Prevention of Tooth Decay is Worth Everything

John D.B. Featherstone
Distinguished Professor and Dean
School of Dentistry
University of California San Francisco

Frank occlusal cavity

Childhood Caries
Courtesy Dr. Ling Zhan

Root caries
Disclosure

- I have no personal financial interest in any company relevant to this presentation.
- I have consulted for, or have done research funded or supported by:
  Arm and Hammer, Beecham, Cadbury, GSK, KaVo, Novamin, Omnii Oral Pharmaceuticals, Oral B, Philips Oralcare, Procter and Gamble, 3M ESPE Preventive Care, Wrigley, and the National Institutes of Health.
About Your Instructor

- John Featherstone, Distinguished Professor of Preventive and Restorative Dentistry, and Dean of UC San Francisco’s School of Dentistry
- I have been involved with research and clinical applications of this research for dental decay prevention for 40 years
- I have published over 280 articles and book chapters

Prevention of Tooth Decay

Course Objectives

- To understand the process of dental caries (tooth decay) as an infectious and transmissible disease.
- To learn about pathological and protective factors related to caries initiation, progression and prevention.
- To understand the principles of clinical intervention in the caries process, and how to put this into personal practice.

Course Objectives

What is Dental Caries?

- Dental caries is tooth decay
- Specific bacteria (Streptococcus mutans, Streptococcus sobrinus, lactobacilli and more) on the tooth surface feed on carbohydrates and make acids as waste products
- Acids travel into the tooth and dissolve mineral - if mineral loss is not halted or reversed a cavity is formed
- Dental caries is a transmissible bacterial infection
Some cold hard facts about dental caries that you need to know

Acid producing bacteria are usually less than 1 percent of the total flora in the plaque.

Streptococcus mutans culture showing active cell division. S. sobrinus is similar. Sucrose leads to extracellular polysaccharides that stick the plaque together.

Lactobacillus culture. Lactobacilli species produce predominantly lactic acid from fermentable carbohydrates.
Protective Factors

Cariogenic foods contain fermentable carbohydrates such as sucrose, glucose, fructose and cooked starch.

Demineralization:

Step 1
- Cariogenic Bacteria
  - S. Mutans
  - S. Sobrinus
  - Lactobacilli
- Fermentable Carbohydrates
  - Sucrose
  - Glucose
  - Fructose
  - Cooked starch
- Organic Acids
  - Which penetrate enamel and dentin
  - Dissolve tooth mineral

Step 2
- Organic Acids
- Dental Mineral = Carbonated Hydroxyapatite
  - Acid soluble
- Demineralization:
  - Calcium and phosphate into solution
- Biofilm Modification is necessary as part of our therapy for high bacterial challenge individuals. Caries is a transmissible bacterial infection.
- If demineralization continues it produces 1) decalcified areas, 2) cavities
Protective Factors

- Saliva flow and components
- Fluoride, Calcium, Phosphate remineralization
- Antibacterials: chlorhexidine, silver, xylitol, new?

Pathological Factors

- Acid-producing bacteria
- Frequent eating/drinking of fermentable carbohydrates
- Sub-normal saliva flow and function

Featherstone, Community Dent Oral Epidem, 1999

Stay in balance to survive

Male, 55 years old, before radiation to the head and neck for cancer treatment. Causes saliva flow and function to be cut by at least 90%

Same male, after radiation to the head and neck. Six months later, showing rampant decay and massive destruction of the teeth
Salivary Dysfunction-Hyposalivation

- Radiation to the head and neck for cancer treatment - knocks out saliva glands
- Chemotherapy
- Dehydration
- Medications with hyposalivatory side effects
  - Antianxiety
  - Antidepressants
  - Antihistamines
  - Antipsychotic
  - Multiple medications

Salivary Dysfunction-Hyposalivation

- Probably the most under recognized cries risk factor (pathological factor)
- Recreational drugs a major factor – “meth mouth”
- Recognize the symptoms of “dry mouth”
- At follow up visits always talk to your dentist about new medications
- Patients do not know the hazards and neither do many physicians

What about the clinical relevance?

Does drilling and filling really fix caries?
Patients With Cavities

- One or more frank cavities indicates high risk for future new cavities
- Moderate to high levels of mutans streptococci
- Moderate to high levels of lactobacilli
- Patients have a high bacterial challenge that most likely can not be completely overcome by fluoride alone
- Placing restorations does not reduce the bacterial loading in the rest of the mouth

Protective factors

- Salivary components and flow
- Fluoride, calcium and phosphate: remineralization
- Antibacterials from extrinsic sources
Saliva Contains Numerous Important Components
- Calcium, phosphate and fluoride
- Proteins and lipids that form the pellicle that protects the tooth surface
- Proteins that keep calcium in solution - they maintain supersaturation
- Buffers against acid: bicarbonate, phosphate, peptides
- Antibacterial substances & immunoglobulins

Saliva Contains Proteins (e.g. Statherin) That Maintain Calcium and Phosphate in Supersaturated Solution

\[ \text{Ca}^{2+} + \text{Statherin ion} \rightarrow \text{Soluble calcium complex} \]

Protective factors
- Salivary components and flow
- Fluoride, calcium and phosphate: remineralization
- Antibacterials from extrinsic sources
Protective Factors

"White spot" lesion

Acid-damaged enamel crystals from a carious lesion at 3,000,000x showing rows of calcium atoms. Hexagonal white patches (arrows) are where acid has dissolved mineral from calcium deficient/carbonate rich regions.

Demineralization:
Step 2

If fluoride is present in the solution between the crystals it inhibits mineral loss.

Schematic cartoon of adsorption of fluoride ions onto crystal surfaces.

Dental Mineral = Carbonated Hydroxyapatite

Acid soluble

Calcium and phosphate into solution

Crystal of dental mineral

Dissolved regions

Organic Acids

Ca^{2+} PO_4^{3-} Ca^{2+} PO_4^{3-} Ca^{2+} PO_4^{3-} Ca^{2+}

F^-

F^-

Schematic cartoon of adsorption of fluoride ions onto crystal surfaces.
Fluoride adsorbs to the surface of the crystals protecting against acid attack.

Fluoride works primarily via topical (surface) mechanisms (Fluoride in water, foods, beverages, products)

- Fluoride inhibits demineralization

What can be done to alter the surface of the enamel or dentin crystals?
Remineralization creates a new surface.

Remineralization/Tooth Repair

- Calcium in tooth water (from saliva)
- Phosphate in tooth water (from saliva)

Remineralization builds on existing crystal remnants
New mineral less soluble
Fluoride helps

Fluoride speeds up remineralization -> less soluble mineral
Subsurface Demineralization/Remineralization

- Acids diffuse into the subsurface of dental enamel or dentin partially dissolving the calcium phosphate crystals
- If this mineral loss is not halted or reversed a cavity results
- Reversal by remineralization produces low solubility mineral

SEM in the body of a carious lesion (~30,000x) showing remaining crystal remnants awaiting remineralization

Partly demineralized enamel crystal (3,000,000x) dissected from inner enamel showing carbonate rich acid soluble regions (white patches).

Enamel crystal after remineralization with calcium, phosphate and fluoride, showing a well-formed, low solubility, fluorapatite-like veneer overlying the original defective crystal.
Demineralized surface blocks need to be replaced with new calcium, phosphate and fluoride to make a more acid resistant surface on the crystal.

**Chemical Equations:**

1. $\text{Ca}^{2+} \text{PO}_4^{3-} \text{Ca}^{2+} \text{PO}_4^{3-} \text{Ca}^{2+} \text{PO}_4^{3-} \text{Ca}^{2+}$
2. $\text{F}^{-}$

**Diagram Description:**

- Schematic enhancement of remineralization by fluoride.
- $\text{Ca}^{2+} \text{PO}_4^{3-} \text{Ca}^{2+} \text{PO}_4^{3-} \text{Ca}^{2+} \text{PO}_4^{3-} \text{Ca}^{2+}$
- Crystal of dental mineral.

**Additional Text:**

- Fluoride speeds up remineralization and makes acid resistant mineral.

**Chemical Reaction:**

- $\text{Enamel/dentin crystal} = \text{Carbonated apatite}$
- $\text{Partly dissolved crystal}$
- $\text{Acid resistant} \quad \text{Ca}_{10} (\text{PO}_4)_6 (\text{F})_2 = \text{fluorapatite-like coating on crystals}$
- $\text{Crystal nucleus}$
Frequent snacking throughout the day = multiple acid challenges = multiple demineralization periods. Remineralization occurs between demineralization times.

**Fluoride works primarily via topical (surface) mechanisms** (Fluoride in water, foods, beverages, products)

- Fluoride inhibits demineralization
- Fluoride enhances remineralization
Fluoride inhibits demineralization
Fluoride enhances remineralization
Fluoride can inhibit plaque bacteria

Fluoride works primarily via topical (surface) mechanisms (Fluoride in water, foods, beverages, products)

Fluoride in Drinking Water
Effective Posteruptively in Children and Adults

- Hardwick et al., 1982, showed caries reduction of ~27% over 4 years in 12 year olds when fluoride was added to their drinking water
- Stamm et al., 1990, showed reduction in root caries in older adults living in fluoridated drinking water area

What about the clinical relevance of remineralization?
Fluoride products enhance remineralization
Remineralization is the body’s natural repair mechanism for dental caries

What can we do with this knowledge?
Numerous clinical trials showed ~30% reduction with fluoride toothpaste 1000-2800 ppm F.
Curnow, Pine, et al, 2002 reported 56% reduction with supervised brushing 2 x daily with a 1000 ppm F toothpaste compared with unsupervised

Brushing at least twice daily with a fluoride-containing toothpaste is one of the most effective ways to control dental decay.
High bacterial challenge overcomes the therapeutic effects of fluoride.

Sodium Fluoride
Stannous Fluoride
Sodium Fluoride plus multiple agents
Sodium Fluoride + Baking Soda
Sodium Fluoride + Whitening

Sodium Monofluorophosphate
Over the counter fluoride rinses (0.05% NaF) are effective in moderate caries risk patients: twice daily for one minute, plus a fluoride-containing dentifrice. O’Reilly and Featherstone, 1987

Caries Management by Risk Assessment (CAMBRA): Fluoride in the Dental Office and by Prescription

Office-Applied Fluoride Products
- Gel (> 5,000 ppm F) and Fluoride Varnish
  - Do not require continuing patient compliance
  - Forms slowly soluble calcium fluoride-like deposits in lesions and the plaque
  - Gives slow release fluoride for several weeks
  - Three times a year for high risk patients
Evidence-based Clinical Recommendations: Professionally Applied Topical Fluoride
The Council on Scientific Affairs, American Dental Association
May, 2006

- Fluoride gel applied for 4 minutes or more is effective
- Fluoride varnish applied every 6 months is effective
- Two or more applications of fluoride varnish per year are effective in high caries risk individuals
- Office topical applications no added benefit for low risk individuals

Fluoride Varnish for High Caries Risk of All Ages
White “Vanish” Varnish – 3M ESPE Prev Care


Caries Incidence Infants Over 2 years

Fluoride Varnish Applications

Preventive Effect of High-Fluoride Dentifrice (5,000 ppm) in Caries-Active Adolescents: A 2-Year Clinical Trial
A. Nordström, D. Birkhed

- 5000 ppm F vs 1450 ppm F (as NaF) toothpaste
- Caries incidence and caries progression
- Compliance assessed
- Prevented fraction 40%: 5,000 ppm versus 1450 ppm F
- Caries still progressed in many, even with high concentration fluoride
High concentration fluoride products for high risk patients. Proven effective for root caries.

Clinpro™ 5000 1.1% NaF Dentifrice
3M ESPE
Contains Tri-calcium phosphate

Protective factors
- Salivary components and flow
- Fluoride, calcium and phosphate: remineralization
- Antibacterials from extrinsic sources

Biofilm Modification is necessary as part of our therapy for high bacterial challenge individuals. Caries is a transmissible bacterial infection
Caries is a Transmissible Bacterial Infection

- Multiple acid-producing species of bacteria are responsible
- Children are infected by mothers, care-givers, siblings, playmates, through saliva transfer
- Babies and infants are most susceptible from birth to about 4 years of age
- Children infected early have more cavities later in life
- Need to break the chain of infection and deal with the bacteria

The Caries Balance

Pathological Factors
- Acid-producing bacteria
- Frequent eating/drinking of fermentable carbohydrates
- Sub-normal saliva flow and function

Protective Factors
- Saliva flow and components
- Fluoride, Calcium, Phosphate remineralization
- Antibacterials: chlorhexidine, xylitol, silver, HClO, new?

The Caries Balance

Featherstone, Community Dent Oral Epidem, 1999

Caries Research

Caries Res, 2012

A Randomized Clinical Trial of Anticaries Therapies Targeted according to Risk Assessment (Caries Management by Risk Assessment)

University of California, San Francisco, Calif, USA

Mean (SE) logMS

Log MS Control
Log MS Intervention
Restorations
Chlorhexidine plus Fluoride
Visit # - 6 month intervals
Chlorhexidine was effective at reducing the bacterial challenge in high caries risk individuals even when compliance was problematic. 24% reduction in $\Delta$DMFS.

- Preferred regimen is once a day rinse for one week every month for a year.
- Monitor success by bacterial testing.
- Ideally we need a better antibacterial therapy.
- Must combine with remin/fluoride.

Chlorhexidine Gluconate 0.12%, 10 ml, daily for 1 week reduces MS markedly and LB somewhat after restorations completed. Repeat every month.
CariFree Treatment Rinse
- Sodium hypochlorite and sodium fluoride in separate bottles mixed before use
- Clinical trial - unpublished, indicates very good clinical efficacy
- No microbiological data published

Silver Diamine Fluoride
- Silver antibacterial
- Fluoride available
- Paint on lesions
- Black on dentin and clothing
- Repeat depending on risk level
- Adults as well as children

Xylitol Gum, Mints
- Xylitol
- Noncariogenic sweetener
- Inhibits transfer of bacteria from mother to child
- Can reduce loading of cariogenic bacteria in the mouth
Zhan et al, J Dent Res, 2012 showed 7 fold difference between xylitol and placebo.

The Caries Balance-Low Risk

**Pathological Factors**
- Acid-producing bacteria-LOW
- Frequent snacker-NO
- Sub-normal saliva-NO

**Protective Factors**
- Saliva flow and components NORMAL
- Fluoride, 2X DAILY
- Antibacterials- NO NEED

Featherstone, Community Dent Oral Epidem, 1999

Therapy for Low Caries Risk Individual

- Maintain 2 x daily fluoride toothpaste brushing and other habits.
- Recall 12 months.
**High Risk Patient**

**Pathological and Risk Factors**
- Bacteria high
- Cavities
- Snacking
- Hyposalivation?

**Protective Factors**
- Office applied Fluoride Varnish
- Chlorhexidine 10 ml daily one week a month for 6 months
- Brush with 5000 ppm F toothpaste 2x daily - enhance remineralization
- Xylitol gum 4x daily
- Recall 4-6 months

Caries On Hold

No New Caries

**Extreme Risk Patient**

**Protective Factors**
- Office applied Fluoride Varnish
- Chlorhexidine 10 ml daily one week a month for 6 months
- Brush with high 5000 ppm F toothpaste daily - enhance remineralization
- Xylitol gum 4x daily
- Baking soda rinse
- Consider MI paste
- Recall 3-6 months

Caries On Hold

No New Caries

Much to Reflect Upon