Overview Caries Process and the New Model for Management of Caries

| Domenick Zero, DDS, MS, Andrea Ferreira Z, DDS, MSD, PhD

OUTLINE

- Caries Theories/Working Hypotheses
- Dental Caries Process
  - Etiologic Factors
  - Site-specific
  - Dynamic Disease Process
- Personalized Approach Caries Management
  - Where we are
  - Where we need to go

Simple Truths About Dental Caries

- People like to eat and our diets are largely influenced by what food is presented to us (opportunistic)
- Food manufacturers exploit our biology (preference for sweets and grazing)
- Government plays a only minor role in modifying the food choices
- Attempts at behavior modification by health care professions has not had a major impact (but we should keep trying)

- Bacteria and humans have co-evolved over millions of years and its hard to change this relationship overnight
- Non-specific chemotherapeutic approaches are not effective and may even be deleterious
- Targeted approaches at specific organisms have not as yet been proven to be effective
- Genes plays some role, but probably not a major role given the localized nature of the disease process

Chemoparasitic Theory

Caries is brought about by acid dissolution of the mineral phase of the teeth, the acid being produced by metabolism of dietary carbohydrates by oral bacteria. In a secondary step the organic phase of enamel and dentin is broken down.

W.D. Miller (1890)

We have had a scientific basis understanding the caries process for over 120 years

Dental Caries Working Hypotheses

- Infectious and transmissible disease caused by Streptococcus mutans (Losche, 1976) "Medical Model"
- Dietary carbohydrate-modified infectious disease (Bowen & Birkhed, 1986)
- Ecological shift in dental plaque resulting in a pathogenic microflora (Marsh, 2003)
- Biopsychosocial disease model (Resine and Lilt, 1993)
- Genetic basis for increase risk of dental caries (Hassell & Harris, 1995)

Are we preventing or controlling dental caries based on any of these hypotheses?
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Ecological Plaque Hypothesis

- Adaptation
- Selection
- Increased acid tolerance
- Increased acid production

Updated Scheme

Key Features of Dental Caries
- Multifactorial etiology
- Site-specific disease
- Time-dependent dynamic disease process modified by protective factors

Main Etiological Factors
- Tooth location and morphology
- Dental biofilm microorganisms with acidogenic and aciduric properties
- Frequent dietary exposure to fermentable carbohydrates
- Salivary flow rate and composition

Working Hypothesis:
Dental caries is primarily the consequence of physiological adaptation by (endogenous) plaque bacteria to a low pH environment.


Marsh (2006)
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Types of Caries
- Smooth Surface Caries
- Occlusal Caries (pit and fissure caries)
- Approximal Caries
- Root Surface Caries
- Caries Adjacent to a Restoration (Secondary Caries)

Main Etiological Factors
- Tooth location and morphology
- Dental plaque (biofilm) microorganisms with acidogenic and aciduric properties
- Frequent dietary exposure to fermentable carbohydrates
- Salivary flow rate and composition

Microorganisms Associated with Dental Caries in Humans
- Streptococcus mutans
- Streptococcus sobrinus
- Lactobacillus species
- Actinomyces species
- non-mutans streptococci
- Other species – yeasts, Bifidobacterium, Propionibacterium, Atopobium

Dental Biofilm Diversity
- 197 bacterial different species/phytypes detected using 16S rRNA gene cloning, of which 50% were not cultivable
- 10% of the subjects with dental caries did not have detectable levels of S. mutans
- Bacterial species other than S. mutans, likely play important roles in caries progression

Caries-Associated Virulence Traits
- Biofilm formation - adherence and colonization
- Acid producing ability – mainly lactic acid from fermentable carbohydrates
- Aciduric potential - ability to survive and continue to produce acid at a low pH
- Formation and utilization of storage polysaccharides
- Formation of insoluble extracellular glucans

S. mutans has all of these traits; however, many other species found in the dental biofilm also have them

Main Etiological Factors
- Tooth location and morphology
- Dental plaque (biofilm) microorganisms with acidogenic and aciduric properties
- Frequent dietary exposure to fermentable carbohydrates
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Conclusions Based on the Vipeholm Study

- The amount of sugar eaten is not as important as the form in which it is eaten.
- Sticky sugar products which tend to be retained on teeth have a greater caries potential than sugar consumed in a liquid form.
- The more frequent sugar is consumed the greater the risk.
- Sugar consumed between meals has much greater caries potential than when consumed during a meal.

Gustafsson et al. (1954)

Is sucrose “the arch criminal of dental caries”?

Newbrun (1969)

Cariogenic Properties of Sucrose

- Highly soluble in oral fluids
- Freely diffusible in dental plaque
- Readily metabolized by plaque bacteria
- Serves in the formation of insoluble extracellular glucan (mutan) in the presence of the enzyme glucosyltransferase from S. mutans
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1. Role of Extracellular Polymers
   - Bacterial adherence and colonization
   - Structural matrix for plaque
   - Reserve carbohydrate source
   - Protective function
   - Modify diffusion properties of plaque

2. Main Etiological Factors
   - Tooth location and morphology
   - Dental plaque (biofilm) microorganisms with acidogenic and aciduric properties
   - Frequent dietary exposure to fermentable carbohydrates
   - Salivary flow rate and composition

3. Salivary Tooth Protective Mechanisms
   - Mechanical cleansing action
   - Dilution and buffering of plaque acids
     - Buffering systems: Carbonic acid-bicarbonate, phosphate, proteins
     - Ammonia and urea
     - Small peptides (salin)
   - Anti-solubility Factors
     - Calcium, phosphate, fluoride
     - Statherins, histatins, proline-rich proteins
     - Acquired pellicle
   - Remineralization and repair of enamel
     - Calcium, phosphate, fluoride
     - Organic matter
   - Antimicrobial properties
     - Secretory IgA, non-immunological aggregating macromolecules, lysozyme, lactoferrin, peroxidase/myeloperoxidase

4. Stephan Curve in Patient With Salivary Gland Hypofunction
   - 10% Sucrose Rinse
   - Critical pH

5. Hypothetical Change in Tooth Mineral Content Over a 24 hour Period
   - Net loss
   - Modified from Zero (1999)

6. Key Features of Dental Caries
   - Multifactorial etiology
   - Site-specific disease
   - Time-dependent dynamic disease process modified by protective factors

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Mandello (1989)
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Site-specific Disease Process

Dental caries is a highly localized and complex process which occurs in areas of stagnation where plaque can accumulate undisturbed. Each tooth site represents a unique environment that influences plaque composition, metabolic status and thickness, as well as access by dietary substrates, saliva and anticaries agents.


Site-specific Biological and Behavioral Modifying Factors

- Pre-eruptive and post-eruptive fluoride exposure
- Oral hygiene practices
  - Plaque removal, fluoride use
- Dental biofilm
  - Composition, metabolic state, thickness, diffusion properties, degree of saturation with respect to tooth mineral
- Saliva flow rate and composition
  - Proximity to salivary gland orifices, salivary film thickness and velocity
- Acquired pellicle
  - Composition and thickness
- Eating and drinking pattern
- Oral physiology affecting clearance pattern
  - Cariogenic foods and beverages
  - Fluoride

Site Specific Plaque Biofilm Factors

Composition
Metabolic state
Thickness
Diffusion properties
Degree of saturation with respect to tooth mineral

Site Specific Salivary Factors

Proximity to salivary gland orifices
Pellicle composition and thickness
Salivary film thickness
Salivary film velocity

Key Features of Dental Caries

- Multifactorial etiology
- Site-specific disease
- Time-dependent dynamic disease process modified by protective factors

Dynamic Nature of Dental Caries

\[ 8H^+ + Ca_{10}(PO_4)_{6}OH_2 \rightarrow 6(HPO_4)^{2-} + 10Ca^{2+} + 2H_2O \]

Supersaturated conditions in oral fluids

Remineralization

Undersaturated conditions in oral fluids

Demineralization
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Carious Lesion Development (hypothetical)
(modified from Zero DT. Dental Clinics of North America, 1999)

White Spot Lesion

Demineralization Progression

White Spot Surface Layer

The caries process is initially driven by an interaction between the biofilm and the tooth surface

Factors Affecting Remineralization

- Tooth
  - enamel or dentin, surface involved, extent of demineralization
- Acquired Pellicle
  - composition, thickness
- Dental Biofilm
  - thickness, diffusion properties, Ca, PO₄, and F content, pH
- Saliva
  - flow rate, composition (proteins, Ca, PO₄, and F content)
- Diet
  - indirect effects on plaque metabolism (acid production), and direct effects by introducing reparative factors such as the calcium and phosphate from dairy products

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Changes in Our Understanding of Dental Caries

- Moved from the concept that caries is a treatable disease to caries is a totally controllable disease
- Lesions progress more slowly and cavitate later in the post-fluoride era
- Caries is a dynamic process that can be arrested or reversed at an early stage

Has the way we manage caries changed, or are we stuck?
And if so, what do we need to do to get unstuck?

Premise

Our current system for treating dental caries in most countries is too expensive and not very effective, because it doesn’t appropriately manage the disease process.

We need a whole new approach with new tools to make additional significant improvements in oral health.

Simple Truths About Our Current System of Managing Dental Caries in the US

- Dentists will not change the way they are managing dental caries without external drivers
  - New technology (tools) that dentists perceive will improve their practice
  - New financial incentives or disincentives
  - New regulatory/legal environment
    - Standard of Care driven by evidence based dentistry
    - Law suits
- The few Cariologists in US dental schools have only limited impact on changing the way graduating dentists manage dental caries
- The major impactor on practice behavior is what is taught in the clinic, mainly by part-time faculty and what patients and third party payers are willing to pay for.

Historical Understanding of Dental Caries

- $8H^+ + Ca_{10}(PO_4)_{6}OH_2 \rightarrow 6(HPO_4)_{2}^- + 10Ca^{2+} + 2H_2O$
- Demineralization

Modern Understanding of Dental Caries

- $8H^+ + Ca_{10}(PO_4)_{6}OH_2 \rightarrow 6(HPO_4)_{2}^- + 10Ca^{2+} + 2H_2O$
- Remineralization

The early stages of dental caries can be prevented, reversed or arrested, primarily through the elimination or modification of etiological factors (dietary, microbial) and/or by enhancing protective factors (fluoride, sealants and salivary stimulation).

Very good for dentists
Maybe not the best for patients

Our profession is heavily biased towards our successes and not our failures
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Modern Management of Dental Caries

Preventive Intervention (prevent, reverse, arrest)

(Early) Lesion Detection & Assessment
Risk Assessment Diagnosis & Prognosis

risk/benefit cost/benefit patient preferences

Oral Health Outcome

Restorative Intervention (only when absolutely necessary)

Modern Management of Dental Caries

Preventive Intervention (prevent, reverse, arrest)

(Early) Lesion Detection & Assessment
Risk Assessment Diagnosis & Prognosis

Oral Health Outcome

Restorative Intervention (only when absolutely necessary)

We currently evaluate these components as independent processes and not as one system that impacts the long-term health of patients.


Personalized Caries Management

Primary Prevention at the Patient Level

Secondary Prevention

Tertiary Prevention (Care)

Caries Risk Assessment at the Patient Level

ICDAS 0
Initial Lesion ICDAS 1
Initial Lesion ICDAS 2
Moderate Lesion ICDAS 3
Moderate Lesion ICDAS 4
Extensive Lesion ICDAS 5
Extensive Lesion ICDAS 6

Staging of Lesion Severity

Caries Risk Assessment at the Tooth Surface Level

Radiographs and Other Diagnostic Aids

Additional Information that Informs Diagnosis

Caries Lesion Activity Assessment

Remineralize
Arrest
Sealant
Minimal Surgical
Traditional Surgical
Endodontic Surgical
Extraction

Secondary Prevention

Tertiary Prevention (Care)

Interactions Between Caries Risk Assessment and Caries Diagnosis

- Caries Diagnosis should inform Caries Risk Assessment
  - Based on careful examination of the oral cavity, patients with the presence of detectable caries active lesions are at a minimum at moderate caries risk.
  - Patients without the presence of clinically detectable caries active lesions may be at moderate or high risk depending on recent changes in their risk factors/indicators.

- Caries Risk Status should inform Caries Diagnosis and Treatment Decisions by helping to:
  - determine if incipient lesions are active.
  - determine the appropriate level of preventive intervention.
  - determine if operative care is indicated (or not), especially for questionable lesions.

Problem Definition

The Institute of Medicine’s (IOM) review of evidence-based health care found that, despite benefits from rapid growth in medical research and increasing expenditures for health care in the United States, far too much time is spent on health care activities that do not improve health, and not enough time is spent on healthcare activities that will.

Olson, Akner, McGinnis (2007)
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Preventive Treatment Planning

- Fluoride (highly effective in all forms)
  - Water fluoridation
  - Professionally applied
  - Home delivery
- Sealants (highly effective if applied correctly)
- Salivary stimulation
  - Chewing gum
- Diet modification
  - Behavioral
  - Protective food additives
- Antimicrobial
  - Non-specific
  - Targeted
- Non-fluoride remineralizing strategies

What This Conference Should Be About Is How Can We Get Dentistry Unstuck

What This Conference Should Be About Is How Can We Get Dentistry Unstuck

GOAL FOR THE DENTAL PROFESSION

- Dental caries never progresses beyond the ICDAS code 3 stage for patients who are routinely seeking dental care.
- What is needed to achieve this goal:
  - High accurate technology-based diagnostic tools
    - To detect and stage lesion severity
    - To determine caries lesion activity status
  - Caries Risk Assessment at the patient level
    - Practitioner friendly electronic aids
  - Caries Risk Assessment at the tooth surface level
    - Point-of-care diagnosis test to determine biofilm pathogenicity
  - Algorithm-based computer clinical decision support systems that factor in all components of the diagnosis process.
  - New interventions strategies that target the main etiological factor – dietomicrobial interaction

"Human progress is neither automatic nor inevitable."

Rev. Dr. Martin Luther King Jr.

Systems Approach To Oral Health Management

Government
- Community Reid and Policy
- Needs/Participation
- Public Policy
- Community Health

Private Practice
- Education
- Research

Third Party Payers

Professional Organizations