

DENTAL PLAQUE

DENTAL PLAQUE: A HOST-ASSOCIATED BIOFILM

- Dental plaque is a **host-associated biofilm**.
- The significance of the **biofilm environment** has been increasingly recognized in recent years because the environment itself **may alter properties** of the microorganisms.
- The **biofilm community is initially** formed through bacterial interactions with **the tooth** and *then* through **physical and physiologic interactions among different species within the microbial mass**.

Macroscopic Structure and Composition of Dental Plaque

- Dental plaque can be defined as the soft deposits that form the biofilm adhering to the tooth surface or other hard surfaces in the oral cavity, including removable and fixed restorations.
- Materia alba refers to soft accumulations of bacteria and tissue cells that lack the organized structure of dental plaque and are easily displaced with a water spray.
- Calculus is a hard deposit that forms by mineralization of dental plaque and is generally covered by a layer of unmineralized plaque.

- Dental plaque is broadly classified as **Supragingival plaque** is found at or above the gingival margin; the supragingival plaque in direct contact with the gingival margin is referred to as marginal plaque.
- **Subgingival plaque** is found below the gingival margin, between the tooth and the gingival sulcular tissue.

- The different regions of plaque are significant to different processes associated with diseases of the teeth and periodontium.

- For example,
marginal plaque → gingivitis.

Supragingival plaque and tooth-associated subgingival plaque are critical in **calculus** formation and **root caries**.

Subgingival plaque → soft tissue destruction
→ different forms of periodontitis.

Dental plaque is composed primarily of **microorganisms**. **Cultivation** studies, in which bacteria are isolated and characterized in the laboratory, indicate that more than **500 distinct microbial species** are found in dental plaque

Nonbacterial microorganisms that are found in plaque include *Mycoplasma species*, *yeasts*, *protozoa*, and *viruses*.

The microorganisms exist within an intercellular matrix that also contains a few **host cells** such as *epithelial cells, macrophages, and leukocytes*.

The **intercellular matrix**, estimated to account for **20% to 30% of the plaque mass**, consists of organic and inorganic materials derived **from saliva, gingival crevicular fluid, and bacterial products**.

- **Organic constituents** of the matrix include:
 - ❖ **Glycoproteins** from *saliva* are an *important component of the pellicle & incorporated into the developing plaque biofilm.*
 - ❖ **Polysaccharides** produced by *bacteria*, of which *dextran is the predominant form*, contribute to the organic portion of the matrix.
 - ❖ **Albumin** (*proteins*), probably from *crevicular fluid*, has been identified as a *component of the plaque matrix.*
 - ❖ **The lipid** material consists of debris from the *membranes of disrupted bacterial and host cells and possibly food debris.*

- **The Inorganic Component** of plaque is predominately *calcium and phosphorus*, with *trace* amounts of other minerals such as *sodium, potassium, and fluoride*. The source of inorganic constituents of supragingival plaque is primarily **saliva & derived from crevicular fluid, which is a serum transudate.**

- **Subgingival calculus** is typically *dark green or dark brown*, probably reflecting the *presence of subgingival matrix components distinct from those of supragingival calculus* (e.g., blood products associated with subgingival hemorrhage).
- The *fluoride component* of plaque is largely derived from external sources such as *fluoridated toothpastes and rinses*.

- plaque is actually heterogeneous in structure, with clear evidence of open fluid-filled channels running through the plaque mass. These channels may provide for circulation within plaque to facilitate movement of soluble molecules such as nutrients or waste products.
- The bacteria exist and proliferate within the intercellular matrix through which the channels course.

Formation of Dental Plaque

- Dental plaque may be readily visualized *on teeth after 1 to 2 days with no oral hygiene* measures. Plaque is *white, grayish, or yellow* and has a globular appearance.
- Movement of tissues and food materials over the teeth results in mechanical removal of plaque on the coronal two thirds of the tooth surface. *Thus plaque is typically observed on the gingival third of the tooth surface.*

- **Plaque deposits also** form preferentially in *cracks, pits, and fissures in the tooth structure; under overhanging restorations; and around malaligned teeth.*
- Small amounts of plaque that are not discernible on the tooth surface may be detected by *running a periodontal probe or explorer*, and by using of *disclosing solutions.*

- The process of plaque formation can be divided into three phases:
 1. **Formation** of the pellicle coating on the tooth surface.
 2. Initial **colonization** by bacteria, and
 3. Secondary colonization and plaque **maturation**.

Formation of the Dental Pellicle

- **Formation** of the dental pellicle on the tooth surface is the **initial phase** of plaque development.
- All surfaces are *coated with a glycoprotein* pellicle. This pellicle is **derived from** components of *saliva and crevicular fluid* as well as bacterial and host tissue cell products and debris.

- The *hydroxyapatite surface* has a predominance of **negatively charged phosphate groups** that interact directly or indirectly with **positively charged components of salivary and crevicular fluid macromolecules**.
- Pellicles function as a **protective barrier**, providing **lubrication for the surfaces** and **preventing tissue desiccation**. However, they also **provide a substrate** to which **bacteria** in the environment attach. Because the epithelial tissue cells are continually sloughed, the bacterial population on the tissue surfaces is continually disrupted.

Initial Colonization of the Tooth Surface

- Within a few hours, bacteria are found on the dental pellicle. The **initial bacteria colonizing** the pellicle-coated tooth surface are *predominantly gram-positive* facultative microorganisms such as **Actinomyces viscosus** and **Streptococcus sanguis**.
- These initial colonizers adhere to the pellicle, through specific molecules, **termed adhesins**, *on the bacterial surface that interact with receptors in the dental pellicle*.

- There is a transition from the **early aerobic environment** characterized by **gram-positive facultative species** to a highly **oxygen-deprived environment** in which **gram-negative anaerobic microorganisms predominate**.

Secondary Colonization and Plaque Maturation.

- Secondary colonizers are the microorganisms that do not initially colonize clean tooth surfaces, including *Prevotella intermedia*, *Prevotella loescheii*, *Capnocytophaga spp.*, *Fusobacterium nucleatum*, and *Porphyromonas gingivalis*. These microorganisms adhere to cells of bacteria already in the plaque mass.

- Extensive laboratory studies have documented the ability of different species and genera of plaque microorganisms to adhere to one another, a process known as **coaggregation**. This process occurs primarily through the highly specific *stereochemical interaction of protein and carbohydrate molecules located on the bacterial cell surfaces*, in addition to the less specific interactions resulting from *hydrophobic, electrostatic, and van der Waals forces*.

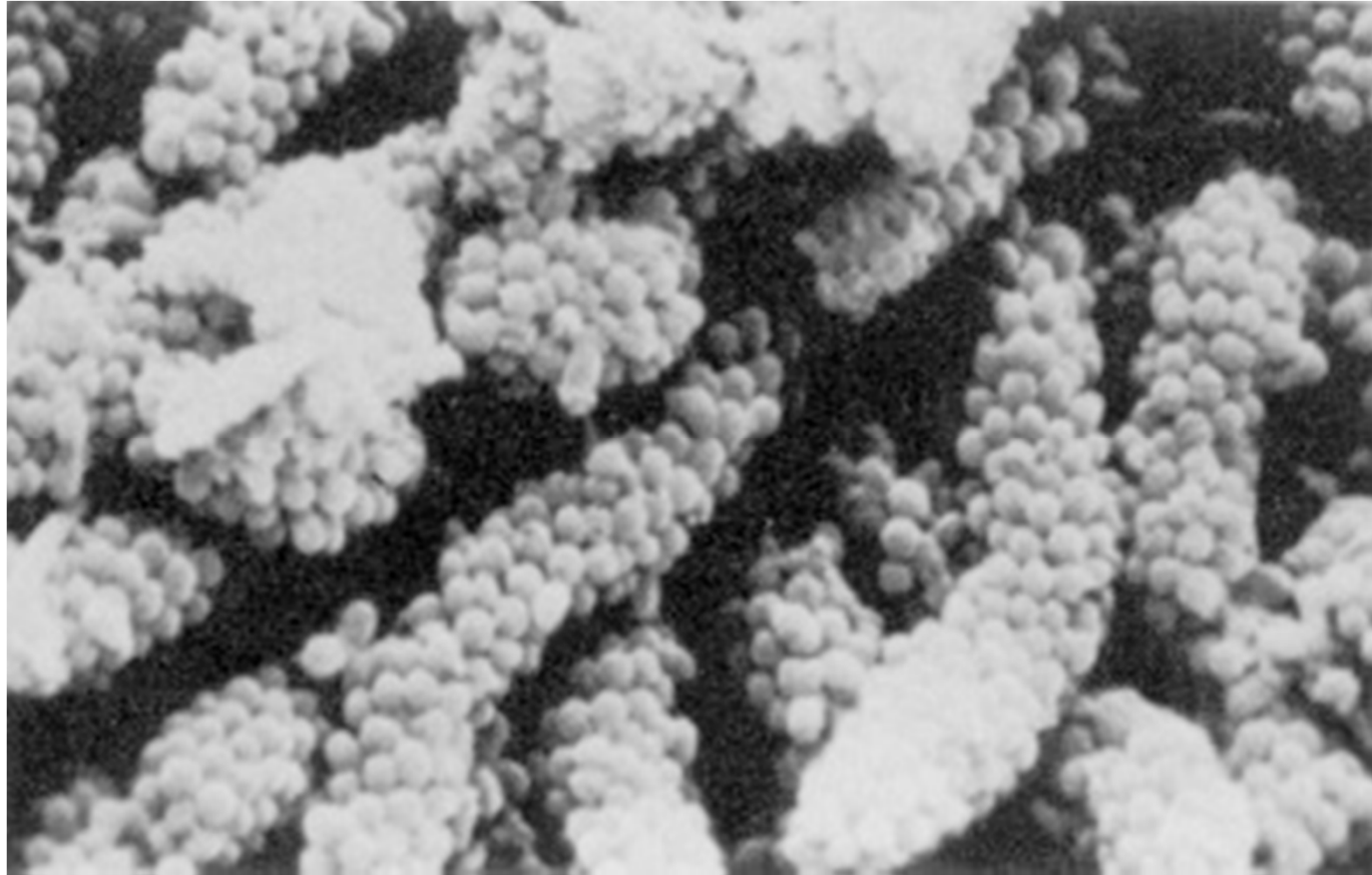
- Most studies of *coaggregation* have focused on interactions among different *gram-positive species* and *between gram-positive and gram-negative species*.
- In the **latter stages** of plaque formation, **coaggregation between different gram-negative species** is likely to predominate. Examples of these types of interactions are the coaggregation of **F. nucleatum** with **P. gingivalis**, or **Treponema denticola**.

Microscopic Structure and Physiologic Properties of Dental Plaque

Supragingival plaque

- Supragingival plaque typically demonstrates a stratified organization of the bacterial morphotypes. ***Gram-positive cocci and short rods*** predominate at the tooth surface, ***whereas Gram-negative rods and filaments as well as spirochetes predominate in the outer surface of the mature plaque mass.***

- **Highly specific cell-to-cell interactions** are also evident from the “**corncob**” structures often observed. Corncob formations have been observed **between rod-shaped bacterial cells** (e.g., *Bacterionema matruchotii* or *F. nucleatum*) that **form the inner core of the structure and coccal cells** (e.g., *streptococci* or *P. gingivalis*) that attach along the surface of the rodshaped cell.



Long-standing supragingival plaque near the gingival margin demonstrates “corn cob” arrangement. A central gramnegative filamentous core supports the outer coccoid cells, which are firmly attached by interbacterial adherence or coaggregation.

- The environmental parameters of the **subgingival region differ from those of the supragingival region**. The gingival crevice or pocket is bathed by the flow of *crevicular fluid, which contains many substances that the bacteria may use as nutrients*.
- *Host inflammatory cells and mediators* are likely to have considerable influence on the establishment and growth of bacteria in this region.

Plaque/bacteria

Tooth
attached
plaque

Unattached
plaque

Epithelial
associated
plaque

Bacteria within
connective tissue

Bacteria on
bone surface

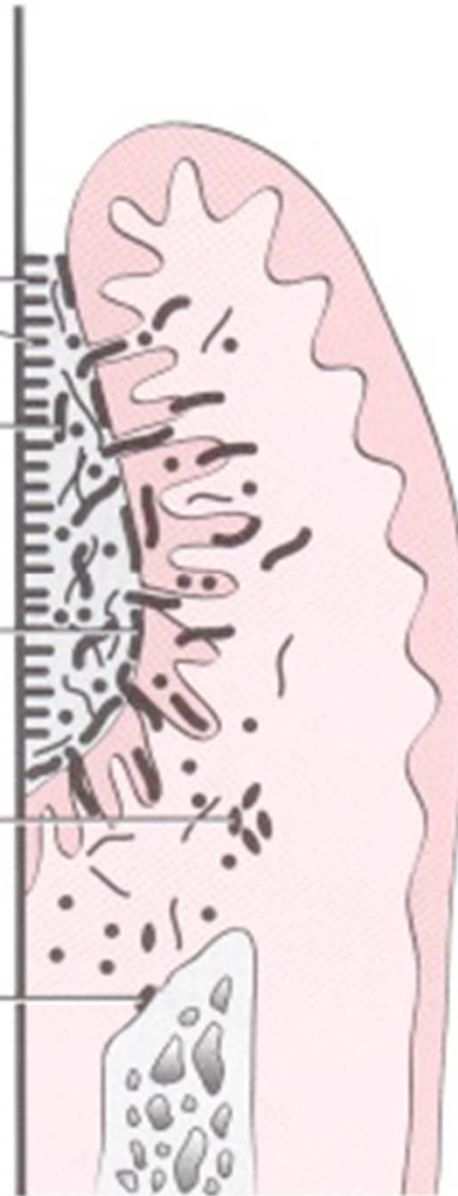


Diagram depicting the plaque-bacteria association with tooth surface and periodontal tissues.

- The tooth-associated (attached) plaque is characterized by gram-positive rods and cocci, including *Streptococcus mitis*, *S. sanguis*, *A. viscosus*, *Actinomyces naeslundii*, and *Eubacterium* spp.
- **The apical border of the plaque mass is separated from the junctional epithelium by a layer of host leukocytes, and the bacteria of this apical tooth-associated region show an increased concentration of gram-negative rods.**

- It **contains** primarily **gram-negative rods and cocci**, as well as large numbers of **filaments, flagellated rods, and spirochetes**.
- **Host tissue cells** (e.g., white blood cells and epithelial cells) also may be found in this region.
- Studies of tissue-associated plaque indicate a predominance of **species** such as *S. oralis*, *S. intermedius*, *P. micros*, *P. gingivalis*, *P. intermedia*, *Bacteroides forsythus*, and *F. nucleatum*.

- **The transition from gram-positive to gram-negative** microorganisms observed in the structural **development of dental plaque** is paralleled by a physiologic transition in the developing plaque.
- The **early colonizers** (e.g., streptococci and Actinomyces species) **use oxygen** and lower the reduction-oxidation potential of the environment, which then favors the growth of anaerobic species.
- **Gram-positive species use sugars as an energy source and saliva as a carbon source.**

- The bacteria that predominate in mature plaque are anaerobic and asaccharolytic, and use amino acids and small peptides as energy sources.

- Laboratory studies have demonstrated many physiologic interactions among the different bacteria found in dental plaque
- **The host also functions as an important source of nutrients.** For example, *Hemin iron* from the breakdown of host hemoglobin may be important in the metabolism of **P. gingivalis**. Increases in **steroid hormones** are **associated** with significant **increases** in the proportions of **P. intermedia** found in subgingival plaque.

Any Question?