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Junctional Epithelium: The Key of Understanding Periodontal Attachment and Disease

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ABSTRACT

A crucial element located at the nexus of the periodontal connective tissues that need to be protected from bacterial exposure and the gingival sulcus, which is home to a varied microbial community, is the junctional epithelium. This specialized epithelial layer serves as a vital barrier, protecting the delicate connective tissues from the constant onslaught of microbial threats. Junctional epithelium is uniquely equipped to handle this formidable challenge, possessing a remarkable array of antimicrobial defense mechanisms. However, despite these robust protective measures, gingival and periodontal lesions can still develop, often signaling the onset of more severe oral health complications. Of particular interest to researchers is the transformation of the junctional epithelium into the pocket epithelium, a transition that is recognized as a crucial indicator of disease progression. This structural and functional shift is a crucial focus of ongoing investigations, as it holds the key to understanding the pathogenesis of various periodontal conditions.

Recent studies have stressed the role of the junctional epithelial cells in innate defense mechanisms, suggesting that these cells play a more active and dynamic part than previously believed. These cells have been found to produce specialized virulence factors, which can disrupt the intricate cell-to-cell contacts that are essential for maintaining the structural and functional integrity of the junctional epithelium.

We will briefly examine the structural makeup of the junctional epithelium in this thorough examination, as well as the various roles that its constituent cells play. By enhancing our understanding of the junctional epithelium's complex role in oral health, we can pave the way for the development of more effective diagnostic and therapeutic strategies to combat the periodontal diseases.

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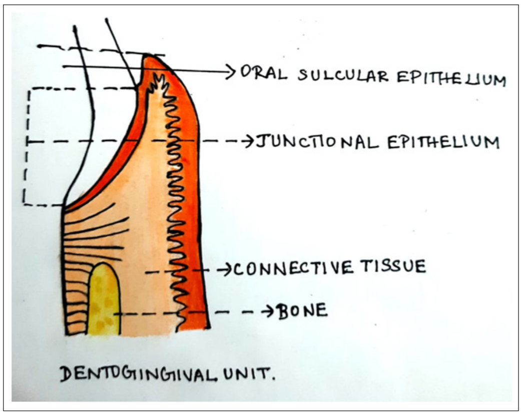
Introduction

In this article we will be discussing about the key role of junctional epithelium. The junctional epithelium is an epithelial component of the dento-gingival unit that connects to the tooth's surface [1]. It is important in keeping out foreign substances and actively participates in the body's defense system [2]. The junctional epithelium's basal layer is composed of two parts

- The internal basal layer attaching with the tooth surface and
- The external basal layer which connects to the underlying tissues [3].

Besides, the junctional epithelium also produces a variety of substances that attack bacteria and their products [1].



Concepts in Development of Junctional Epithelium

Holton's research in 1937 revealed that adding dyes to the attachment did not actually establish a connection between the epithelium and enamel.

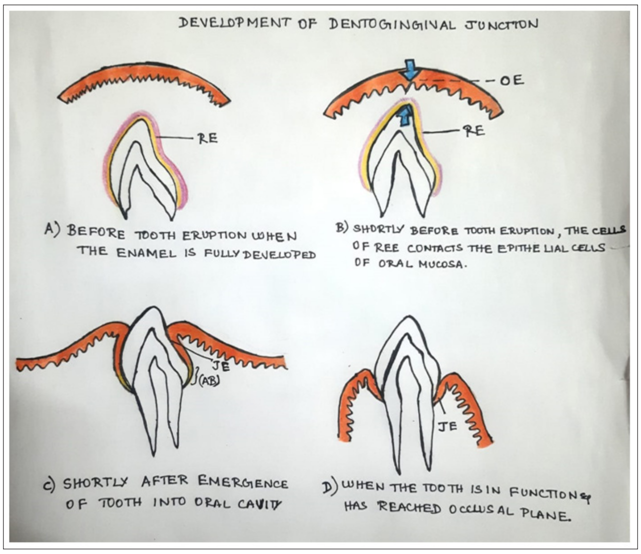
Waerhaug's findings in 1952 showed that epithelial cells adhered to the surface of artificial crowns that came into contact with the pocket epithelium, and he termed this junction the "EPITHELIAL CUFF" [3].

Orban's experimental study in 1960 involved inserting steel blades into the sulci of dogs and monkeys, and he observed that epithelial cells firmly adhered to the teeth [3].

Gottlieb's Concept

Gottlieb demonstrated how the tooth crown erupts into the oral cavity and the development of junctional epithelium. In initial stage, the reduced enamel epithelium, composed of reduced ameloblasts and cells from the enamel organ, enfold the enamel surface before eruption. This reduced enamel epithelium develops into junctional epithelium. After the ameloblasts finish forming the enamel matrices, they leave a thin membrane on the enamel surface. As the tooth erupts, the enamel surface make contact with the oral mucosa, causing the enamel epithelium and oral epithelium to merge together.

The primary junctional epithelium is such reduced enamel epithelium which forms when the edge of the crown breaks through. This reduced enamel epithelium gradually shortens as the tooth continues to emerge into the oral cavity, resulting in a shallow groove called the gingival sulcus. The delicate enamel coating fades and is replaced by a new layer of connecting tissue called the secondary junctional epithelium. Both the contact with enamel, dentin, or cementum and the underlying connective tissue affects the structure and function of the junctional epithelium [1,3].



Cellular Inclusions

The basal cell layer of the junctional epithelium is composed of cuboidal cells to slightly spindle-shaped cells, whereas the remaining cell layers of junctional epithelium (JE) are flat, oriented parallel to the teeth surfaces, closely resemble each other, and exhibit wide intercellular spaces. This distinct morphology of the basal and suprabasal cells within the JE is thought to contribute to the unique permeability and barrier properties of this specialized epithelium. The term "directly attached" (DAT) cells refers to the innermost suprabasal cells that are nearer the tooth surface. These DAT cells are directly firmly affixed to the surface of the teeth through specialized adhesion structures. When there is a periodontal pocket formation, these DAT cells become degenerated and detached from the tooth surface, resulting in the creation of the pocket space. The DAT cells are typically cuboidal in shape or sometimes flattened in their morphology, depending on their location and state of differentiation within the JE. In addition to the epithelial cells, the junctional epithelium also contains several other cellular inclusions that play important roles in the structure and function of this tissue. Lysosomal bodies, which are membrane-bound organelles containing hydrolytic enzymes, are found abundantly within the JE. These lysosomes play a critical role in the eradication of bacteria that may penetrate the epithelial barrier, contributing to the innate immune defense mechanisms of the periodontium. Cytokeratin proteins are also present in the JE, providing mechanical support and facilitating various functions of the epithelial cells, such as cell-cell adhesion, cell signalling, and cytoskeletal organization. The presence of these structural proteins helps maintain the integrity and resilience of the junctional epithelium in the face of the challenging oral environment [1,3].

Finally, polymorphonuclear neutrophils (PMNs), which are specialized immune defense cells, are abundantly found in the central region of the junctional epithelium. These cells play a vital role in the initial response to microbial challenges, migrating from the gingival connective tissue into the JE to help combat invading pathogens and prevent the advancement of periodontal disease.

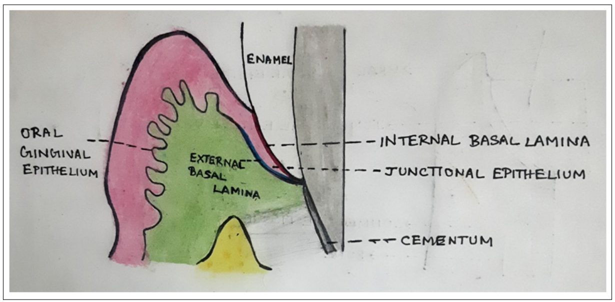
The PMNs have mainly 2 types of granules that help in killing the bacteria. The primary granules consist of lysozyme, elastse, urokinase, hydrolases, myeloperoxidase and defensins. The secondary granules mainly contain lactoferrin, elastase, and lysozyme where lactoferrin is an important antimicrobial protein that helps in bacteriostatic activity. When these cells get activated they produce hydrogen peroxide and highly reactive oxygen radicles that help in the destruction of the bacteria [4]. The unique cellular composition and organization of the junctional epithelium, with its specialized cell types, inclusions, and immune components, contribute to its essential functions in maintaining the delicate balance between the tooth surface and the oral environment, serving as a critical barrier and defence mechanism for the underlying periodontal tissues [2,3].

Epithelial Attachment

A thin membranous layer of connective tissue known as the basement membrane separates the epithelial cells from lamina propria. It is made up of external basal lamina and internal basal lamina. In between the internal basal lamina and the basal cells, external basal lamina lies. The internal basal lamina is continuous with the external basal lamina at the apical end of the JE. Epithelial attachment consists of hemidesmosomes and the internal basal lamina. Hemidesmosomes helps in attachment of the cells to internal basal lamina by providing an epithelial attachment between the gingiva and the tooth surface. The internal basal lamina is composed of the following

- Lamina lucida
- Lamina densa
- Lamina fibroreticularis [3].

The internal basal lamina is devoid of typical basal lamina components such as collagen type IV, perlecan, and nidogen. The structure and functions of both the external and internal basal lamina are influenced by physiological functions, chemical composition, and the mechanical properties of the tissue with which they contact [1,5].



Major Cell Junctions
Three major types of cell junctions enable communication between neighboring through specialized proteins.

- **Anchoring Junctions:** They contain the desmosomal junctions the hemidesmosomal junctions and adheren junctions [3].
  These mechanically attach the cells either to the neighboring or the extracellular matrix. Adheren and desmosomal junctions hold cells together and are formed by transmembrane adhesion proteins. Cells are attached to the extracellular matrix by focal adhesions and hemidesmosomes [6].
- **Gap Junctions:** These are intercellular connections that connect the cytoplasm of 2 cells. They allow different molecules, ions, and impulses to pass between the cells [3].
- **Tight Junctions:** This also referred as occluding junctions that seal cells together in an epithelium that even prevents small molecules from leaking. Their primary role is to impede the diffusion of certain membrane proteins [6].

Role of Junctional Epithelium in Antimicrobial Defense
The junctional epithelium acts as the first line of defense against microbial invasion by combining active cell populations with antibacterial activities. Even though junctional epithelial cell layers operate as a barrier against bacteria, many bacterial compounds, such as lipopolysaccharide, easily pass through the epithelium but possess limited access to the connective tissue via external basal lamina. Both internal and external gives protection against infections. As such, rapid turnover plays a vital role in the microbial defense of junctional epithelium. Moreover, because the region covered by proliferating cells in the junctional epithelium is at least 50 times bigger than the area through which epithelial cells desquamate into the gingival sulcus, a considerable funneling effect adds to epithelial cell flow. Antimicrobial defense mechanisms at the dentogingival junction rely heavily on removing microbes from epithelial cells quickly and effectively.

Various antimicrobial defense systems include

- A high J.E. turnover rate is essential for anti-microbial defense.
- Because J.E.'s surface area is 50 times greater, it effectively facilitates the passage of epithelial cells, inhibits bacterial colonization, functions as a barrier. We refer to this as the Funneling effect.
- J.E. cells produce defensins and lysosomal enzymes that operate as antimicrobial defense.
- Chemokines released by activated epithelial cells attract a variety of cells, including defensins and lymphocytes, which trigger further inflammatory processes [3].

Turnover and Proliferative Activity
The junctional epithelium has a rapid cell turnover rate. The junctional epithelium's turnover period is believed to be 50-100 times faster than that of the oral epithelial surface, taking into consideration the basement membranes of both. This could be due to excessive epithelial cell desquamation. The rapid rate of proliferation in the junctional epithelium indicates that it is a non-differentiating tissue. Non-differentiating epithelial cells are unlikely to have phagocytotic activity, as seen in specifically differentiated cells. The junctional epithelium's basal cells showed maximal proliferative activity when brushing with 200 g of force, which was significantly higher than that achieved with 100 g of force. Topical administration of lipopolysaccharides and mechanical stimulation can also increase the levels of proliferation in the junctional epithelium [1,2].

Conclusion
The Junctional Epithelium (JE) plays a pivotal role in maintaining the structural and functional integrity of the periodontium by serving as a key barrier against microbial invasion. Its specialized cellular composition, rapid turnover rate, and production of antimicrobial substances like defensins and lysosomal enzymes contribute to its defense mechanisms. These unique properties allow the JE to constantly renew itself, which is essential in protecting the underlying connective tissues from bacterial penetration. However, when this protective barrier is disrupted, the detachment of Directly Attached (DAT) cells and the degradation of epithelial cell junctions can lead to the formation of periodontal pockets, marking the progression of periodontal disease.

Moreover, the dynamic interaction between the junctional epithelium and immune cells, particularly the Polymorphonuclear Neutrophils (PMNs), highlights its active role in bringing out the body's innate immune response. Understanding how the JE functions, its structural components like the internal and external basal lamina, and the factors that influence its proliferative activity, can significantly aid in advancing diagnostic tools and therapeutic interventions for periodontal diseases.

In conclusion, the junctional epithelium is not just a passive barrier but an active participant in maintaining oral health. Its failure or alteration signals the onset of periodontal disease, making it a critical target for future research and clinical strategies aimed at improving periodontal care.

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