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Cementum Revisited

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Abstract: Cementum is a specialized calcified avascular mesenchymal tissue that form the outer covering of the anatomic root. The term 'cementum' is derived from the Latin word "caementum" which means the quarried stone. Cementum may undergo alterations in structure as well as in the composition of its organic and inorganic components consequential to pathological changes in the immediate environment. Hypermineralization: the cementum of periodontally involved teeth,and in particular the hypermineralized surface zone, is also charecterized by an increased fluoride content. The high fluoride content of the surface layer also contributes to the subsurface and undermining character of the demineralization process in the cementum caries. Moreover, translocation of mineral ions during the caries process may result in the development of a more densely mineralized surface zone in the early cementum caries lesion than in the adjacent exposed, noncarious cementum surface.

Keywords:– Cementum, Hypermineralization regeneration, rootcaries, repair

I. INTRODUCTION

Cementum is a specialized calcified avascular mesenchymal tissue that form the outer covering of the anatomic root. The term 'cementum' is derived from the Latin word "caementum" which means the quarried stone. Frankel and Rachko (1835) first examined cementum on the roots of human teeth. Cementum possesses 45 to 50% inorganic material.[1]

Histologically it shows that cementum is thicker at cementoenamel junction. It is important in adaptive and reparative functions. It has an important role in maintaining occlusal relationship and also protects the integrity of the root surface. Cementum increases in thickness towards the apex. Cementum continues to grow in thickness throughout life and itwon't undergo continues remodeling like bone. Based on histologic evidence cementum has a critical role for appropriate maturation of periodontium during development and regeneration of periodontal tissue.[2]

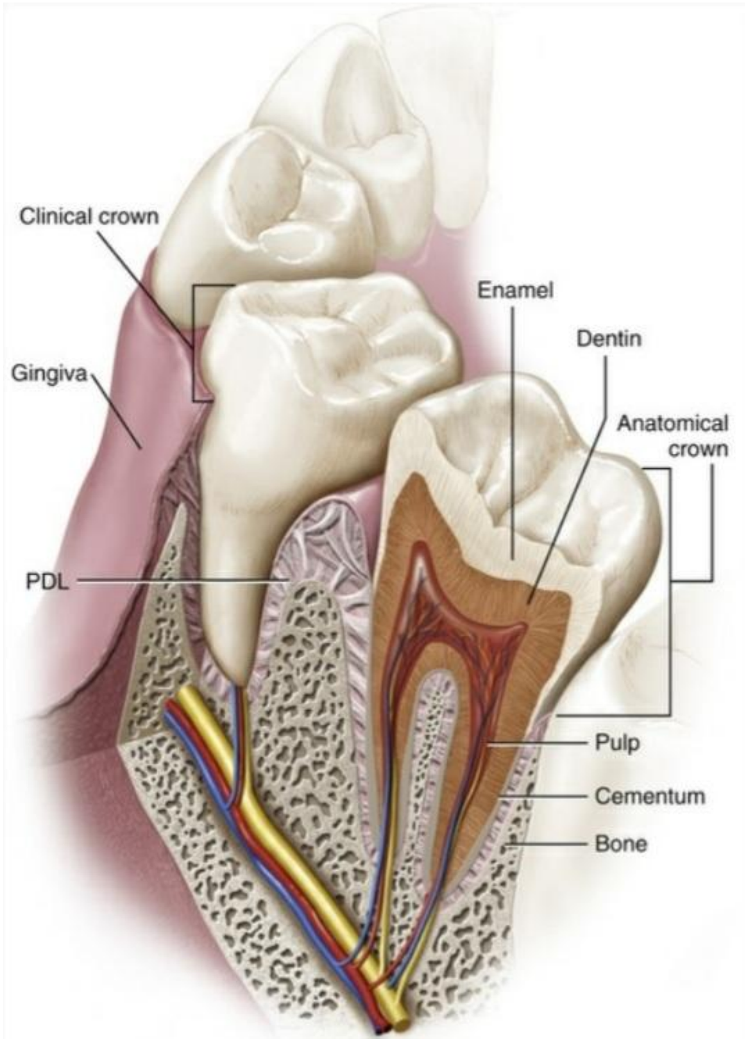

FIGURE 1

II. HISTORY OF DENTAL CEMENTUM[3]

Though cementum of the tooth root is critical for periodontal structure and tooth attachment and function, this tissue was not discovered and charecterized on human teeth until a full century later than enamel and dentin.

Early observations from the 17th to the 19th centuries by Marcello Malpighi, Antonie van Leewenhook, Robert Blake, Jacques Tenon, and George Curvier founded a confusing and conflicting nomenclature that obscured the nature of cementum, often conflating it with bone.

Advances in microscopy and histological procedures yielded the first detailed descriptions of human cementum in the 1830s by Jan Purkinje and Anders Retzius, who identified for the first time acellular and cellular types of cementum, and the resident cementocytes embedded in the later. Comparative anatomy studies by Richard Owen and others cover the latter half of the 19th century identified coronal and radicular cementum varieties across reptilia and mammalia.

The functional importance of cementum was not appreciated until detailed anatomical studies of the periodontium were performed by G.V Black and others in the late 19th and early 20th centuries.

These early studies on cementum laid the foundation for more advanced understanding of cementum ultrastructure. composition, development, physiology disease, genetics, repair and regeneration throughout the 20th and into the 21th centuries.

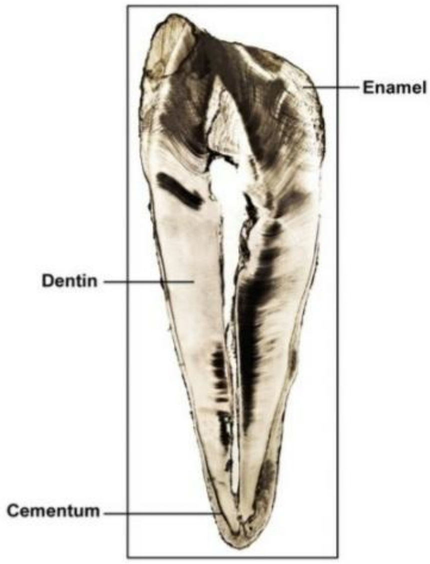

FIGURE 2 Ground section of a premolar showing the distribution of cementum around the root. Increasing amounts of cementum occur around the apex.

III. CLASSIFICATION OF CEMENTUM [4]

Depending on location, morphology and histological appearance, Schroeder (1992) has classified cementum as

1. ACELLULAR AFIBRILLAR CEMENTUM(AAC)
2. ACELLULAR EXTRINSIC FIBER CEMENTUM (AEFC)
3. CELLULAR MIXED STRATIFIED CEMENTUM (CMSC)
4. CELLULAR INTRINSIC FIBER CEMENTUM (CIFC)
5. INTERMEDIATE CEMENTUM (OR) THE HYALINE LAYER OF HOPEWELL-SMITH

ACELLULAR AFIBRILLAR CEMENTUM (AAC)

A mineralized ground substance makes up the composition. Cementoblasts produce this substance, which contains no cells, extrinsic or intrinsic collagen fibers. Coronal cementum with a thickness of 1 to 15 mm was found.

ACELLULAR EXTRINSIC FIBER CEMENTUM (AEFC)

Sharpey'sfiber bundles that project perpendicularly from the cementum matrix into the periodontal ligament, makes up the composition. They lack cells but are made up of fibroblasts and cementoblasts. Found in the cervical part of the roots, but can extend apically 30 and 230m in thickness.

CELLULAR MIXED STRATIFIED CEMENTUM(CMSC)

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Composition may contain cells and is made up of intrinsic and extrinsic (Sharpey's) fibers. Cementoblasts and fibroblasts produce it as a byproduct. Found in the apical third of the roots and apices, as well as in furcation zones, 30 and 230m in thickness.

CELLULAR INTRINSIC FIBER CEMENTUM (CIFC)

Cementoblasts from the composition, which contains cells but no external collagen fibers. Found in the resorption lacunae. Properties cellular mixed stratified cementum properties. It is linked to the healing of root fractures and the repair of resorptive deformities.

INTERMEDIATE CEMENTUM(OR) THE HYALINE LAYER OF HOPEWELL-SMITH

It is a poorly defined zone near the cementodentinal junction of certain sheath embedded in calcified ground substance. The significance of this layer is that it contains enamel like proteins, which help in attachment of cementum to dentin.

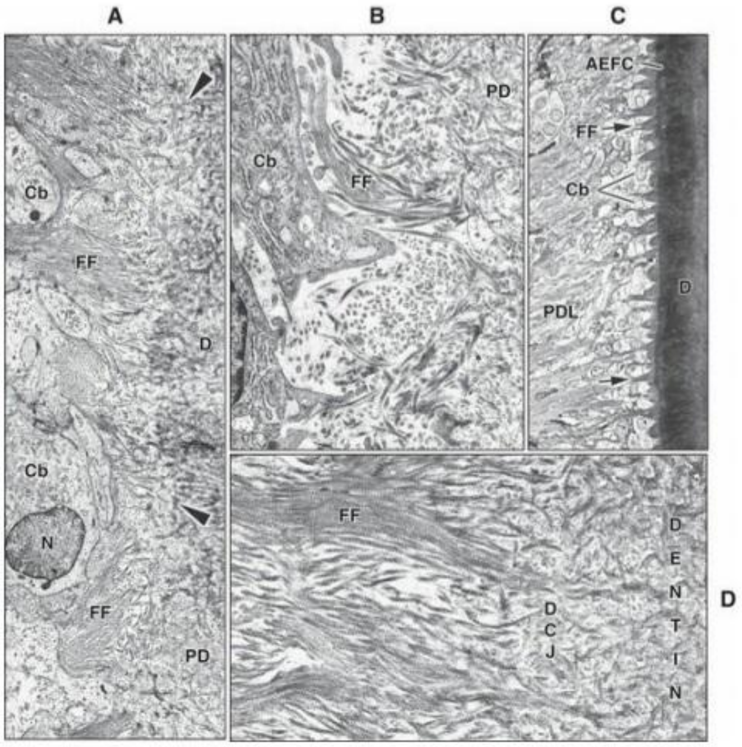

FIGURE 3 Early human acellular extrinsic fiber cementogenesis *(AEFC)* **A,** Intermingling of collagen fiber bundles with those at the unmineralized dentin (predentin, PD) surface. Arrowheads indicate the external dentin mineralization front. **B,** Details of the intermingling. **C,** The final connection between the collagen fiber bundles of acellular (primary) cementum and dentin (D) surface are shown. **D,** The fibrous fringe (FF) extending from cementum. Cb, Cementoblast; DCJ, dentinoenamel junction; N, nucleus; PDL, periodontal ligament. (Courtesy D.D. Bosshardt.)

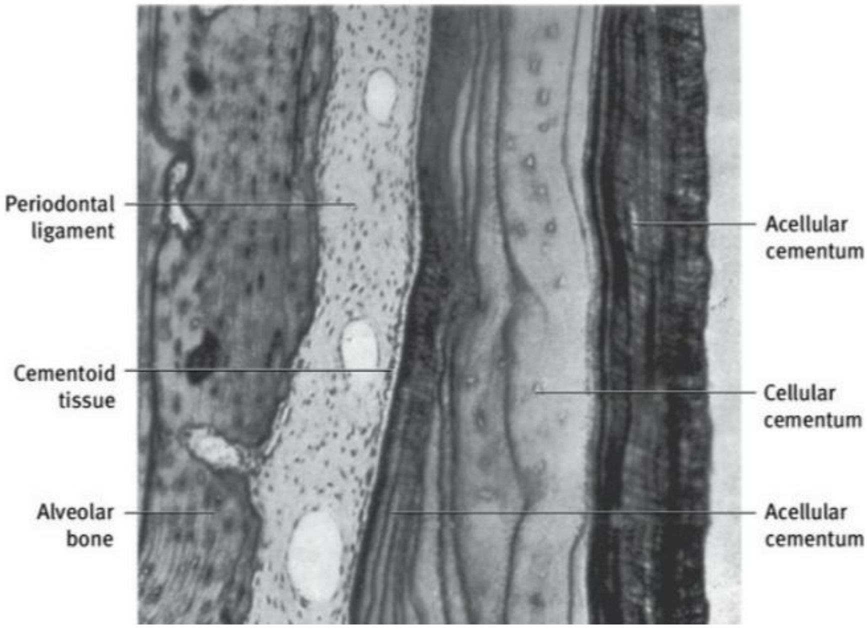

FIGURE 4 Cellular cementum on surface of acellular cementum and again covered by acellular cementum (incremental lines). Lacunae of cellular cementum appear empty, indicating degeneration of cementocytes.

IV. COMPOSITION OF CEMENTUM [5]

Since cementum is not a uniform, mineralized connective tissue, differences in the proportional composition of the chemical constituents exist between cementum varieties. Thus, the percentages of its chemical components may vary from sample to sample, particularly in different different species.

Cementum is composed of water, inorganic matrix and mineral. About 50% of the dry mass is inorganic, and consists of hydroxyapatite crystals. The remaining organic matrix contains largely collagens, glycoproteins and proteoglycans.

EXTRACELLULAR MATRIX

The extracellular matrix of human cementum consists mainly of collagen type1(90% of organic matrix) and collagen type III (5%) according to the classic study by Christoffersen and Landis.

A number of non-collagenous cell attachment proteins with only partially characterized properties, have been detected in cementum.

1. Fibronectin. Osteopontin and Osteocalcin
2. Vitronectin
3. Cementum attachment proteins
4. Enamel protein
5. Alkaline phosphatase

INORGANIC COMPONENTS

The primary mineral component is hydroxyapatite (Ca10(PO4)6(OH2)) containing amorphous calcium phosphate. Trace elemental concentration of Cu, Zn, and Na were further detected by electron microprobe analysis in human root cementum of healthy and periodontally involved teeth.

V. DEVELOPMENT OF CEMENTUM AND CELLS INVOLVED IN IT [6]

Cementogenesis is a process which results in deposition of cementoid, fiber component and leads to mineralization. Then this mineralized tissue will undergo constant remodeling.

Cementum is formed by cementoblasts during root formation, this process is known as cementogenesis.

Development of cementum occurs as prefunctional development which occurs during root formation and functional development occurs when tooth reaches occlusal level and continues throughout life.

Initially cementum formation occurs only at the deepest margin of Hertwigs epithelial root sheath. Cementum formation occurs during lifetime throughout the whole root surface.

One of the first events in cementogenesis is the disruption of Hertwigsepithelial root sheath. Before the degeneration of Hertwigs epithelial root sheath a thin layer which are cell free forms on the surface of dentine which is the intermediate cementum. After the degeneration of epithelial root sheath ectomesenchymal cells from dental follicle differentiate and forms cementoblasts. Cementoblasts are large cuboidal cells which contains golgi apparatus, well developed RER numerous mitochondria and the cementum is deposited in as rhythmic process until full thickness is achieved. After attaining full thickness cementoblasts enters into a quiescent stage. Fibroblasts from collagen fibers (Sharpey'sfibers) which provide attachment of root to surrounding bone. After forming the first layer of matrix mineralization begins. Remnants of HERS which disintegrates into the PDL are malassez cells.

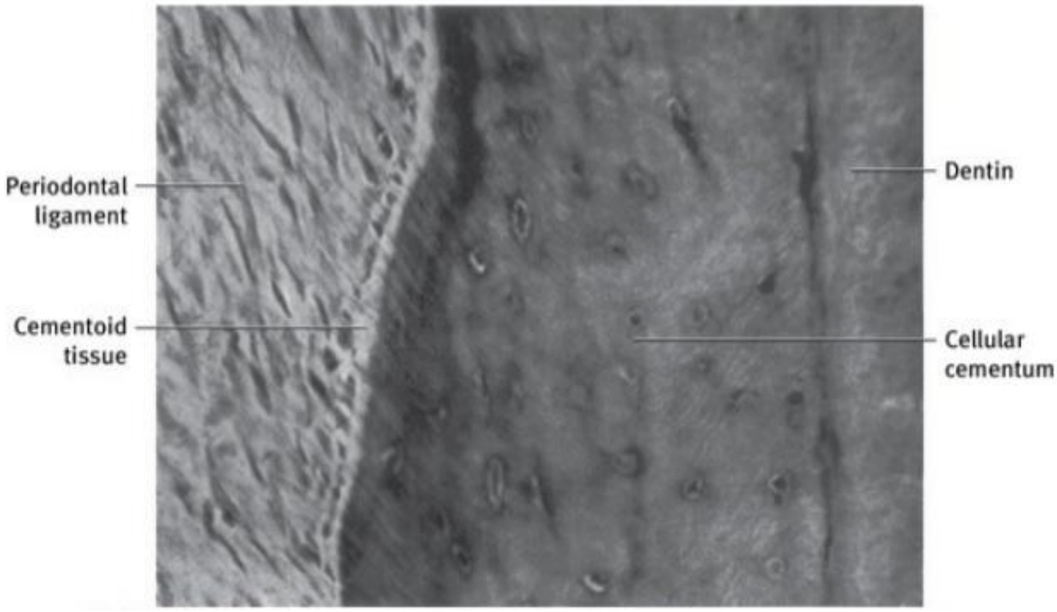

FIGURE 5 Cellular cementum forming entire thickness of apical cementum. (Source: from Orban B: Dental histology and embryology, Philadelphia, 1929, P Blakistons Son& Co).

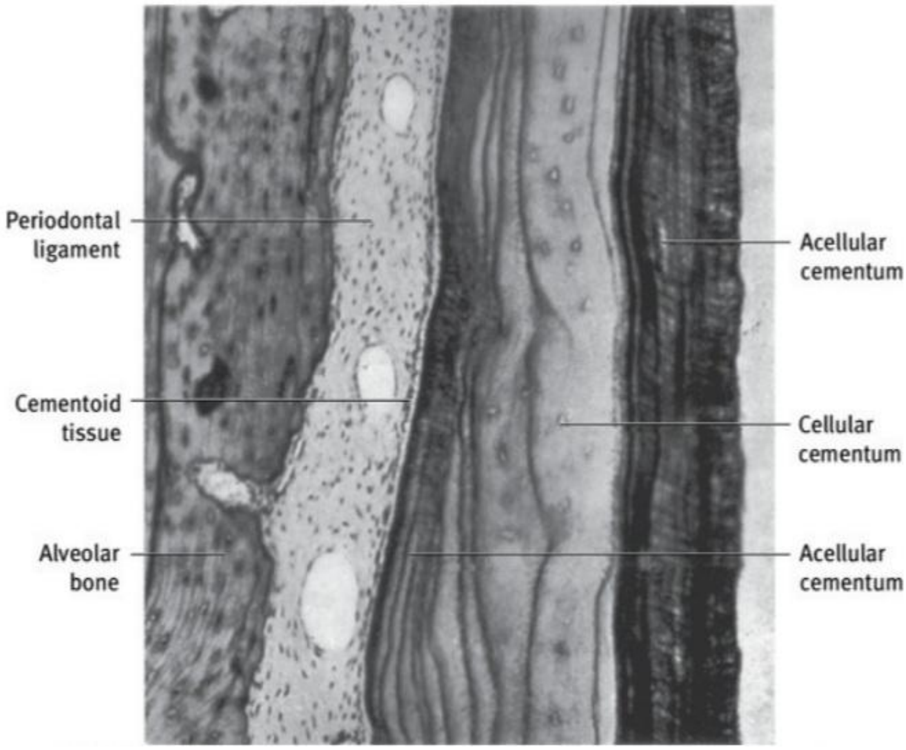

FIGURE 6 Cellular cementum on surface of acellular cementum and again covered by acellular cementum (incremental lines). Lacunae of cellular cementum appears empty. Indicating degeneration of cementocytes.

VI. CEMENTOGENESIS AT THE TOOTH CREVICE[7]

One of the study showed two findings when they analyzed the tooth cervix of developing mouse. It showed the absence of HERS cells from cervical margin of the developing root surface and it also showed presence of a cementoid tissue between cervical most ameloblasts and dentin surface.

The disintegration of HERS is only found in mammals. One of thestudyconfirmed that HERS is disrupted prioi to cementum. Amelogenin transcripts were limited to coronal ameloblasts and absent in Hertwigs root sheath. Cells along the root surface were completely devoid of amelogenin hybridization products. Cells involved in cementogenesis include cementoblasts, fibroblasts, cementocytes. Cementoblasts help in rapid resorption of the roots of deciduous teeth. Cementocyte seen only in cellular cementum. Cementoblastsderived from the ectomesenchyme layer of the developing tooth germ. Cementum is deposited on the tooth surface by cementoblasts.

VII. PHYSICAL PROPERTIES OF CEMENTUM

Hardness-fully mineralized cementum has a lower hardness than dentin.
Light yellow in tone with a dull luster and a deep hue.
Acellular and cellular cementum are both permeable to oral fluids, allowing dyes to diffuse from the pulp and the exterior root surface.
Thickness-16 to 60 m in coronalhalf of the root, 150 to 200m in the apical third and in the furcation zones, thicker in distal surfaces than in mesial surfaces due to functional stimulation from mesial drift over time, cementum thickness increases with age, with average thickness of 95m at 20 years old and 215m at 60 years old, indicating a threefold increase with age.[4]

VIII. FUNCTIONS OF CEMENTUM

The main function of cementum is tooth support or tooth anchorage together with the principal fibers and alveolar bone. Acellular extrinsic fiber cementum is therefore cementum for tooth support.[8]

ANCHORAGE [4]

- The key function of cementum is to provide a medium for collagen fibers to bond the tooth to the alveolar bone.
- Without cementum, a connective tissue attachment to the tooth is impossible because periodontal ligament collagen fibers cannot be integrated to dentin.[4]

FUNCTIONAL ADAPTATION

- Cementum deposition in an apical area can compensate for tooth material loss due to occlusal wear.
- The continual deposition of cementum is crucial for function.
- To maintain the attachment mechanism intact, a fresh layer of cementum must be deposited as the most superficial layers of cementum matures.

REGENERATION

- Cementum regeneration is essential for the proper maintenance and regulation of periodontium.
- Malassez epithelial cell rests play a critical role in cementum regeneration, because they are the only odontogenic epithelial cells that survive in the periodontium following tooth eruption.

IX. AGE ESTIMATION FROM DENTAL CEMENTUM

Cementum, a mineralized hard tissue has incremental lines which acts as a reliable tool for age estimation. As cementum is nonvascular in nature it is rarely remodeled or absorbed. The incrementing lines are a series of alternating light and dark bands. Zander and Hurzeler were the first to discover a linear relationship between the growth of cementum and chronological age based on examination of single rooted teeth. They also stated that age estimation can be done better due to its unique position in alveolar process. In a study of human cadavers Stott et al counting tooth cementum annulations in uncalcified, stained tooth sections provided a close estimation of real age. Wittwer-Backofen and Buba established technique and protocol which are widely used in tooth cementum annulations estimation. Recent studies shows that longitudinal sections were more appropriate with the real age.[9]

Accuracy of tooth cementum annulation counting depends upon the microscopic examination. Phase contrast microscopy has better impact on age estimation. Age estimation with cementum was first done by observing the width of the total cementum layer. Cementum thickness shows characteristic variations among tooth groups and tooth surfaces. Nonfunctioning impacted teeth generally have thicker cementum than the functioning teeth. Age estimation by counting incremental lines is a reliable method for teeth without periodontal diseases.Cementum annulations present in human teeth may give a close estimation of age of an individual.[10]

Secondary dentin forms continuously throughout life, it starts when root formation is completed. The amount can be used to estimate the age of an individual. Age estimation using cementum is reliable to the teeth which is not affected by periodontal disease. Cementum will not undergo much pathological changes when compared with other structures of teeth. So incremental lines can be used as the tool for age estimation.

Annulation counting when done in computer software by Wittwer-Backofen et al showed that there is a difference of 2 to 3 years of actual age and estimated age.[11]

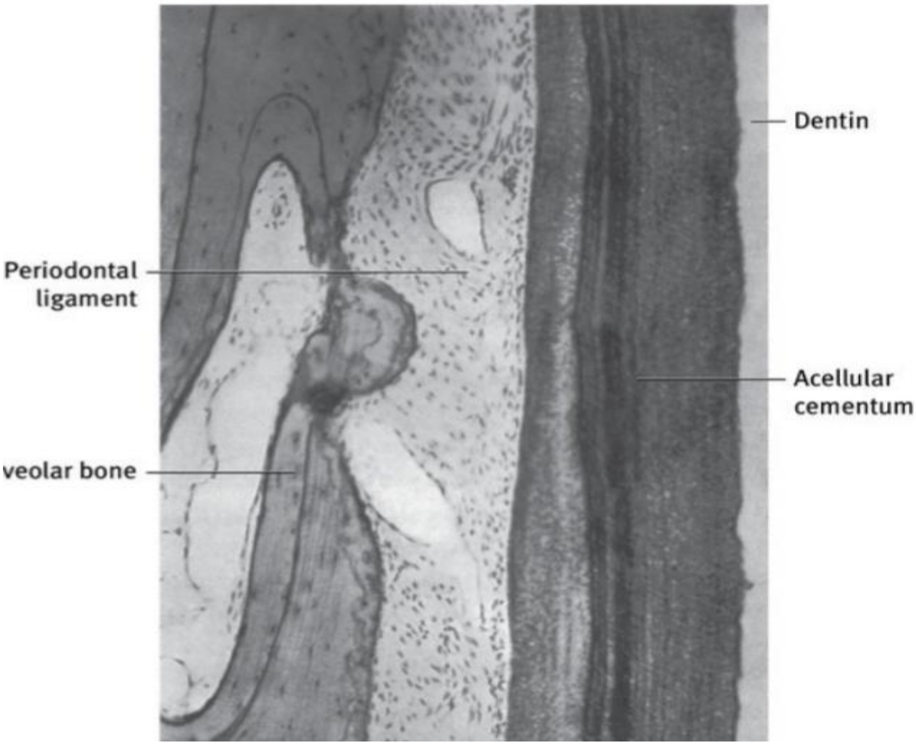

FIGURE 7 Incremental lines in acellular cementum.

AGE ESTIMATION IN ANIMALS

The technique of age estimation was first done in marine mammals. Stoneburg and jonkel microscopically examined TCAs in decalcified and stained teeth of known age of black and stated that it can be used for age estimation.

Calvert and Ramsay estimated ages of polar bears by counting growth layer growth layer groups in premolar teeth. The result was having high degree of accuracy.[12]

X. AGE CHANGES ASSOCIATED WITH CEMENTUM [13]

Hypercementosis: It is an abnormal thickening of the cementum. It may be generalized or localized, diffused or limited. Hypercementosis is termed **cementum hypertrophy** if the overgrowth improves the functional qualities of the cementum and is termed as **cementum hyperplasia** if it is not correlated with increased function.

Cementicles: they are ovoid or round calcified structure that are formed as a result of calcification of the degenerated periodontal tissue or the epithelial rests of Malassez.

Cementicles may be,

1. Free in the periodontal ligament
2. Attached to the cementum
3. Embedded in the cementum.

Permeability: the permeability of cementum decreases gradually by age. The permeability of cementum decreases gradually by age. The permeability from the periodontal side is lost except in the most recently formed layers of cementum, while that from the dentin side remains only in apical region.

Cementum resorption and repair: cementum resorption can occur after trauma or excessive occlusal forces. After the resorption ceases the damage is usually repaired. If the repair establishes the former outline of the root surface it is called **anatomic repair**. However if only a thin layer of cementum is deposited and the root outline is not constructed it is called **functional repair**.

Cementum increased with age while CDJ width decreased with age. [14]

XI. DISORDERS ASSOCIATED WITH CEMENTUM

ROOT SURFACE CARIES AND CEMENTUM

Different forms of ROOT affected areas are associated with cavitation. Nyvad et al described that experimentally induces ROOT caries model will have histopathological changes after covering of exposed cementum with plaque. Continous layer of subsurface loss of mineral and redefinition of minerals in surface cementum layer. This were hypermineralized while comparing with neighboring cementum. Root surface caries affected cementum have larger apatite crystals.[5]

MINERALIZATION DEFECTS IN CEMENTUM

Bone sialoprotein is a multifunctional extracellular matrix protein found in mineralized tissue in tooth root cementum and dentin. Analyzing BSP null mice and wild type. BSP null mice revealed that molars lack functional acellular cementum and loss of sharpey's collagen fiber insertion into tooth root structure. Analysis confirmed that there is a critical role in process of cementogenesis.[15]

XII. CLINICAL SIGNIFICANCE OF CEMENTUM

POSSIBLE ROLE OF CEMENTUM IN PERIODONTAL REGENERATION [16]
The growth factors and adhesion molecules present in cementum are active toward cells of the gingiva, periodontal ligament, and alveolar bone. Therefore, it is possible that cementum components have the potential to participate in the regulation of homeostasis and regeneration of these tissues.

ALTERATIONS RESULTING FROM PERIODONTAL PATHOLOGY [17]
Cementum may undergo alterations in structure as well as in the composition of its organic and inorganic components consequential to pathological changes in the immediate environment.
Hypermineralization: the cementum of periodontally involved teeth,and in particular the hypermineralized surface zone, is also charecterized by an increased fluoride content. The high fluoride content of the surface layer also contributes to the subsurface and undermining character of the demineralization process in the cementum caries. Moreover, translocation of mineral ions during the caries process may result in the development of a more densely mineralized surface zone in the early cementum caries lesion than in the adjacent exposed, noncarious cementum surface.

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