth and bone. This newly formed bone is a sort of trabecular bone which is suited to rapid bone remodelling observed in Piranhas[18].

4. The replacement of teeth

The shedding of eruptive teeth is caused by mechanical abrasion. No absorption image of bone by osteoclast as in the case of trout[19] is seen. As in a flat-fish[20] the eruptive tooth is defaced in turn from the outer layer.

As Oplegnathus fasciatus pecks at hard materials, abrasion of the functional tooth occurs so often that the tooth is replaced rather quickly. As indicated by Berkovitz[21], the mode of eruption of the next tooth fits in with feeding mechanism. The structure of dentition of Oplegnathus fasciatus fits in with the aim of pecking at hard materials.

5. The relationship between the structure of jaw-tooth and feeding habit

There is clearly a structural differentiation in piranhas that the anterior teeth grasp foods firmly and the posterior teeth are suited for cutting[18].

In Semicossyphus reticulatus the same differentiation is observed that the outer anterior four teeth are strong like canine teeth and the inner teeth are small and finger-shaped[22].

In the jaw-tooth of Oplegnathus fasciatus is also an obvious structural differentiation. The anterior teeth of the mesial outer teeth which peck at hard materials are sharply pointed and their replacement dentition is densely packed. On the other hand, the inner teeth and outer teeth of the labial distal edge which grasp materials are round in shape like molar teeth. Thus the dentition is correlated favorably with the feeding habit.

Conclusion

The development of small teeth in the jaw-tooth of Oplegnathus fasciatus was examined by light microscopy, and the correlation between its change in shape of jaw-tooth and the mode of feeding was studied.

Results are as follows.

1. The tooth germs are formed at the top of the dental lamina which penetrates into the mesodermal region like a sac.

2. The penetration of the dental lamina occurs from two directions; namely, from the oral vestibulum epithelium and the oral cavity proper epithelium. This makes it possible to form many tooth germs.

3. The rapid increase of tooth numbers after the juvenile stage is caused by
increase of penetration numbers of dental lamellas.

4. In the adult, an obvious structural differentiation is observed between the mesial outer teeth which peck at hard materials and the inner teeth which grasp materials.

5. The eruptive tooth in each replacement dentition is only an outermost tooth.

6. The shedding of the eruptive tooth is caused by mechanical abrasion with the jaw bone.

References
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