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REVIEW

Origin and Evolution of Cementum as Tooth Attachment Complex

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Abstract：A general view of the origin and development of cementum is discussed. The evolutionary origin of the cementum is a lining bone tissue that ties the dermal bone to the dermal tooth in Ostradodermi (armored fish, Agnatha, cartilaginous vertebrate). The connective tissue around the dermal tooth forms it, and it is absorbed after connecting the tooth in tooth replacement. The odontoblast forming the dermal tooth loses its polarity, but the osteoblast which forms the lining bone remains multi–polar. Connective tissue forming the dermal tooth has further developed to form the pedicle and fibrous tissue connecting the teeth and jaw bones in fish and amphibians. In reptiles, teeth unite to the jaws with the pedicle bone, which is formed from the periodontal connective tissue. The formation aspect of the pedicle on the jaws differs from the dentine surface of the tooth root, because the pedicle is deposited on the jaw after absorption, but is directly deposited on the dentine. Some parts of the pedicle show as Sharpey's fibers but others are similar to the hyaline cartilage structures. It has been shown that the formation mechanisms have two polarities, like the human periodontal membrane, between the jaws and tooth root.

Cementum is deposited not only on the surface of the root but also on the tooth crown as coronal cementum in mammals. When the coronal cementum develops, the enamel surface is absorbed by dental follicle tissue in horses etc., the enamel development is partially inhibited and forms a rugged surface in elephants etc., and enamel reduction is seen in *Berardius* (tooth whale). The ivory (lateral incisor) of the elephant and the tusk of the walrus (*Odobenus*) are covered in thick cementum；this is a root cellular cementum with rhythmic incremental lines, because the top of it has thin enamel.

Introduction

Cementum has a similar structure to the three calcified tooth tissues, but shows quite different biological features to bone tissues because tooth attachment does not exhibit remodeling. Enamel is reduced and disappears when the cementum develops over and covers the crown, becoming the coronal cementum. The authors have examined the comparative tooth histology in living and fossil amphibians, reptiles, and various mammals, and discuss the features of the cementum from the point of view of phylogeny.

The tooth attachment patterns can histologically be classified into three types；the fibrous, the ankylosis and the gomphosis, in the systematic animal classification. Fibrous means that the tooth is attached to the jaws with fibrous tissue and a bone–like pedicle, and is observed mainly in fish. Ankylosis means that the tooth and jaw bone are

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attached with a pedicle, as mainly observed in reptiles. Almost all mammals show the gomphosis pattern where the tooth is attached to the jaws with a cementum－periodontium－alvelolar bone complex[1]. Teeth positioning patterns in the jaws can also be classified fundamentally into three types； the acrodont, the pleurodont, and the techodont. The acrodont shows dentition lines up on the margins of the jaws. When the dentition is placed on the side of jaws, it is called the pleurodont. The techodont has tooth sockets in the jaws. The gomphosis belongs to the techodont pattern. Cementum, one component of the tooth attachment complex, has evolved with each structure[2].

Origin of Cementum

It is reported that the origins of teeth are in the dermal skeletons of armored fish in Odontostraci. A lot of denticles or dermal teeth (Odontodes, Corium) are arranged on the surface of the dermal bone although the structure has various patterns[2,3]. The denticle has the structure of enamel (enameloid), dentine and bony lining supporting tissue for attachment to the dermal bone. All these structures are derived from the mesoderm, and the supporting lining bony tissue is called Aspidin, which is proposed to be the precursor of cementum[4]. New denticles or armored teeth form on the surface of the bone under the skin one after another and are ankylosed with the bone, while old teeth are absorped or shed out[3].

The authors concluded that the precursor of the cementum arises from dermal tissues of the denticle, because the odontoblast develops to form the dentine and enamel (enameloid), and supporting bone tissues cause the lining bone to connect to the dermal bone (Fig. 1). However the dermal bone develops into the internal skeleton separately from this denticle and has different functional features in the body. The osteoclast originates from this denticle replacement mechanism, so it is reasonable to say that the osteoclast originates from the odontoclasts.

Pedicle

Fish, amphibians, and reptiles have polyphyodont dentitions consisting of many teeth and multiple exchanges of teeth during their lives. The teeth are attached to the jaws with a fibrous or ankylosis pattern. Although the pike has a special attachment consisting of an elastic fiber to move the teeth, belonging to the fibrous pattern, many other fish have fibrous attachments with a pedicle to the jaws[1]. The bone of the pedicle (pedestal bone, pedicel or cementum) unites the teeth to the jaw bone. In *Xenopus* (amphibia) the pedicle is formed from the periodontal tissue cells and odontoblast[5] (Fig. 2). The border between the teeth and the pedicle is not distinct, so some scientists suggest that the pedicle is formed by both odontoblast and osteoblast[6]. Other amphibians have various attachment systems, some have pedicles and others have teeth which contact directly to the jaws. The osteoblast and odontoblast forming the pedicle are not differentiated so far, so the junction of these two structures is unclear with usual staining. It may be distinguished by some other immunohistology technique in the future[7].

As for reptiles, the authors examined *Valanus albigularis*, *Iguana iguana* and alligators. The pedicle of *Valanus* develops from periodontal tissues between the teeth and jaw bones. It grows to a trabecular bone and contacts and fuses to the teeth and jaws to form the plicidentine (Fig. 3). In the *Iguana*, the pedicle also derives from periodontal tissue quite similar in aspect to human cementogenesis (Fig. 4). However the structure shows various forms, such as Sharpey's fibers, and cartilaginous and bone-like structures. The pedicle calcifies after absorption and is reconstructed on the surface of the jaw as bone (Fig. 4). Such phenomena show that the pedicle arises from the periodontal tissues. It does not have such a high differentiation pattern as alligator periodontium, because the root apex odontoblasts, in the pedicle area, differentiate far from Hertwig's epithelial sheath. The periodontal tissues forming the cementum