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Review Article

CEMENTUM IN HEALTH - A REVIEW

Aparna Suraj. N., Suchetha Aghanashini., Sapna.N., Darshan.B.M., Apoorva.S.M and Divya Bhat

Department of Pedodontics and Preventive Dentistry Guru Nanak Institute of DAPMRV Dental College, J.P.Nagar, Bangalore, Karnataka

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A B S T R A C T

Cementum is an important calcified tissue, which covers the root surface.1It is one of the tissues of the periodontium, which is responsible for the the normal development and functioning of the tooth.2It is responsible for maintenance of the tooth integrity and provides adequate support, and also provides adaptive and reparative functions. This tissue shares some similarity with the alveolar bone.3The junctions of this tissue such as cemento-dentinal and cemento-enamel junctions, play their significant role in the diagnosis and management of dental surface defects.4

Cementum helps in the estimation of age and also acts as a significant marker of lifestyle events.5,6 Hence, acquiring the knowledge of the structure, composition and functions of cementum, helps in applying appropriate therapeutic strategies.3

INTRODUCTION

Periodontium comprises of four different tissues- Gingiva, Periodontal ligament, Root Cementum and Alveolar bone. These tissues, together constitute and behave as a '*biological, developmental and functional unit'*.[2]

Cementum is derived from the Latin word '*caementum',* meaning *"quarried stone"*.[7]The cementum is a specialized, avascular, alymphatic and non-innervated, calcified tissue of mesenchymal origin which covers the root surface, forming an interface between the periodontal ligament and dentin and provides for the attachment of the periodontal fibres to the surface of the root.[1,3,7]

Cuvier (1769-1832) coined the term *cement.* The modern term 'cementum' was derived from Cuvier's neologism.[8]Frankel and Rachko (1835), were the first to examine cementum on the roots of human teeth and cementum was first described by Denton GB in 1939. [2,3]

When compared to the enamel and dentinal tissues, cementum does not appear to be specific at the cellular and molecular level. But there are histological evidences that is being accumulating, describing the critical role of cementum in the appropriate maturation of the periodontium, during the development, as well as in association with the regeneration of periodontal tissues.

Corresponding author:* **Aparna Suraj. N
Department of Pedodontics and Preventive Dentistry Guru Nanak Institute of DAPMRV Dental College, J.P.Nagar, Bangalore, Karnataka

Various studies detailing the possible involvement of various molecular factors in cementum regeneration do exist, but cementogenesis, on a cell biological basis, continues to be poorly understood. So, this literature review aims to give a comprehensive review about some important aspects of this unique tissue in health.[9]

Development

Cementum is initially formed by the appositional growth from the dental sac and later from the periodontal membrane under the influence of cementoblasts.[10]Cementoblasts are the cells responsible for the formation of cementum. Certain cementoblasts gets entrapped and are called the 'Cementocytes', which are present in the spaces called lacunae.[11]With the incorporation of Sharpey's fibers into a fibrillar matrix, which undergoes calcification, formation of laminated layers of primary cementum is resulted.[3]Cementum, like enamel, is developed from within outwards.[12]

The root formation begins, when the enamel organ has reached its final size and the inner and outer cell layers of the enamel epithelium proliferate from the cervical loop to form Hertwig's epithelial root sheath. Hertwig's root sheath becomes discontinuous, once after the first matrix of radicular mantle dentin is formed by the maturing odontoblasts. Epithelial cell remnants of Hertwig's root sheath persist in the still developing aging periodontal ligament and are referred to as the epithelial rests of Malassez.[10]

Mineralization of the first formed dentin of hyaline layer occurs within matrix vesicles. Mineralization does not occur at the outermost surface of hyaline layer, but occurs within it. From this initial centre, mineralization spreads towards pulp and towards periodontal ligament. Thus, the outermost part of the hyaline layer shows a delayed mineralization. Later this layer spreads outwards, until it is fully mineralized and continues into fibrous fringe secreted by the cementoblast. Thus, the first few layers of acellular cementum are attached to the dentin. Once the periodontal ligament fibres get attached to the fibrous fringe, the cementum is classified as 'Acellular extrinsic fiber cementum'. In permanent teeth the attachment of the fibres occurs only after the tooth has erupted into the oral cavity. Thus, acellular cementum lining the root before this time is considered as 'Acellular intrinsic fiber cementum'. When there is a premature loss of reduced enamel epithelium, the "Acellular afibrillar cementum" is formed. It is deposited as a thin layer on the enamel at cervical margin of the tooth.

During the process of cementogenesis, there are periods of rest and periods of activity, which are seen as incremental lines in the cementum, called 'Lines of Salter'. Periods of rest are associated with these lines. As the acellular cementum is formed slowly, these lines are closer in this cementum. After the formation of the acellular cementum, a less mineralized cementum called the 'Cellular cementum' is formed. At the apical and the furcation areas, cellular intrinsic fiber cementum alternates with the acellular extrinsic fiber cementum to form "Cellular mixed stratified cementum.

Epithelial cell rests may be entrapped in the cementum near the cemento-dentinal junction. That part of cementum is called 'Intermediate cementum'. it usually occurs in the apical half of the roots of the molar teeth.[11]

Composition

Extracellular Matrix: The organic matrix of cementum consists primarily of collagens type I (90%) and III (5%). Type XII collagen, types V, VI, and XIV are the other types found. Also, non-collagenous proteins like alkaline phosphatase, bone sialoprotein, dentin sialoprotein, dentin matrix protein, osteocalcin, osteonectin, fibronectin, osteopontin, proteoglycans, proteolipids, tenascin, and several other growth factors are found. [10,13]

Cellular Matrix: Composed of cells like:

Cementoblasts: which are cuboidal in shape and are associated with the synthesis of collagen, which forms the organic matrix of cementum. [7,11]

***Cementocytes*:** these are derived from the cementoblasts, resembling cementoblasts when they are young. These are present in spaces called lacunae.[7,14]

***Fibroblasts*:** the role of this cell is to produce the structural connective tissue proteins, collagen and elastin. These cells are also capable of phagocytosing foreign objects and ingesting cross-linked collagen, increasing further this cell's ability to control homeostasis in the periodontium.[15]

Cementoclasts: remodelling of cementum does not occur in the similar fashion as that of alveolar bone and periodontal ligament. However, resorption of cementum can occur under certain circumstances, and in these instances cementoclasts play a role in resorption. [11]

Mineral Component: consists primarily of hydroxyapatite, which contains other elements incorporated into it, such as magnesium, calcium, fluoride and phosphorous.[9,16]

Physical characteristics

Thickness: The cementum occurs as a thin acellular layer around the root neck, with thicker cellular cementum covering the lower part of the root up to the apex.[17]Normally it varies in width from 1 to 175 or 250Å.[12]

Density: Cementum has a less dense structure and the numerical density of the inserting fibers in the cellular is low.[18,19]

Surface Characteristics: Cementum has a dull surface, which is softer than dentine. [20]

Colour: Cementum is light yellow in colour. [21]

Permeability: only in the very young cementum, some penetration through acellular cementum may be found.[20]

Elastic Modulus: cementum has a lower elastic modulus when compared to dentine.[16]

Classification

Ten Cate (1998) has classified the following types of cementum:

1. Primary Acellular Intrinsic fiber cementum
2. Primary Acellular Extrinsic fiber cementum
3. Secondary Cellular Intrinsic fiber cementum
4. Secondary Cellular Mixed fiber cementum
5. Acellular Afibrillar cementum

Others- intermediate and cellular mixed stratified cementum.[7]

Table 1 Classification of Cementum Based On The Type, Distribution And Functions.[13]

Type	Origin of fibres	Location	Function
Acellular/ Primary	Extrinsic	From cervical margin to the apical third	Anchorage
Cellular/ Secondary	Intrinsic	Middle to apical third and furcation	Adaptation and repair
Mixed (alternating layers of acellular and cellular)	Intrinsic and Extrinsic	Apical portion and furcation	Adaptation

Functions of Cementum

1. Provides tooth support by providing anchorage to the tooth in its alveolus
2. To anchor the principal collagen fibres of periodontal ligament
3. Tooth attachment to surrounding alveolar bone
4. Adaptive and reparative functions
5. Integrity of root surface
6. Repair of root fractures, walling in filled canals, sealing off necrotic pulps and protection of subjacent dentinal tubules.[3]
7. To assist in maintaining occlusal relationships.[15]

Cemento Dentinal Junction

Cementum is attached to root dentin through a hydrophilic fibrous cementum-dentin junction **(CDJ)**, which is also known as the **intermediate cementum/ innermost cementum layer,** and consists of collagen fibrils and remnants of epithelial cells of Hertwig's epithelial root sheath (HERS).[22] It is approximately 1□3□μm□thick and represents a barrier

against permeation of substances experimentally applied to the root surface. [23,10]

Cemento Enamel Junction

Three types of Cemento-enamel junctions **(CEJ)** have been reported:

1. overlap- cementum overlaps enamel
2. abutment- cementum butts with enamel;
3. gap- a finite space between cementum and enamel.[19]
4. yet another pattern seen is the overlapping of the enamel on cementum.[24]

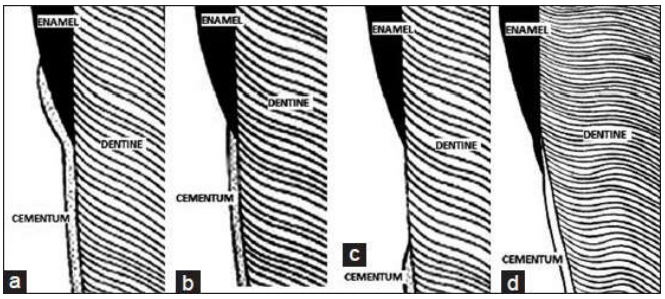

Fig 1 Patterns of Cemento-Enamel Junctions.
©Michael G. Newman. The Tooth-Supporting Structures. In: Textbook of Carranza's Clinical Periodontology.10th ed. Ed. Joseph P. Fiorellini, David M. Kim, and Satoshi O. Ishikawa. St. Louis, Missouri, Saunders, Elsevier, 2006; pg-189.

Histology

The general appearance of the cemental matrix is either granular or hyaline, like ground-glass, or composed of many multitudes of amorphous bodies. Bounding and separating the lamellae are several markings called "incremental lines".[12]

Cellular/Secondary Cementum

Cellular cementum is formed after the tooth reaches the occlusal plane. It is more irregular and contains cells (cementocytes) in individual spaces (lacunae) that communicate with each other through a system of anastomosing canaliculi.[25]It covers the apical third of the root surface and the furcation areas.[26]Cellular cementum resembles bone in that formative cells are incorporated in lacunae spaces from which there are radiating canaliculi. Because of morphological similarity to bone, it has been designated as osteo-cementum.[1]

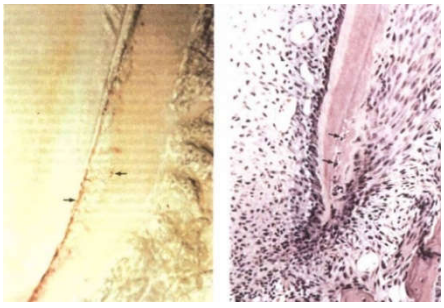

Fig 2 Cellular Cementum (Arrows Indicate The Epithelial Cells In The Cellular Cementum).
© Cho MI, Garant PR. Development and general structure of the periodontium. Periodontology 2000. 2000 Oct;24(1):9-27.

Acellular/Primary Cementum

Acellular cementum is found at the cervical two-thirds of the root surface and covers approximately the cervical third or half of the root. [26,25]It is formed before the tooth reaches the occlusal plane and does not contain cells. Sharpey's fibers make up most of the structure of acellular cementum. [25]

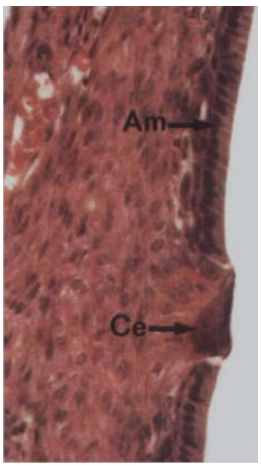

Fig 3 Acellular Cementum (Ce) Located Within Ameloblastic Layer (Am).
© Cho MI, Garant PR. Development and general structure of the periodontium. Periodontology 2000. 2000 Oct;24(1):9-27.

Acellular Afibrillar Cementum (AAC)

It is located over cervical enamel, covering the minor areas of the enamel, particularly at and along the cementoenamel junction.[27]

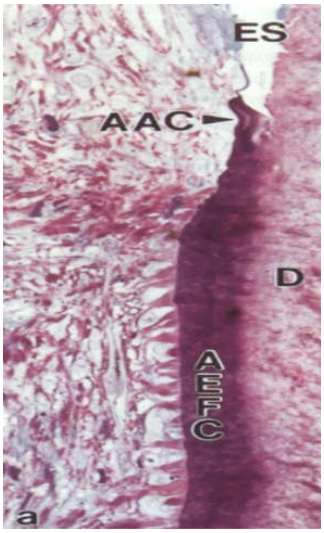

Fig 4 Acellular Afibrillar Cementum (AAC).
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AAC stands out by its basophilia and its more or less uniform appearance. It contains a variable number of layers, which can be either granular or reticular, with varying electron density.[10] It neither contains cells nor intrinsic or extrinsic collagen fibers, but contains a mineralized ground substance. AAC is a product of cementoblasts and is found as coronal cementum in humans, with a thickness of 1 to 15 µm.[25]

Acellular Extrinsic Fiber Cementum (AEFC)

The acellular extrinsic fiber cementum usually covers the coronal half of the root.[10] It is a product of fibroblasts and cementoblasts.[3]**AEFC** matrix contains a dense fringe of short collagenous fibers that are inserted into the dentinal matrix and oriented about perpendicularly to the root surface.[10]

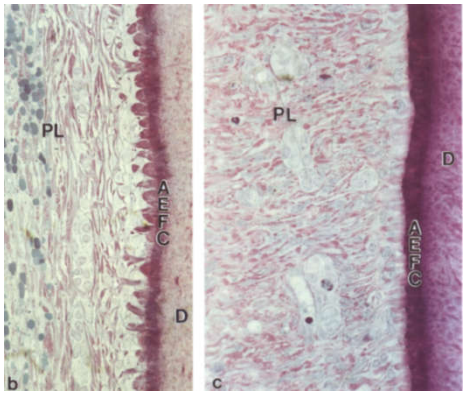

Fig 5 Acellular Extrinsic Fiber Cementum (AEFC).
©Bosshardt DD, Selvig KA. Dental cementum: the dynamic tissue covering of the root. Periodontology 2000. 1997 Feb;13(1):41-75.

Cellular Mixed Stratified Cementum (CMSC): These are the matrix of acellular extrinsic fiber cementum that intermingles or alternates with the intrinsic fibers. Their numerical density may be distinctly lesser than in pure acellular extrinsic fiber cementum. This mixed cementum is referred to as cellular mixed stratified cementum.[10]

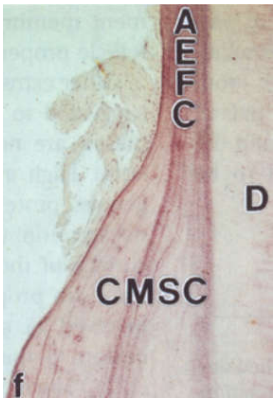

Fig 6 Cellular Mixed Stratified Cementum (CMSC)
©Bosshardt DD, Selvig KA. Dental cementum: the dynamic tissue covering of the root. Periodontology 2000. 1997 Feb;13(1):41-75.

Cellular Intrinsic Fiber Cementum (CIFC)

It is deposited initially on the root surface areas, where no acellular extrinsic fiber cementum has been laid down on the dentin. This may occur in the furcation and on the apical root portions.[10]It contains cells but no extrinsic collagen fibers.[3] The extrinsic fibers of **CIFC** often contain an unmineralized central core, surrounded by a highly mineralized cortical part.[28]

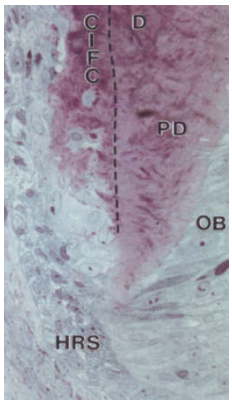

Fig 7 Cellular Intrinsic Fiber Cementum (CIFC).
©Bosshardt DD, Selvig KA. Dental cementum: the dynamic tissue covering of the root. Periodontology 2000. 1997 Feb;13(1):41-75.

Intermediate Cementum

Although originally described for the apical portion of human teeth there exists no interfacial layer between dentin and cementum in human teeth.[10]Earlier, Hopewell Smith had observed a homogeneous layer between AEFC and the granular layer of Tomes. This homogeneous layer is referred to as the hyaline layer of Hopewell Smith. Bencze (1927) first used the term ‘‘intermediate cementum’’, to indicate a narrow part containing cellular elements and/or lacunae between dentin and CMSC. The two investigators proposed different views, with regard to its origin. Hence, it is now referred to as ‘intermediate cementum’ in the CMSC region and ‘hyaline layer of Hopewell-Smith’ in the AEFC region.[28]

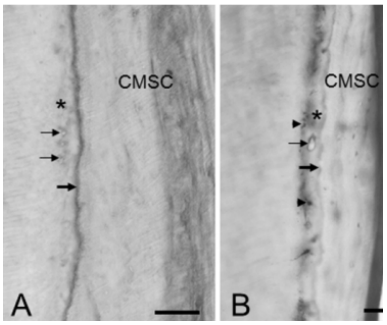

Fig 8 (A, B) Light Micrographs Showing The Apical Roots Covered With Cellular Mixed Stratified Cementum (Cmsc) And Intermediate Cementum(*) Containing Lacunae (Small Arrows), Existing On The Dentin Side Of Cemento-Dentinal Junction (Large Arrow).
©Renz H, Radlanski RJ. Incremental lines in root cementum of human teeth-a reliable age marker?. Homo. 2006 Feb 24;57(1):29-50

Incremental Lines*:* when observed under the light microscope, cementum shows alternating light and dark lines in cross-sections. It has also been suggested that the lines could be caused by abrupt change in the direction of Sharpey’s fibers. These lines could be hyper and hypo mineralized areas.[29]

Cementum vs Alveolar Bone
Similarities

Cementum has an organic fibrous network, crystal type, ground substance, chemical composition, developmental processes and re-organizational capabilities similar to alveolar bone.

Diseases that affect the properties of bone often alter cementum’s properties as well. For example: Paget’s disease results in hypercementosis; Hypophosphatasia results in no cementum formation; Hypopituitarism is associated with decreased cementum formation; Defective cementum formation is seen in cleidocranial dysplasia.[30]

Differences

Table 2 Differences Between Cementum And Alveolar Bone.[3,30]

Cementum	Alveolar bone
Cementum does not undergo remodelling like alveolar bone.	Alveolar bone is a dynamic structure and continuously remodelled. Remodelling is characteristically observed in the alveolar process
Inorganic salts constitute 46% of cementum.	Inorganic salts constitute 70% of alveolar bone.
Consists of type I and type III collagen.	Contains only type I collagen.
Contains more non-collagenous proteins than bone.	Contains less non-collagenous proteins.
It is relatively permeable.	It is non-permeable.

Cementum normally forms only around teeth or occasionally on materials that are in contact with teeth	Bone is found from the tip of the toe to the crown of the head.
AEFC grows throughout life with an appositional rate between 0.005 and 0.01 μm/day	The linear appositional rate for human lamellar bone is 1-2 μm/day
Cementum seems to function without a complex cell system. Signals from the adjacent periodontal ligament likely influences cementoblasts function	For proper functioning of bone, a system consisting of osteoblasts, osteocytes, bone-lining cells, and osteoclasts is required

Clinical Significance

***Estimation of age using Cemental Annulations*:** Cementum is a hard tissue in the root, which is deposited around dentin in layers throughout life.[31]

In a study conducted by Avadhoot *et al*, 25 teeth from patients of known ages were selected, out of which 76% demonstrated countable annulations were considered for study. The age estimated from these specimens was within 2−3 years of the actual chronological age of that patient, thus showing that they are fairly reliable guide for age determination.[32] Findings matched those published by Stott *et al* who carried out a study on teeth extracted from cadavers.[33]

When computer software was used for counting the annulations by Wittwer-Backofen *et al*, the variation between the actual and estimated age was found to be in the range of 2−3 years.[34]

Clinical Implications of CEJ

- CEJ is a significant landmark for determining the level of the clinical attachment in the presence of periodontal disease.
- It is a landmark to diagnose cervical enamel projections (CEPs)
- In the diagnosis and treatment of dental surface defects, CEJ serves as an important reference landmark.
- Clinical CEJ can be used as a guideline for the apical preparation of the composite restoration in cases of deep abrasion defects associated with gingival recession.

Implications in restorative dentistry: Utilization of gingival retractors, causes iatrogenic removal of cementum leading to dentin exposure and hypersensitivity. Hence, special care must be taken with the CEJ area.[24]

Role as a marker for lifestyle events

Paola Cerrito conducted a histo-morphological analysis of 47 teeth among 15 individuals with known life history events. They were able to detect reproductive events and menopause in all females. All the males included in this study presented an unexpected change in cementum bire-fringence corresponding to approximately 20 years of age. The timing of this change in cementum microstructure aligns closely with the timing of changes of free testosterone levels in males. Thus, the changes in cementum are a positive indicator of physiologically stressful events and also a histological marker corresponding not only to parturitions and menopause, but also illnesses and drastic changes in lifestyle. Furthermore, cementum constitutes a chronologically reliable biological marker of an individual, from which life history milestones, thus far not inferable from other mineralized tissues, can be detected and accurately timed.[6]

CONCLUSION

Cementum is a highly responsive mineralized tissue, which maintains the integrity of the root.[33]By virtue of its structural and dynamic qualities, cementum provides tooth attachment and maintenance of occlusal relationship.[10]

Cementum has unique properties that benefit the study of past and present populations. Most notably, these tissues continue to accumulate mineral after the tooth has finished growing. The biological inputs of this process are especially useful for attaining life history information from adults, such as age at death.[34]

The knowledge of the biology, structure and functions of cementum in health is crucial to understand the pathological issues in periodontal disease and to develop innovative treatment strategies for regenerating the cementum. The dynamic composition of cementum helps in opening new avenues for enhancing regeneration and accelerating healing of periodontal tissues following periodontal therapy.[3]

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