Bulletin of Fish Biology	Volume 11	Nos. 1/2	31.12.2009	87-98

On the structure of teeth in the viperfish *Chauliodus sloani* Bloch & Schneider, 1801 (Stomiidae)*

Zur Struktur der Zähne des Viperfisches *Chauliodus sloani* Bloch & Schneider, 1801 (Stomiidae)

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Summary: We used histology (LM) and scanning electron microscopy (SEM), some data obtained by transmission electron microscopy (TEM) and x-ray microanalysis (EDX) to characterize functional oral teeth of the viperfish *Chauliodus sloani*. Teeth are of different length and their apices are variable to some extent. The longest are the front teeth of the lower jaw, which extend out above the upper jaw up to the eyes. The second longest are the front teeth of the premaxillae. Teeth form a kind of cage when the mouth is closed probably preventing prey items from escaping. Teeth are non-depressible and firmly attached to the jaw bone. Labially the tooth is elongated forming a tongue-like projection that covers parts of the dentigerous bone probably allowing the teeth to resist pressure from inside the mouth, e.g. by struggling prey. Teeth are not clearly divided in a pedestal (“bone of attachment” of many authors) and the dentine shaft proper, but the transition to the putative bone of attachment is characterized by a diaphragm-like structure inside the tooth, which is more conspicuous lingually than labially. Teeth possess enameloid caps and a layer of collar enameloid decreasing in thickness towards the base. The dentine appeared stratified in some teeth with alternating layers of densely and less densely arranged collagen fibrils. The pulpa contains a network of pigmented cells closely attached to the (pre)dentin, which probably represent odontoblasts. Ca-contents decreases towards the tooth base and was smallest in the jaw bone.

Key words: Oral dentition, mode of attachment, Ca-content

Zusammenfassung: Die Bezahnung der Prämaxillaria, Maxillaria und Dentalia des Vipernfisches *Chauliodus sloani* wurde vornehmlich lichtmikroskopisch und rasterelektronenmikroskopisch, zum Teil auch transmissionselektronenmikroskopisch und röntgenmikroanalytisch (EDX) untersucht.. Die Zähne sind unterschiedlich lang; die Form ihrer Apices variiert. Die Frontzähne des Unterkiefers sind am längsten und reichen außen bis zu den Augen. Die zweitlängsten Zähne sind die Frontzähne des Prämaxillare. Wenn Unter- und Oberkiefer geschlossen sind, bilden die Zähne eine Art Käfig, der möglicherweise einmal gefangene Beute nicht entkommen lässt. Die Zähne sind fest am zahntragenden Knochen verankert. Die Zahnbasis ist labialseits zu einer Zunge verlängert, die so auf dem Kieferknochen liegt, dass sie offenbar dem starren Zahn erlaubt, einem Druck, der z.B. von einem größeren, sich im Maul bewegenden Beutetier ausgeht, standzuhalten. Die Zähne sind nicht deutlich in Sockel (=Anheftungsknochen) und Dentinschaft gegliedert, doch ist der Übergang zu einem möglicherweise vorhandenen Sockel durch einen Wulst, der wie eine Blende ins innere des Zahnes vorspringt, gekennzeichnet. Der Wulst ist labial schwächer ausgebildet als lingual. Die Zähne besitzen eine Kappe aus Enameloid sowie eine Enameloidschicht auf dem Dentinschaft, die zur Basis hin dünner wird. Das Dentin ist zum Teil geschichtet und enthält dichter und weniger dicht angeordnete Kollagenfibrillen. In der Pulpa findet sich unmittelbar am (Prä)dentin ein Netzwerk von

*Dedicated to Prof. Dr. F. Kirschbaum on the occasion of his 65th birthday and retirement.

pigmentierten Zellen, sehr wahrscheinlich Odontoblasten. Der Ca-Gehalt (gemessen an der Oberfläche der Zähne) nimmt in Richtung Basis und zahntragendem Kochen ab.

Schlüsselwörter: Mundzähne, Dentale, Verankerung, Ca-Gehalt

1. Introduction

The viperfish *Chauliodus sloani* is a predacious, mesopelagic teleost living in depths ranging from 200-4700 m; usually, however, these fishes are found at depths of 494-1000 m (e.g. GAGE & TYLER 1991, SHINOHARA et al. 1994, MUNDY 2005). Larger specimens tend to reside at a greater average depth than smaller specimens, but vertical migrations typically occur (GIBBS 1984, BUTLER et al. 2001). As shown by stomach examinations, *C. sloani* specimens have broad diets and appear to eat just about anything they can fit into their mouths. Prey items range from crustaceans and cephalopods to fishes (e.g., SUTTON & HOPKINS 1996, WILLIAMS et al. 2001, for further readings see FROESE & PAULY 2009). Larger specimens are believed to be exclusively piscivorous and may swallow fishes reaching 63% of their own body length. Hunting strategies of *C. sloani*, however, elude direct observation. Fishes probably pursue ambush predation alluring the prey with their photophores and/or arching of their elongated first dorsal ray over the head and in front of the widely opened mouth (CLARKE 1982; GARTNER et al.1997, BUTLER et al. 2001; see also TCHERNAVIN 1953).

The feeding apparatus of *C. sloani* is remarkable and has attracted considerable attention over the years. The most comprehensive morphological and functional analysis was published by TCHERNAVIN (1953), who showed that the skull is hinged and can rotate. Further, *C. sloani* lacks a floor in the mouth to allow for jaw expansion and large prey items to be ingested. TCHERNAVIN (l.c.) also described the long and sharp teeth (fig. 1 A), relatively few in number on the premaxillary and dentary, mentioned their strikingly identical number, position, relative size and shape in all specimens he examined and assigned the variously long and shaped teeth to specific functions.

In this note we present some new details of the oral teeth of *C. sloani* obtained from some specimens immediately frozen after capture.

2. Material and methods

2.1. Animals

The *Chauliodus sloani* specimens were collected from 11.10 to 22.11.2002 during the expedition of the "Walther Herwig III" to the Irminger and Greenland sea (Atlantic Ocean) organized from the Institute of Marine Research at the University of Kiel, Alfred-Wegener-Insitute for Polar NSD Marine Research, Bremerhaven, and the Institute of Hydrobiology and Fisheries Science Hamburg. Fish were captured with a Gloria net in depths of 680-708 m. After capture the specimens varying from 22-24 cm in total length were frozen and stored in a deep freezer until use.

2.2. Preparation for SEM, LM and TEM

The heads of defrosted specimens were macerated in water for five days. Then, the dentigerous bones were exposed to 0.5% KOH, cleaned after some days with a fine brush, washed in water and stored in ethanol. Further, some teeth stored in 70% ethanol were decalcified in a 25 % (w/v) EDTA solution at pH 7.5 up to four weeks (ROMEIS 1989), washed in buffer and distilled water and stored also in 70 % ethanol.

Whole teeth or fragments of teeth, untreated or decalcified, were viewed under a light microscope using transmission light and the DIC (Nomarski) technique. Despite the general poor preservation of specimens, fragments of demineralised teeth (upper part and the attachment zone) were fixed in 2% osmium tetroxide in phosphate buffer at pH 7.4, dehydrated in a graded series of ethanol

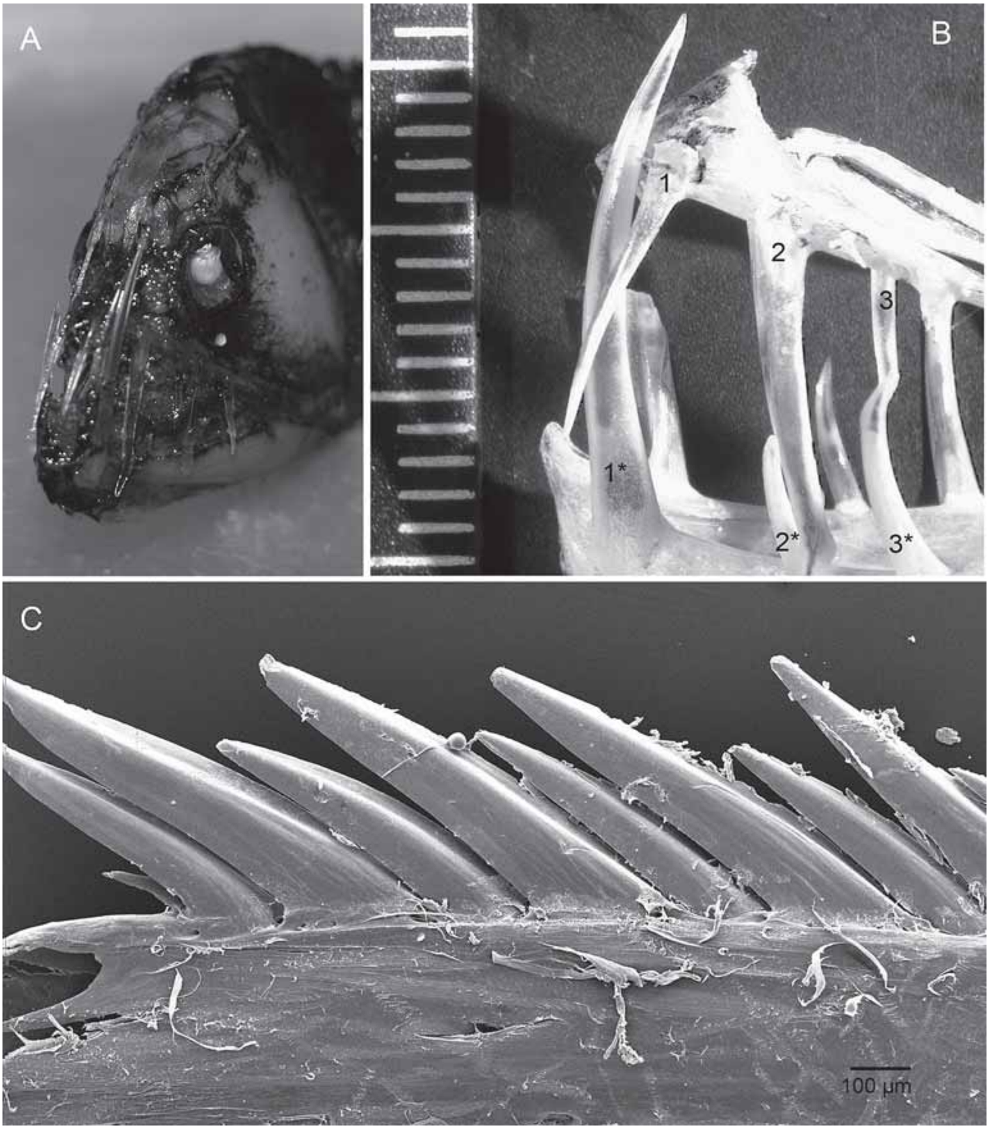


Fig. 1 A-C: Dentition of *Chauliodus sloani*. **A** Head, overview. **B** The first three teeth of the left premaxilla (TP 1, 2, 3) and the opposing teeth of the dentary (TD 1*, 2*, 3*). **C** Teeth of the maxilla (SEM), lingual view.
Abb. 1 A-C: Bezahnung von *Chauliodus sloani*. A Kopf, Übersicht. **B** Die ersten drei Zähne des linken Prämaxillare (TP 1, 2, 3) und die gegenüberliegenden Zähne des Dentale (TD 1*, 2*, 3*). **C** Zähne des Maxillare (REM), lingual.

and embedded in Epon. For histology (LM) semithin sections (1 µm thick) were stained with toluidine blue-borax. Despite decalcification periods up to four weeks ultrathin sectioning proved to be extremely difficult. The few usable ultrathin sections were stained with uranyl acetate and lead citrate and examined under a Hitachi H 6000 transmission electron microscope (TEM).

For scanning electron microscopy (SEM) untreated and decalcified teeth were dehydrated, air-dried or freeze-dried, glued on metal stubs, sputtered with gold and examined under a JEOL JSM 35 CF scanning electron microscope. Some pieces of the untreated jaws with attached teeth were broken to have a look inside the teeth.

Material was digitally photographed and images postprocessed using Adobe Photoshop 4.0.

2.3. Electronprobe x-ray microanalysis

Calcium, phosphor, magnesium and iron levels were de-termined in various regions (apical, middle, basal and jaw bone) at the surface of teeth. The air-dried specimens were glued to aluminium stubs with carbon pads and analysed by an energy dispersive system (EDX; Ametec, Wiesbaden) in the Hitachi REM S3000. The EDX system was calibrated with Al-Cu (Software: Genesis, Version 5.1.2 updated in 2008). Quantitative analysis was made measuring the intensity of Kα-emissions obtained by the mode of point analysis. Each point was measured for 200 seconds at a counting rate of 2000-4000 cps.

3. Results

3.1. Gross morphology

The oral teeth of *C. sloani* are located on the dentary and the premaxillary and maxillary bones and form a single row along the crest of the bones (see figs. 1 B, C). The terminology and numbers of teeth follow Tchernavin (1953; see plate VI figure 29 in this article) and do not include replacement teeth.

The most conspicuous teeth of the premaxillae, i.e. TP1-TP4 (they are two very small teeth close to TP2 and TP3), and the most anterior teeth of the dentaries (TD1-TD3) are large, but considerably differ in size and shape (figs. 1 A, B). They are larger than the theeth on the posterior portion of the dentaries (TD4-TD6) and on the maxillae. The numerous maxillary teeth stand close with each other like the teeth of a saw. They are directed backwards and have a sharp anterior and posterior ridge (fig. 1 C).

On the premaxilla TP1 is nearly straight, thin and pointed with distal cutting surfaces. TP2 is the longest in the series with a cylindrical basis and a curved flattened distal part. TP3 and TP4 are similar to TP2, but considerably smaller. The strong dentary tooth TD1 is the longest of all teeth. Its distal portion is bent posteriorly and has sharp anterior and posterior edges and the inner edge shows a small indentation.. The remaining teeth (TD2-TD6) differ in size (TD3 is the largest), but are more or less similarly shaped with pointed apices bent posteriorly and an anterior and posterior sharp ridge (see fig. 1 B).

Attachment of the teeth to the jaw bone is remarkable. At the labial face the basis is elongate forming a tongue-like extension, which covers a part of the labial surface of the bone. At the lingual surface this tongue is missing and the tooth appears to be directly attached to the crest of the bone (fig. 1 B; see also fig. 4).

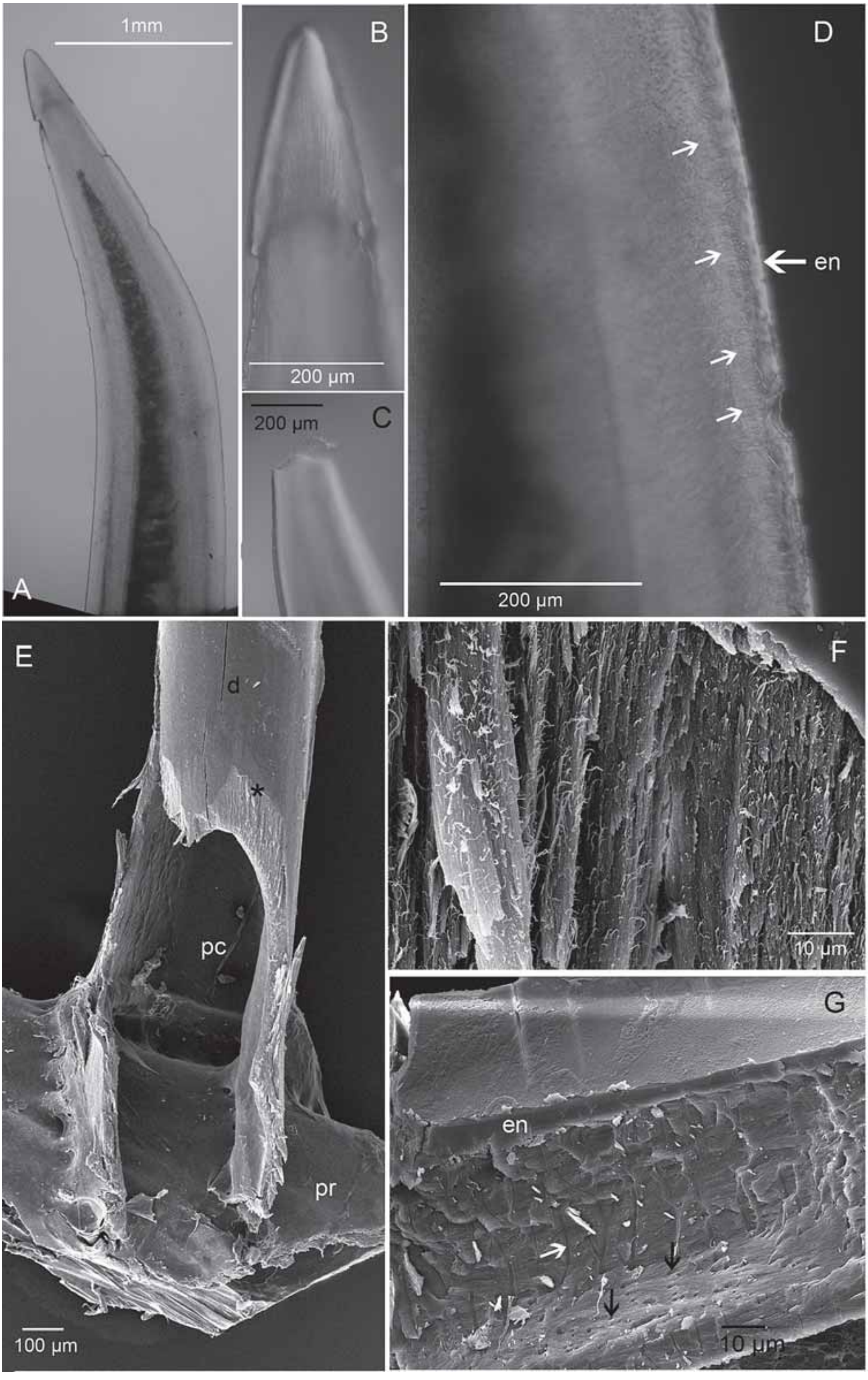
The following descriptions only refer to the larger premaxillary and dentary teeth.

3.2. Structure of teeth

When viewed under the light microscopy, teeth showed a pigmented network in their pulps

Fig. 2 A- G: Total preparations (A-D) and SEM of the teeth (E-G) of *Chauliodus sloani*. **A.** Note pigmentation in the pulp cavity. **B** Enameloid cap and dentine tubules (Nomarski). **C** Ditto, decalcified (Nomarski). The enameloid cap is missing. **C** Dentine shaft, periphery. Note dentine tubules and the enameloid layer (Nomarski). **D** Premaxillary tooth with broken basis, labial view. The asterisk marks the region pictured in E. **E** Dentine, detail of D. **F** View into the pulp showing dentine tubules (arrows); d dentine shaft, en enameloid, pc pulp cavity, pr premaxilla.

Fig. 2 A-G: Totalaufnahmen (A-D) und REM-Bilder (E-F) der Zähne von *Chauliodus sloani*. **A** Man beachte die Pigmentierung der Pulpa. **B** Schmelzkappe und Dentinkanälchen. (Nomarski). **C** Dito, entkalkt (Nomarski); die Enameloidkappe fehlt. **D** Praemaxillarzahn mit aufgebrochener Basis, labial. Der Stern kennzeichnet den in E abgebildeten Bereich. **E** Dentin, Ausschnitt aus D. **F** Blick in die Pulpa. Dentintubuli (Pfeile). d Dentinschaft, en Enameloid, p Pulpahöhle, pr Prämaxillare.



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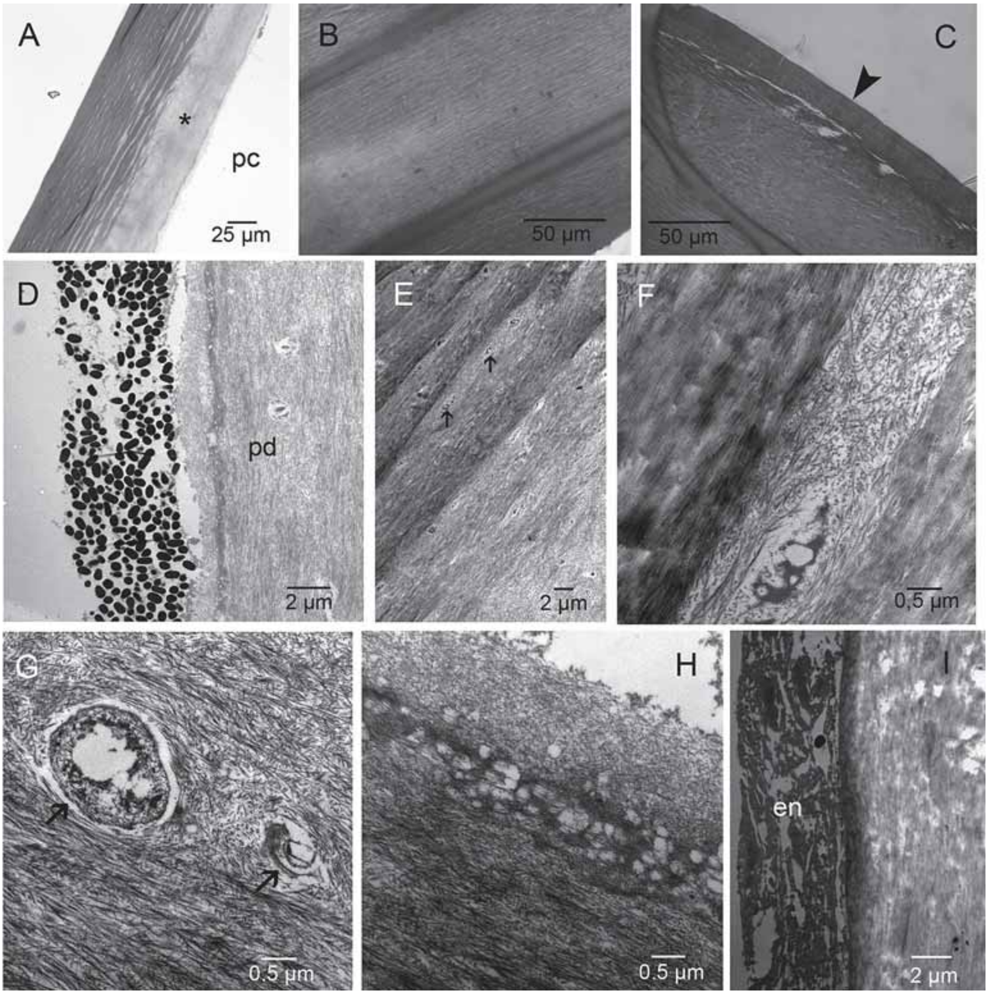

Fig. 3 A-I: Longitudinal semi-thin sections (A-C) and TEM-micrographs (D-I) of decalcified teeth of *Chauliodus sloani*. **A** Dentine shaft with densely outer and less densely arranged inner collagen (= predentine). **B** Periphery of a tooth. Note dentine tubules (arrows). **C** Outer partly preserved enameloid layer (arrowhead). **D** Pigmented odontoblasts (left side). **E-H** Different aspect of collagen layers and dentine tubules (arrows) in the dentine shaft. **I** Periphery of a tooth with remnants of the enameloid layer (right side). en Enameloid,, pc pulp cavity, pd predentine.

Abb. 3 A-I: Semidünnschnitte, längs (A-C) und TEM-Bilder (D-I) von entkalkten Zähnen *Chauliodus sloani*. **A** Dentinschaft mit dichtem äußeren Kollagen und weniger dicht gelagertem innerem Kollagen (= Prädentin; Stern). **B** Peripherie eines Zahnes. Man beachte die Dentinkanälchen (Pfeile). **C** Teilweise erhalten gebliebene Enameloidschicht (Pfeilkopf). **D** Odontoblasten mit Pigmentgrana (links). **E-H** Unterschiedlich dichte Anordnung der Kollagenfibrillen sowie Dentinkanälchen (Pfeile) im Dentinschaft. **I** Peripherie eines Zahnes mit Resten der Enameloidschicht. en Enameloid, pc Pulpahöhle, pd Prädentin.

extending up to the apex (fig. 2 A). Teeth are covered by a more or less compact layer considered as enameloid. This layer appears more or less homogeneous; its thickness varies considerably. It is thickest in the apex ("cap enameloid") and the blades, so far present, and becomes thinner toward the base ("collar enameloid"). In some teeth the cap was no

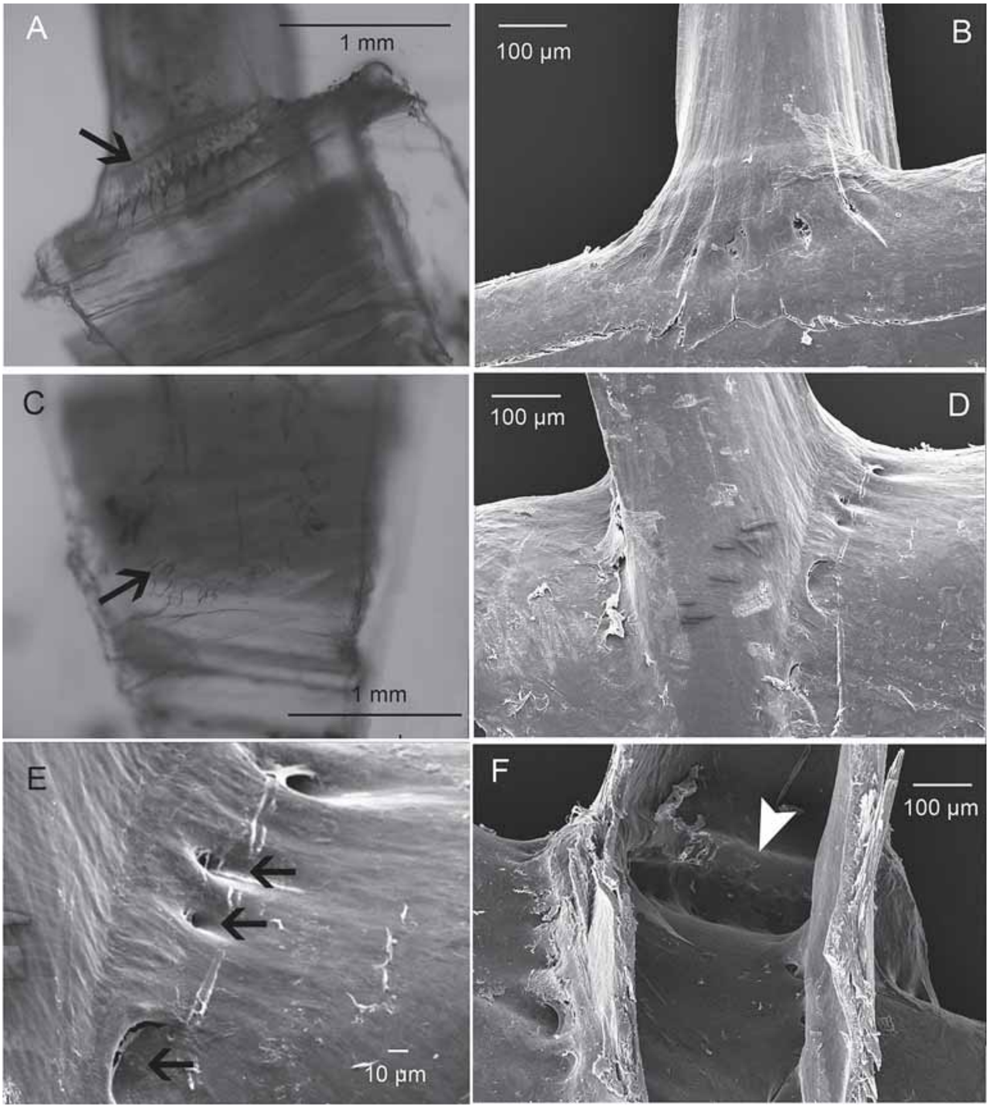

Fig. 4 A-F: Attachment of the teeth of *Chauliodus sloani* to the jaw bone, LM (A, C) and SEM (B, D-F). **A**, **B** Lingual view. The arrow in A point to the diaphragm-like ossification within the tooth. **C**, **D** Labial view. **E** **L**ateral view. Note the various breakthroughs (arrows). **F** Broken basis; note the projecting diaphragm-like ring inside the tooth (arrowhead).

Abb. 4 A-F: Verankerung der Zähne von *Chauliodus sloani* am Kiefer, LM (A, C) and SEM (B, D-F). **A**, **B** Lingual. Der Pfeil in A kennzeichnet die ringförmige ins Zahninnere vorspringende Verknöcherung. **C**, **D** Labial. **E** Lateral. Man beachte die verschiedenen Durchbrüche (Pfeile). **F** Aufgebrochener Zahn mit vorspringendem Ring in der Zahnbasis (Pfeilkopf).

longer present after decalcification, but bundles of fibres were observed in this region (figs. 2 B, C). Dentine tubules end immediately below the enameloid (fig. 2 D).

As seen under the SEM, the surface of teeth including their apices is largely smooth (figs. 2 E, G). Fractures of the dentine shaft allow recognizing longitudinally arranged strands of mineralised tissue and collagen fibrils (fig. 2 F). Towards the tooth base teeth these structures appear more disordered (not shown).

In the dentine shaft of decalcified teeth, collagen fibres and dentine tubules run more or less diagonally and/or longitudinally. A clear division in strata such as mantle dentin and circumpulpal dentine seems to be absent, although some differences in the density of collagen was recognized in several teeth showing zones with densely arranged collagen fibres and zones with less densely arranged collagen fibres. The latter regularly borders the pulp cavity (predentine) (fig. 3 A-C). The outer layer, so far preserved, appears bi-layered. The outermost layer, especially thick in the apical portions, occasionally showed a regular striation perpendicular to the tooth surface and to the underlying layer (fig. 3 C).

Due to the poor preservation of tissue, TEM-pictures were analyzable to a very limited extent. The pigmented network within the pulp obviously consists of melanin containing cells closely attached to the (pre)dentine (fig. 3 D); they obviously represent odontoblasts. The dentine matrix shows densely and less densely layers of interwoven collagen fibrils, perhaps incremental layers, and putative dentine tubules preferably in the less dense zones (figs. 3 E-H). The outer covering (enameloid) is largely absent after decalcification leaving a thin "membrane-like" structure (not shown) or is present as thick amorphous layer (fig. 3 I). Collagen fibrils could not be identified in the remnants of the outermost layer.

Total preparations of teeth for LM and SEM reveal lingually a more or less distinct demarcation line between the tooth and the jaw bone (figs. 4 A, B) and a distinct demarcation line, irregularly in some cases, labially (figs. 4 C, D).Generally this zone shows several small perforations (figs. 4 B-D). Inside the tooth a bony diaphragm-like ring, more prominent lingually than labially, projects into the pulp in this region (fig. 4 F; seen also in fig. 4 A arrow). Semithin sections show that lingually this projection comprises numerous canals or cavities exhibiting a relatively large diameter and dentine tubules; in the small bulge on the opposite side the cavities are missing (fig. 5 A). Larger magnifications show that the intensely stained dense collagen is largely missing in the "diaphragm" (figs. 5 B, C). In the periphery, however, it is present and bundles of fibres run diagonally and continue up to the jaw bone (fig. 5).

The underlying bone is made of thin bony trabeculae, parallel to each other and horizontally oriented with regard to the established teeth. It can be considered as a lightweight construction (fig. 5 A). The bony tissue is acellular as in the zone of attachment.

3.3. Elemental analysis

Table 1 shows the contents of Ca, P, Mg and Fe in the different regions of the tooth and the jaw bone. Values obtained diverge widely, but at least Ca seems to decrease towards the base and the jaw bone.

Tab. 1: Konzentration verschiedener Elemente eines Fangzahnes und des zahntragenden Knochens von *Chauliodus sloani* (je drei Messungen pro Region von verschiedenen Stellen).

Tab. 1: Content of several elements in a fang tooth and the dentigerous bone of *Chauliodus sloani* (three measurements per region at different points).

measuring site	% (w/w) surface
Tip	Ca : 9.3; 22.3.; 10.21 P: 5.9; 5.6; 18.2 Mg: 0.4; 0.4; 0,.3 Fe: 0.1; 0.2; 0.3
central crown	Ca: 14.0; 11.9; 4.8 P : 8.6; 9.4; 3,.3 Fe: 0.15; 0.1; 0.2 Mg : 0.4; 0.4; 0.5
base	Ca : 14.9; 4.6; 4.8 P : 8.5; 3.4; 3.0 Fe: 0.29; 0,3;0,35 Mg: 0.4; 0.4; 0.1
bone	Ca: 5.54; 7.2; 1.8 P: 1.3; 4.1; 5,2 Fe : 0.31; 0.43; 0.5 Mg: 0.2; 0,4; 0.3

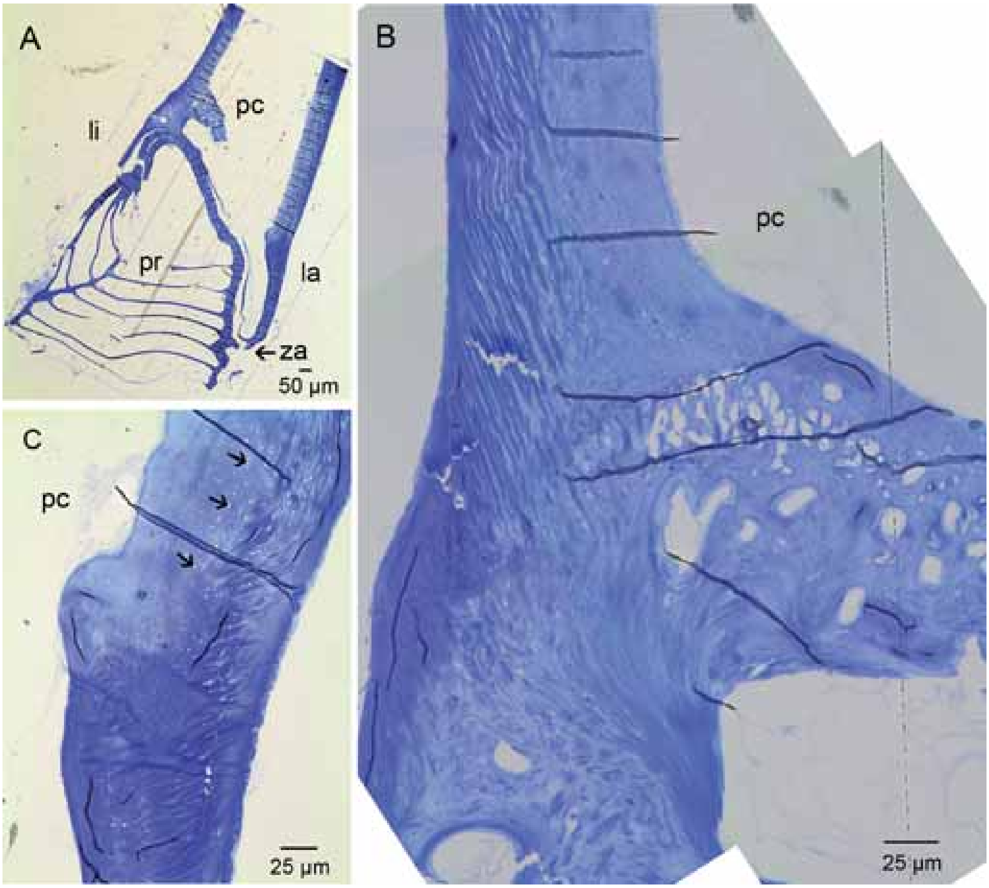

Fig. 5 A-C: Attachment of the teeth of *Chauliodus sloani* to the jaw bone, semi-thin sections. **A** Overview. Note the lightweight construction of the jaw showing thin parallel trabeculae. **B** Detail of the lingual side with the ring-like cavernous projection. **C** Detail of the bulge opposite to the cavernous projection, labial side. la labial, li lingual, pc pulp cavity, pr premaxilla, za zone of attachment.

Abb. 5 A-C: Befestigung der Zähne von *Chauliodus sloani* am Kiefer, Semidünnschnitte. **A** Übersicht. Man beachte die Leichtbauweise des Kiefers mit parallel angeordneten Trabekeln. **B** Detail der lingualen Seite mit dem „spongiösem" Vorsprung der ringförmigen Verdickung im Zahn. **C** Detail des Vorsprungs auf der entgegengesetzten, labialen Seite. la labial, li lingual, pr Prämaxillare, za Anheftungsregion.

4. Discussion

The feeding apparatus of *C. sloani* appears well adapted to the various prey items the fish feeds on. Due to the special construction of its skull (Tchernavin 1953; see introduction) *C. sloani* is able to swallow large prey (see Clarke 1982, Butler 2001), even though teeth of the upper and lower jaw are not hinged (Fink 1981). This is in contrast to many other actinopterygians, in which hinged, i.e. depressible teeth are an effective tool to allow swallowing much larger prey. Such teeth are able to bend inwardly and once depressed and then released they instantly return into erect position, e.g. the larger teeth in the upper jaw of the piscivorous *Lophius* spp. (Kerebel et al. 1979). Owing to the length of the teeth and their firm attachment, *C. sloani* has to open its mouth enormously, i.e. no less than 90° to catch prey (Tchernavin 1953).

Gross morphology, number, arrangement and shape of teeth of the *C. sloani*-specimens examined herein correspond fully to the careful descriptions made by TCHERNAVIN (1953). Fang teeth in the upper and lower jaws are by no means simple pointed cones as suggested by older drawings, e.g. GREGORY (1933: fig. 59, p. 162), but are highly specialised. The size, number, shape and position of teeth in the lower and upper jaw and their possible specific function have been described and discussed in detail by TCHERNAVIN (1953). In brief: The relatively straight foremost premaxillary tooth with it sharp ridges, i.e. cutting surfaces and a pointed tip may inflict cleaving wounds on the prey. The strong and curved second premaxillary tooth may function like a dagger and may retain prey. The second premaxillary tooth is very large, heavy and dagger-like and directed downwards, when the mouth is closed. The third and forth premaxillary teeth resemble the second teeth, but are smaller.

The foremost dentary tooth is the largest of all with its distal part recurved backwards. These teeth possibly inflict rending wounds, push the prey into the mouth and hold the prey, like a harpoon. The posterior dentary teeth have the shape of highly pointed cones, with their apexes bent posteriorly, and two sharp ridges (anterior and posterior) and my act like daggers.

TCHERNAVIN (1953) has focused his analysis mainly on the capture of large prey. When hunting small- and medium-sized prey, however, the firmly attached teeth, which form a kind of cage, may prevent victims once in the mouth from escaping.

Attachment of the teeth to the jaw bones is unusual in some ways and noticeable. The bases of teeth form a tongue on the labial surface of the jaw bones, which was drawn by TCHERNAVIN (1953: Plate VI, fig. 29, Plate VIII, fig. 32), but interestingly not by GREGORY (1933: fig. 55, p. 162). However, TCHERNAVIN (l.c.) did not further comment on this attachment. We suggest that the labially elongated bases of teeth act like a support to resist the pressure executed by struggling prey.

Attachment modes of teeth in actinopterygians are variable and range from a complete ankylosis, i.e. fusion of the tooth base with a "bone of attachment" (type 1), to types, in which teeth are variously hinged to the "bone of attachment" by collagen (types 2-4; types according to FINK 1981). Viperfishes share type-1-teeth (see also figure 3 in FINK 1981) with several other Actinopterygii (see table 1 in FINK 1981). This type was considered as the "primitive attachment mode for actinopterygians" (FINK (1981: 167). We suspect that the elaborated fang teeth in adult *C. sloani* represent a derived character rather than a "primitive" one, but this has to be substantiated.

Further, attachments modes may differ on a single bone, may vary according to the bone, e.g. pharyngeal teeth of *C. sloani* have been reported as being hinged (FINK 1981), or may change through ontogeny and to the dynamics of the supporting bone. Further, a considerable degree of plasticity in the way they become fixed to the bone has been documented in some teleosts (e.g. FINK 1981, SHELLIS 1982, HUYSSEUNE & SIRE 1997a, b, 1998). "Attachment bones" often develop as annular pedicles or pedestals (for summary and terminology see SHELLIS 1982; HUYSSEUNE & SIRE 1998) and may hardly to be recognized, when teeth are completely ankylosed. For example, SCHAFFER (1977) has presented a histological section showing a tooth of *Amia calva* completely fused with the jaw (see also MOY-THOMAS 1934). HUYSSEUNE & SIRE (1998: fig. 27A, p. 466) used a drawing of this photo to document "ankylosed attachment" and labelled the basis of the tooth, somewhat arbitrarily, as "attachment bone" (see also figures in FINK 1981).

FINK (1981) denoted the small, partly perforated zone between dentin shaft and surface of the jaw at the base of a dentary tooth of *C. sloani* as "bone of attachment". Following this interpretation and considering the presence of canalar dentine (see below), the region, which extends from the above mentioned ring-like "diaphragm" to the surface of the bone including the labial tongue-like projection, represents the pedicel or "bone of attachment". The pedicel is hollow and communicates with the pulp cavity.

We did not find a structure comparable to this "diaphragm" in the literature. However, its organisation, mainly that of the carvernous part, resembles roughly the modified orthodentine comprising dentine tubules and "connecting" or "vasoconnective" canals with relatively large lumina described in the attachment bone of *Lophius* spp. (Kerebel & Le Cabellec 1979, Kerebel et al. 1979) and the canalar dentine documented in the pedicel of sea breams (Sparidae). Canalar dentine was defined as a dentine "that is similar to vasodentine in canal arrangement, but not apparently in canal content" (Hughes et al. 1994, p. 51).

The origin of pedicles may be tooth- or bone-related. However, always odontoblasts appear to be involved in its formation; their various structures are said to fit in the range known for dentinal tissue (for discussion and further readings see Shellis 1982, Hughes et al. 1994, Huysseune & Sire 1998). Concerning this matter, nothing has been published for *C. sloani*.

The poor preservation of our material and the problems to cut it adequately does not allow a broader discussion, especially on the presence of pigmented odontoblasts that have been demonstrated for example in odontoblasts of the tooth plates of *Chimaera monstrosa* (Bargmann 1933), or the structure of the cap and collar enameloid. Enameloid covers the teeth of advanced actinopterygians (for summary and references see Huysseune & Sire 1998, Sasagawa et al. 2009) and is characterized by an organic matrix of collagen fibrils, which may, however, completely degenerate and disappear in mature enameloid (e.g. Sasagawa 1997).

Values obtained by EDX vary greatly. Therefore, definite conclusions are not possible. At least the Ca-content appeared to decrease from the tip towards the base of the tooth and was smallest in the jaw bone. The concentration of iron (0.1-0.5%) was within the error limit of the EDX system used by us, but iron was previously documented in the cap enameloid of jaw teeth of *C. sloani* at levels from 0.8% to 1.2% (Suga et al. 1993).

Acknowledgement

We are indebted to Prof. Dr. Sven Klimpel, Frankfurt, for the frozen specimens of *Chauliodus sloani*, to Mr. Marcel Brenner for the help with the plates, and to B. Rohbeck, Institut für Anatomie II der Universität Düsseldorf, for excellent technical help.

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Received: 15. 11. 2009
Accepted: 25. 11. 2009