Dental Plaque: A Microbial Biofilm

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Topics Overview

• Characteristics of bacteria
• Characteristics of bacterial communities
• Life Cycle of a Biofilm
• How do dental plaque biofilms form?
• How complex is the structure of dental plaque biofilms?
• What is the sequence of bacterial colonization?
• Bacterial attachment zones
• Transmission of periodontal bacteria
• Control of plaque biofilms
• What is the changing role of bacteria in causing periodontitis?
• How are bacteria organized into complexes?

Characteristics of Bacteria

• Bacterium—singular form of the word bacteria
• The simplest organisms; can be seen only through a microscope
• Have existed on earth longer than any other organism; still the most abundant type of cell
• Replicate quickly; adapt rapidly to changes in their environment

Structure of the Bacterial Cell Membrane

• Cell membrane—a tough protective layer that encloses nearly all bacteria.
• The composition of the cell membrane is important in identifying and classifying bacteria.
• A technique called Gram staining is used to classify bacteria.

Where do Bacteria live?

• Live almost everywhere
• Able to live where other life forms cannot survive
• Always present on the skin and in the digestive traits and respiratory systems of humans

Characteristics of Bacteria

• Gram-positive (purple)
• Gram-negative (red)
Bacteria and Biofilms

• Most bacteria live in complex colonies that are called _______.

• 2 types of bacteria:
  • Free-floating – (aka planktonic)
  • Attached – attach to surfaces and each other. These communities of bacteria that are attached to each other and to a surface are called ________.

• Once the bacteria attaches to a surface, it activates new genes that changes its characteristics that it had previously as a free-floating organism.

• 99% of all bacteria on Earth live as attached bacteria.

Bacterial Communities

• Biofilms—a living film—containing a well-organized community of bacteria—that grows on a surface.

Biofilms (cont.)

• Usually consist of many species of bacteria as well as other organisms and debris
• Form rapidly on almost any surface that is wet
• Found nearly everywhere in nature
• Have major impact on human health

Biofilm Environment Examples:

Biofilms form on any solid surface that is exposed to a bacteria-containing fluid.

Medically Significant Biofilms

• Biofilms can be found on:
  — Medical and dental implants
  — Contact lens cases
  — Pacemakers
  — Artificial joints
  — Dental unit water and suction lines
  — Teeth
How Clean is Your Contact Lens Case?

The Life Cycle of a Biofilm

Lifecycle of a Biofilm in 3 Major Stages

1. Attachment  – self-explanatory
2. Growth  
   - Find friends to join together  
   - They also secrete a slimy film to stay attached and protect themselves  
   - The bacteria multiply rapidly and grow away from the surface to form a mushroom-shaped mature biofilm
3. Detachment

Stage 3—Detachment

- Clumps of biofilm break off, are carried away by the fluid, and attach to other portions of a surface to form a new bacterial colony.

Recap—Bacteria

- Gram-negative bacteria play an important role in periodontitis.
- Once attached to a surface, a bacterium exhibits characteristics that are different from those that it had as a free-floating bacterium.
- Biofilms—a living film—containing a well-organized community of bacteria—that grows on a surface.

Recap—Bacteria (cont.)

- The three major stages in the life cycle of a biofilm are—attachment, growth, and detachment.
- Attached bacteria secrete a film known as the extracellular slime layer that acts as a protective shield for the biofilm.
Biofilms and Where They Form

• Biofilm consists of many different types of bacteria as well as other organisms and debris

• 65% of all diseases may be biofilm induced – Biofilm-induced diseases include TB, cystic fibrosis, subacute bacterial endocarditis, and periodontal disease.

• Biofilms are EVERYWHERE!!!
  • Even in places where other life cannot survive
  • Where would you find biofilms? Give some examples:

Dental Plaque: What is it?

• Naturally acquired bacterial biofilm on the teeth
  • A melting pot of different species of bacteria

• Some bacteria are more significant in the development of dental caries and periodontal diseases

What dental biofilm looks like

- Clinically, it is transparent, requires a stain to see,
- Microscopically, it is a mass of intertwined microorganisms

Oral Diseases caused by Dental Biofilm

Dental caries & Periodontal Diseases

Gingivitis

Periodontitis

Phases of Plaque Biofilm Development

Primary (acquired) pellicle: is a transparent natural thin layer of antibodies and salivary glycoproteins that quickly adhere to the tooth surface after the tooth has erupted or cleaned. This pellicle will not respond to disclosing stains initially.

Dental biofilm: is a transparent colony of microorganisms and their by-products living in the oral cavity. Will respond to disclosing stains. Responsible for tooth and periodontal diseases.
Five Phases of Plaque Biofilm Development

Phase 1—Film Coating

- Within minutes after cleaning, a film forms over the tooth surface.
- This film, the acquired pellicle, is composed of a variety of salivary glycoproteins (mucins) and antibodies.

Acquired Pellicle

- Its purpose is to protect the enamel from acids.
- It also, however, alters the charge and energy of the tooth surface, facilitating bacterial adhesion to the tooth surface.

Acquired Pellicle—“Nature’s Sticky Tape” (cont.)

- Hint—To understand the role of acquired pellicle in plaque biofilm formation, it is helpful to think of the pellicle as “double-sided adhesive tape.”
- The “tape” adheres to the tooth surface on one side and provides a sticky surface on the other side that aids bacteria in attaching to the tooth surface.

What is the major difference between the primary pellicle (acquired pellicle) and dental biofilm?

Phase 2—Initial Attachment to Pellicle

- Within a few hours after pellicle formation, bacteria begin to attach to the surface of the pellicle.
- Some bacteria have hair-like attachment structures that enable them to attach rapidly upon contact.
- These hair-like structures are called fimbriae.
Phase 3—New Bacteria Join In

- Bacteria attached to the tooth produce substances that stimulate other free-floating bacteria to join the community.

Phase 4A—Slime Layer Formation

- The act of attaching to the tooth surface stimulates the bacteria to excrete a slimy, glue-like substance called the extracellular slime layer.
- The slime layer helps to anchor the bacteria to the tooth and provides protection for the attached bacteria.

Phase 4B—Microcolony Formation

- In this part of phase 4, the bacteria proliferate and begin to grow away from the tooth surface.
- Bacterial blooms are periods when specific species or groups of species grow at rapidly accelerated rates.

Phase 5—Mature Dental Plaque Biofilm

- The bacteria cluster to form mushroom-shaped microcolonies that attach to the tooth surface at a narrow base.
- The microcolonies are complex collections of different bacteria linked to one another.

Mushroom-Shaped Mature Microcolonies

The Complex Structure of Mature Dental Plaque Biofilms
Structural Elements of the Mature Biofilm

- Bacterial microcolonies
- Extracellular slime layer
- Fluid forces of the surrounding saliva
- Fluid channels
- Cell-to-cell communication system
- Bacterial signaling

Mature Microcolonies

- Each microcolony is a tiny independent community containing thousands of compatible bacteria.
- Different microcolonies may contain different combinations of bacterial species.

Environments Within Microcolonies

- Each microcolony has its own unique environment.
- Differences include oxygen concentration, pH, and temperature within the microcolonies.
- Each bacterial species prefers a certain environment within the biofilm.

Bacterial Diversity Within the Biofilm

- It helps to ensure the survival of the plaque biofilm in widely varying oral conditions.
- If the plaque biofilm only had one species of bacteria, it is much more likely that a toxic agent or condition could destroy the biofilm.

Extracellular Slime Layer

- Is a dense protective barrier that surrounds the bacterial microcolonies
- Acts like a shield protecting the bacteria from antibiotics, antimicrobials, and the body’s immune system

Fluid Forces of Saliva Surrounding the Biofilm

- Fluid forces influence the shape of the biofilm.
- Fluid forces result in the development of extensions from the main body of the biofilm.
- Extensions can break free and be swallowed, expectorated, or form new biofilm colonies in other areas of the mouth.
Fluid Forces of Saliva Surrounding the Biofilm (cont.)

- Fluid forces result in cell-to-cell collisions of the bacteria within the biofilm.
- Collisions lead to a more rapid spread of genes among the bacteria.
- This continuous exchange of genetic information among bacteria means that the bacteria are constantly evolving.

Fluid Channels

- They penetrate the extracellular slime layer.
- They bring nutrients and oxygen to the bacteria.
- They carry bacterial waste products away.
- Included in the fluids is everything from saliva to any beverages consumed.

Cell-to-Cell Communication System

- Direct cell-to-cell interaction occurs among the bacteria in the biofilm.
- Bacteria use chemical signals to communicate with each other.
- This communication also results in the transfer of genes among bacteria.

Bacterial Signaling

- Bacteria within a biofilm produce 100s of proteins that free-floating bacteria do not.
- Some of these proteins trigger the adhesion of additional bacteria and formation of the extracellular slime layer.

II. Changes in Biofilm Microorganisms

- Days 1 and 2
- Days 2 to 4
- Days 4 to 7
- Days 7 to 14
- Days 14 to 21
III. Experimental Gingivitis

- Development
- Demonstration of effects

Materia Alba

I. Definition
II. Clinical Appearance and Content
III. Effects
IV. Prevention

Food Debris

I. Cariogenic foods
II. Food impaction
III. Horizontal or lateral food impaction

Documentation

I. Clinical description
   A. appearance of the teeth relative to biofilm, materia alba, or food debris
II. Patient’s understanding
III. Patient’s description of methods used daily for biofilm control
Factors to Teach the Patient

I. Location, composition, and properties of dental biofilm
II. Cause and prevention of dental caries
III. Effects of personal oral care
IV. Sources of cariogenic foodstuff
V. Relationship of frequency of eating cariogenic foods