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Dental enamel

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ABSTRACT

Dental enamel is the sparsest but most enduring component of all the tissues in the human body, yet contrarily contains the most detailed historiography of its development.

Accordingly, analysis of enamels' chemistry, histology and pathology can reveal detailed ambient information of both fossilized, long-deceased and its contemporary milieu occurring during amelogenesis. In this respect, dental enamel is the most versatile exponent of its developmental mechanisms and acquisition of its complex form. Dental enamel is the ultimate lexicographer of lives lived.

INTRODUCTION

Dental enamel constitutes the least quantitative and rarest component of all tissues in the human body but is the most enduring and hardest constituent of ectodermal cellular development. Dental enamel is composed primarily of apatite and has a hardness between steel and titanium of 5 on the Mohs' hardness scale.

Dental enamel can be a harbinger of history, reflecting the environment during the time it was being formed. Enamel first appeared around 415 million years ago when the suite of genes that encode the proteins required to make enamel appeared in the scales of sarcopterygians.[1]

The evolution of prismatic enamel was an innovation that made teeth more resilient to abrasion and allowed for the expansion of the dietary herbivorous range. Moreover, it diminished the necessity of constant tooth replacement that characterizes reptilians. Thus, the first appearance of prismatic enamel in Late Cretaceous sphenodontians marked an evolutionary advance in odontological development.[2]

The vitreous nature of enamel provides its white lucent, iridescent and gleaming appearance as a physically attractive feature of a human smile, but contrarily, it may provide a snarling repulsive warning of a sneer. The production of enamel by ameloblasts is among the most complex tissues of histogenesis. Amelogenesis is so specialized in its production of enamel that it is not replaceable as enamel in any form of tissue repair.

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Accordingly, any damage to enamel, be it by acidogenic decay or trauma has become the raison d'etre for the dental profession in repairing the consequences of enamel loss. Enamel is an instantaneous fossilized tissue developing *in situ* during amelogenesis in living individuals that consequently reflects the environmental and metabolic status of an individual.

Any deviation of the genetically determined pathway of enamel formation is permanently imprinted upon the histology of enamel, providing enduring evidence of its dysmorphogenesis. Hence, the genetically determined condition of amelogenesis imperfecta is engrafted upon enamel during its formation and is revealed post-eruption on the teeth exhibiting hypoplasia.

Moreover, enamel is unique in both providing information on extant living individuals, and on long-deceased and extinct fossilized species. The elemental signatures retained in enamel can reveal seasonal dietary stresses in both extant and extinct species.[3]

ENAMEL FORMATION

Enamel contains an exquisitely intricate and ordered arrangement of mineral crystals packed so densely that it is harder than iron. Amelogenesis is an enormously complex process involving numerous interactions. The elaboration of enamel as a complex combination of enamelin and tuftelin and amelotin secreted by ameloblasts that take a path from the delicate scalloped amelodentinal junction to the destined cusp tip and down into the crevices of the fissures and along the ultimate enamel margins.

The variation of the thickness of enamel at these different locations must presumably be genetically determined by ameloblast viability, diminishing from the peaks of the tooth cusps to the ultimate cessation of amelogenesis at the enamel margins. It would be interesting to investigate the longevity of marginal ameloblasts if they could be transferred to cusp tip locations. Is their fate determined by genes or by location?

During amelogenesis, the physical or epigenetic interactions between the inner and outer layers of the enamel organ might determine enamel thickness. Six genes are implicated in amelogenesis: enamelin ENAM; ameloblastin AMBN; amelotin (AMTN); AMELX/AMELY amelogenin gene on XY chromosomes; MMP20 matrix metalloproteinase; KLK4 kallikrinen 4 gene.[4] Variable stages of enamel secretion produce cross striations along enamel prisms.

Variation in this daily growth determines the development of the thickness of the enamel. The ameloblastin and amelogenin matrix proteins formed during early stages

of amelogenesis are removed during maturation by degradation. The accumulated degraded matrix proteins inhibit further ameloblast activity, thereby determining the thickness of deposited enamel.

Such interactions may modulate different ameloblast location longevity, and hence, enamel thickness. Ameloblasts located at a molars' highest cusps can produce enamel as thick as 6 mm. Variations in enamel thickness in the deciduous dentitions of hominoids (H. sapiens, Pan troglodytes, Gorilla and Pongo) have recently been explored.[5]

The thickness of dental enamel may act as a proxy for the durability of a tooth and reflect dietary preferences and possibly the lifespan. The varying patterns of wear and of enamel thickness correlates with dietary preferences and can act as a proxy for different diets.[6]

Enamel thickness has been studied in Plio-Pleistocene hominin mandibular molars, wherein the thick enamel of the robust Australopithecus species decreases in early Homo to that of modern humans.[7] Ancient protein analysis of an Homo antecessor molar, dated to 772-949 thousand years ago using electron spin analysis and U-series dating has revealed the dental proteome of this species.[8]

The enamel thickness of Gigantopithecus blacki, over 6 mm in places, was adapted to heavy wear in a way that differed from Pliocene and Pleistocene hominids.[9] G. blacki was adapted to consuming tough fibrous food, and its thick molar enamel allowed for relative longevity.[10]

Dental enamel is the hardest tissue in the body that is initiated in a protein gel that is impregnated by nanometer size minerals in a three-dimensional network. The remarkable strength of enamel comes from its ingenious structure that gives it the hardness and toughness to resist the start and spread of cracks.

The newly formed enamel matrix is an amorphous calcium phosphate that transforms into apatite crystals. Apatite crystals in human enamel deviate from one another by 1-30 degrees in orientation conferring toughness.[11] Misorientation of adjacent enamel crystals induce crack deflections that confers the unique resilience of enamel.[12] The enamel rods or prisms run parallel to one another from the tooth surface to the underlying dentin, but weave and twist as they go by in an elegant configuration that confers the significant durability of enamel.

The complex structure of enamel is revealed by microscopic examination.[13] Enamel has a highly hierarchical structure with complexities arising from chemical gradients. The crystals of enamel are composed of Apatite (Ca5 (PO4) 3 (F, Cl, OH) that is constituted of hydroxyapatite, fluorapatite and chlorapatite.

Nanoscale crystallites of hydroxyapatite are comprised of two flanking nanometric layers enriched with magnesium surrounding a core of sodium, fluoride and carbonate ions. Varying gradients of these chemical ions create stresses that affect the mechanical and solubility resilience of enamel to acid attacks.[14]

Fluorapatite is the least susceptible component to acid disintegration, making it the reason for fluoridation of drinking water to reduce dental decay. The opportunity to regenerate dental enamel is being explored.[15] The composition of dental enamel impacts its varying reactions to its pathological disintegration.[16]

Spectroscopic analysis of enamel formed during a period of high radioactivity of ^{14}C isotopes in the atmosphere, as at the time of the Chernobyl explosion, can identify the date of enamel formation. Similarly, the ^{18}O isotope content of dental enamel provides evidence of the quality of ingested vegetation during wet or dry periods occurring during amelogenesis.

Enamel isotopic evidence provides information of early hominid diets.[17] Analyses of linear enamel hypoplasia indicate aspects of enamel development and morphology.[18] Further, the administration of tetracycline antibiotics during enamel formation is permanently imprinted on teeth, revealed after their eruption.[19,20]

CONCLUSION

Despite being the least quantitative tissue in the human body, the composition of dental enamel comprises the most comprehensive registry of its formation permanently imprinted in the most enduring constitutional component of any anatomical structure.

The incredibly complex combination of diverse chemical elements incorporated in the constitution of dental enamel provides enduring fascination of the vivid tissue emplaced in our mouths. The historiography of an individual is embedded in the composition of the tooth. Dental enamel is the ultimate lexicographer of a life lived.

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