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Review Article

Cementum- A Scientific Whodunit!

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***ABSTRACT*:**
The periodontium is a dynamic structure that is served throughout life by a distinctive vascular arrangement, a lymphatic system and a highly specialized network of nervous elements. It is basically defined as 'tissues investing and supporting the teeth'. The dentin of the roots of the teeth in mammals is covered by a thin calcified tissue referred to as 'Cementum'. Among the mineralized tissues identified in mammals, cementum is anatomically most unique. Scientific research in this area has lagged behind the other three periodontal tissues i.e gingiva, alveolar bone and periodontal ligament. However, for true regeneration to occur, cementum is of prime importance, because in the absence of cementum Sharpey's fibres cannot attach on the root surface. The principle function of cementum is to provide anchorage of the tooth in its alveolus. This article reviews the various aspects of structure and properties of Cementum.
Keywords- Cementum, regeneration, Sharpey's fibres, avascular.

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Introduction

The periodontium comprises of the gingiva, periodontal ligament, cementum and alveolar bone. Although being a component of the tooth itself, cementum belongs functionally to the attachment apparatus. Cementum was first described by Denton GB in 1939 in his article "The discovery of cementum".[1] Cementum is an avascular,alymphic and non-innervated mineralised tissue covering the entire root surface, forming an interface between the periodontal ligament and dentin. It is asymmetrically populated by cells termed as cementocytes.[2] Cementum is essential for the attachment of the tooth to alveolar bone, repair of root fractures and resorption as well as functional adaptation of teeth.

Functions of Cementum[3]

1. Tooth support- anchorage of the tooth in its alveolus
2. To anchor the principle collagen fibres of periodontal ligament
3. Tooth attachment to surrounding alveolar bone
4. Adaptive and reparative functions
5. To assist in maintaining occlusal relationships- as the occlusal and incisal surfaces of the teeth are abraded away due to attrition, tooth eruption occurs to compensate for the lost substance and deposition of new cementum occurs in the apical area.
6. Integrity of root surface
7. Repair of root fractures, walling in filled canals, sealing off necrotic pulps and protection of subjacent dentinal tubules.

Similarities and differences of cementum from alveolar bone[4]

CEMENTUM	ALVEOLAR BONE
SIMILARITIES	
Has similar organic fibrous network, ground substance, crystal type, developmental processes, reorganizational capabilities and chemical composition like alveolar bone.	Has similar organic fibrous network, ground substance, crystal type, developmental processes, reorganizational capabilities and chemical composition like cementum.
Diseases that affect the properties of bone often alter cementum's properties as well. For eg- 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	
DIFFERENCES	
Cementum does not undergo remodelling like alveolar bone.	Alveolar bone is a dynamic structure and continuously remodelled.
46% of cementum is made up of inorganic salts.	70% of bone is made up of inorganic salts.
Consists of type I and type III collagen.	Contains only type I collagen.
It is relatively permeable.	It is non-permeable.
Cementum does not undergo extensive remodelling	Remodelling is characteristically observed in the alveolar process.
Contains more non-collagenous proteins than bone.	Contains less non-collagenous proteins than cementum.

Development of Cementum-

Hertwig's epithelial root sheath (HERS) is formed from inner and outer enamel epithelial cells. HERS consists of double layer of cells continuous with and extending apically from the apical rim of enamel organ. During tooth formation and development,HERS detaches from the dentin surface close to the apical edge of the developing root.[5]This detachment is because of epithelial cell degeneration.[6]After the detachment and disintegration of HERS, the fibroblasts of the dental follicle come in contact with the predentin matrix. These fibroblasts deposit and bundle collagen fibrils at the dentin surface to form a thin layer of perpendicularly oriented "fringe fibers".[5]These fibrils interdigitate and get linked with the unmineralized dentin collagen fibres at the dentinocemental junction. When the mineralization front advances to the peripheral mantle dentin, these fringe fibres undergo slow mineralization to complete the process of acellular extrinsic fiber cementum formation. These fringe fibres after mineralization become continuous with the principal fibres of periodontal ligament. When root development is about two thirds completed and the tooth is about to enter its functional stage, cementum formation converts from acellular extrinsic fiber cementum to a cellular mixed stratified cementum type. The formation of cellular intrinsic fiber cementum closely resembles bone formation. Cementoblasts and cementocytes are involved in the secretion of intrinsic fibers. The fate of HERS is debatable. Some authors suggest that it disintegrates into small clusters or strands of epithelial cells that survive indefinitely in periodontal ligament. Recent studies suggest that the epithelial cells might undergo epithelial/mesenchymal transition into fibroblasts and cementoblasts and secrete acellular and cellular cementum.[7]

Biochemical composition of cementum:

Cementum consists of 50-55% organic and 45-50% inorganic constituents. Organic portion consists of collagen (Type I-90% and Type III-5%), glycosaminoglycans (chondroitin sulphate, dermatan sulphate and heparan sulphate) and non-collagenous proteins such as fibronectin, enamel-like proteins, bone sialoprotein, osteopontin, osteocalcin, osteonectin and alkaline phosphatase. The non-collagenous proteins are similar to those in bone and dentin but are more in quantity in cementum. Inorganic portion consists of calcium and phosphate in the form of hydroxyapatite. Apart from these components, cementum also consists of formative cells i.e. the cementocytes, degradative cell i.e the cementoclasts, adhesion molecule termed as Cementum attachment protein (CAP), cementum derived growth factor, basic fibroblast growth factor and other growth factors. The cementum derived growth factor is similar to platelet derived growth factor.[8]

Types of cementum:

Traditionally, cementum has been classified as acellular and cellular based on the presence or absence of cementocytes and as extrinsic and intrinsic based upon the source of formation of collagen fibres. Third type of cementum is intermediate cementum which is only found at the interface between dentine and other two types of cementum. The classification system devised by Owens et al in 1970 is accepted for the most part today and was summarized recently by Schroeder and Page in 1990[9] as-

Acellular, afibrillar cementum- The acellular afibrillar cementum consists of a mineralized matrix, which appears similar to the interfibrillar matrix of acellular extrinsic fiber cementum, but contains neither collagen fibrils nor embedded cells. The lack of collagen fibrils

indicates that this cementum variety has no function in tooth attachment.

Acellular extrinsic fibre cementum- The acellular extrinsic fiber cementum is usually confined to the coronal half of the root. It is composed almost entirely of densely packed bundles of Sharpeyfibers and lacks cells. Acellular extrinsic fiber cementum is a product of fibroblasts and cementoblasts. It is found in the cervical third of roots in humans, but it may extend farther apically. Its thickness is between 30 and 230 μm.

Cellular intrinsic fibre cementum-Although the intrinsic cementum alone has no immediate function in tooth attachment, its important role is as an adaptive tissue. In addition, only cellular intrinsic fiber cementum can repair a resorptive defect of the root in a reasonable time due to its capacity to grow much faster than any other known cementum type.It contains cells but no extrinsic collagen fibers.

Cellular mixed stratified cementum-It is composed of extrinsic (Sharpey) and intrinsic fibers, and it may contain cells. Cellular mixed stratified cementum is a co-product of fibroblasts and cementoblasts. In humans, it appears primarily in the apical third of the roots and apices and in furcation areas. Its thickness ranges from 100 to 1000 μm

Exposed cementum: the need for root surface biomodification

As a result of pocket formation, structural changes are seen on the cemental surface, which are of great clinical concern. Regeneration does not occur after conventional therapy on a pathologically affected root surface. Several possible reasons for the same may include-

1. Reduce periodontium may possess only a limited potential for regenerating its structural components.
2. Progenitor cell populations present in health may be destroyed by the disease process or lack the potential to form the structures of periodontium.
3. The exposed root surface because of pathological alterations is no longer anapt substrate for attachment of cells and collagen fibres. These alterations include loss of collagen fibre insertion, contamination of the surface by bacteria and their endotoxins and alteration in the mineral density and composition.
4. Pathologically exposed root surface lacks the necessary chemotactic stimuli for migration of cells responsible for periodontal regeneration.
5. The apical migration of junctional epithelium acts a barrier between gingival connective tissue and the root surface.
6. The presence of resorption lacunae may explain a route of entry for bacteria into root cementum and radicular dentine which Adriaens et al. (1988) reported in periodontatly diseased (but not in non-diseased) caries free teeth. Daiy et al. (1982) also showed cracks within cementum from periodontally- involved root surfaces.[10]

Acid demineralization or root biomodification or chemical modification of root surface is the procedure used as an adjunct to non-surgical and surgical periodontal therapy to promote new connective tissue attachment. The goal of this procedure is to create a compatible root surface for the attachment of cells and collagen fibres. With the use of certain chemical agents it is possible to detoxify, decontaminate and demineralize the root surface, thereby removing the smear layer and exposing the collagenous matrix of dentine and cementum. There are two methods of root biomodification- mechanical and chemical. Mechanical method includes scaling and root planing which removes cementum, softened dentine and surface irregularities. However, after scaling and root planing, a smear layer will inevitably cover the instrumented surface. Therefore the efficacy of mechanical method of root surface therapy is questionable. Chemical method centres on acid therapy to demineralize the root surface and includes chemicals such as citric acid, tetracycline, fibronectin, EDTA (ethylene diamine tetra acetic acid), chlorhexidine, growth factors, EMD and lasers.[10]

Cytotoxicity of periodontally involved cementum-

It has been suggested that the periodontally involved root surface exerts cytotoxic effects. It has been reported that endotoxin derived from cell wall of Gram negative bacteria which is a lipopolysaccharide (LPS) present in the periodontal pockets gets adsorbed into the relatively permeable cementum. This was detected using the Lumulus Amoebocyte Lysate Assay (LAL). This cementum bound endotoxin exerts a biologically inhibitory effect on gingival fibroblasts. Nakib et al in 1992 suggested that endotoxin was only weakly adherent onto the periodontally involved root surface and could be readily brushed away. Some authors suggested that the molecular size of the LPS precludes its penetration into the cementum. Eide et al 1983 suggested that in periodontal disease, cementum is coated with a mineralized coating which is derived from the inflammatory exudate present in the pocket and is considered to be the reservoir of cementum bound LPS. Hughes et al in 1988 found that most of the detectable LPS was found associated with the bacteria and that extensive root planing to remove the cementum bound endotoxin may not be justified.[11]

Why is cementum a prerequisite for periodontal regeneration?

The hallmarks of periodontal disease are loss of connective tissue attachment, bone loss and ultimately tooth loss. The goal of periodontal therapy is to regenerate the tissues lost due to periodontal disease to their original form, function and consistency. The prerequisite of regeneration is the restoration of alveolar

bone height to the cemento-enamel junction, regeneration of gingival connective tissue destroyed by inflammation, formation of acellular extrinsic fiber cementum, synthesis of Sharpey's fibres and their insertion into the root surface and re-establishment of epithelial seal at the coronal portion.

Cementum is a site where soft tissue attachment has to be established and cementum matrix is a potential source of many growth factors that affect the growth and function of many periodontal cell types. It is a major site for the attachment of Sharpey's fibres. In periodontal disease, due to periodontal pocket formation, cementum is exposed to bacterial endotoxins which alter the composition of cementum and render the root surface incompatible to connective tissue attachment. Cementum contains certain molecules that promote chemotactic migration, adhesion, proliferation and differentiation of some periodontal cell types and these molecules are not detectable in other periodontal structures. Adhesion molecules that cause negative selection by excluding unwanted cells are also present in cementum. To summarize, the cementum microenvironment contains all components necessary for cell recruitment, proliferation and differentiation and molecules from the circulation are not necessary.

Cementum regeneration is not always predictable for the available regenerative procedures. Root planing removes the diseased cementum and exposes the dentin which if not covered by cementum undergoes resorption. Root biomodification exposes Type I collagen on the root surface which manifests poor cell specificity. Use of growth factors does not provide the complete repertoire of the molecules needed for regeneration, the concentration and type of which change continuously with the healing process. Use of barrier membranes provides specific cell repopulation from the periodontal ligament, but again does not provide the microenvironment necessary for regeneration that is provided by cementum which is the same case with the use of enamel matrix proteins.

The blood clot formed during the healing process contains various growth factors derived from the circulation and inflammatory cells. This provisional matrix has a composition entirely different than from that required for cementum formation in health. These growth factors and extracellular matrix are not conducive to the differentiation of cementoblasts from progenitor cells. Therefore it is nearly impossible to form cementum with the natural healing process once it is destroyed by periodontal disease. Mild and moderate forms of periodontitis being more common, affect the acellular cementum which covers the coronal half of the root portion. That is why acellular extrinsic fibre cementum is desired for regeneration to occur.[12]

Emdogain (EMD)- the artificial cementum producer

It is a commercially available product originally developed at BIORA, in Malmo, Sweden which is available since 1997 and is FDA approved. It is purified acidic extract derived of developing embryonal enamel derived from six month old piglets. It constitutes ofEnamel matrix derivative, Water, Propylene glycol alginate (PGA) that acts as a carrier. The enamel matrix derivative consists of Amelogenins (95%), enamelin, ameloblastin, amelotin, apin, and proteinases.[13]It was demonstrated that EMD has a significant influence on the cell behaviour of many celltypes by mediating cell attachment, spreading, proliferation, and survival, as well as expression of transcription factors, growth factors, cytokines, extracellular matrix constituents, and other molecules involved in the regulation of bone remodelling. Based on the understanding of the biological model, the application of enamel matrix proteins (amelogenins) is seen to promote periodontal regeneration since it initiates events that occur during the growth of periodontal tissues. Its purpose is to acts a tissue healing modulator that would mimic the events that occur during root development and to help stimulate periodontal regeneration.

Hammarstrom 1997[14] et al suggested that EMP may promote periodontal regeneration as it mimics events that take place during development of periodontal tissues. Heijl et al 1997[15] compared EMD along with open flap debridement (OFD) versus OFD alone and found new cementum, new PDL, new bone formation after 4 months when EMD was used in combination with OFD. Froum et al 2001[16], Parodi et al 2000[17] used EMP in intrabony defects and found greater defect fill.

Conclusion

The knowledge of the biology, structure and functions of cementum is crucial to understand the pathological issues in periodontal disease and to develop innovative treatment strategies for regenerating the cementum. Cementum provides a distinctive microenvironment for the ideal healing of periodontal tissues. It also provides tooth attachment and helps maintain occlusal relationships. The acellular extrinsic fiber cementum covers the cervical portion of the root and mainly helps in tooth anchorage. Cellular intrinsic fiber cementum is mainly involved in repair and adaptive functions. In the absence of disease, the thickness of cementum increases throughout the life of the individual. The dynamic composition of cementum helps in opening new avenues for enhancing regeneration and accelerating healing of periodontal tissues following periodontal surgery.

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