

Secondary Caries and Microleakage

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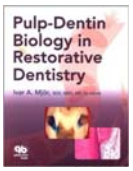
A GREAT MENTOR AND FRIEND



Alligator #1, #2 & #3
Gainesville, Florida, 2009

Secondary caries –questions

1. How to best predict secondary caries?
2. How to best prevent secondary caries?
3. How to best identify secondary caries (early)?
4. How to best manage secondary caries?

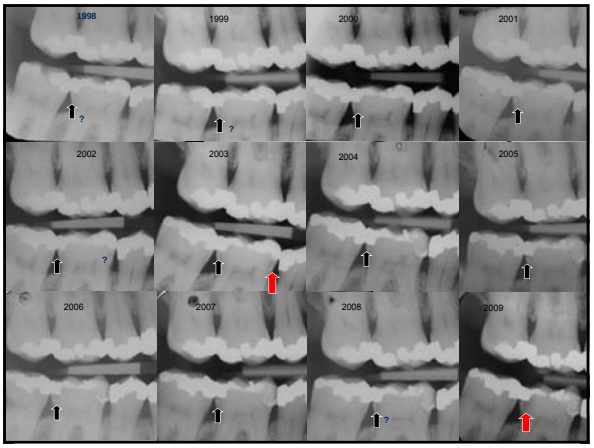
Secondary caries –questions

The answers will undoubtedly be influenced by the **stakeholders' understanding of etiopathogenesis**

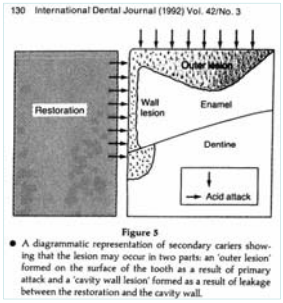
1. How to best predict secondary caries?
2. How to best prevent secondary caries?
3. How to best identify secondary caries (early)?
4. How to best manage secondary caries?

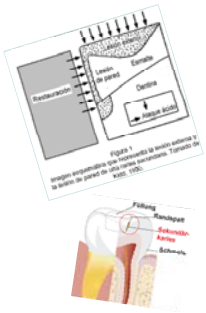
Etiopathogenesis of secondary caries – 1/3

Bulk fracture → caries OR Caries → bulk fracture?



Etiopathogenesis of secondary caries – 3/3





Kiid, Dental Update 1981
Kidd, Quintessence Publ., Co. 1989
Kidd, Toffenetti & Mjör. Int Dent J 1992

Secondary caries –questions

The answers will undoubtedly be influenced by the **stakeholders' understanding of etiopathogenesis**

1. How to best predict secondary caries?
2. How to best prevent secondary caries?
   Material – operator – patient factors

3. How to best identify secondary caries (early)?
   - Understanding of etiopathogenesis + Diagnostic test validity and reliability
4. How to best manage secondary caries?
   - Understanding of etiopathogenesis + Effectiveness of interventions

Desire to avoid adverse clinical outcomes by the development of (minimum) specifications for dental materials

1900 fdi

1920 1930 1940 1950 1960

ADA

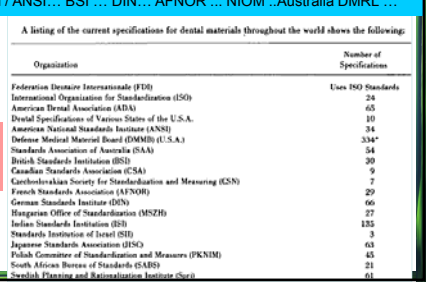
Desire to avoid adverse clinical outcomes by the development of (minimum) specifications for dental materials

fdi ISO TC 106 Dentistry ISO

1920 1930 1940 1950 1960 1970 1980 1990 2000

ADA ASTM / ANSI… BSI … DIN… AFNOR ... NIOM ..Australia DMRL …

From: Paffenbarger, et al. US. National Bureau of Standards pub. #571, 1980



A listing of the current specifications for dental materials throughout the world shows the following:

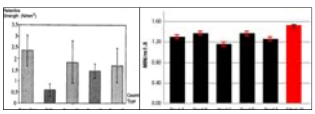
Organization	Number of Specifications
Federation Dentaire Internationale (FDI)	Uses ISO Standards
International Organization for Standardization (ISO)	24
American Dental Association (ADA)	65
Dental Specifications of Various States of the U.S.A.	10
American National Standards Institute (ANSI)	34
Defense Medical Material Board (DMMB) (U.S.A.)	334*
Standards Association of Australia (SAA)	54
British Standards Institution (BSI)	30
Canadian Standards Association (CSA)	9
Czechoslovakian Society for Standardization and Measuring (CSN)	7
French Standards Association (AFNOR)	29
German Standards Institute (DIN)	66
Hungarian Office of Standardization (MSZH)	27
Indian Standards Institution (ISI)	135
Standards Institution of Israel (SII)	3
Japanese Standards Association (JISC)	63
Polish Committee of Standardization and Measures (PKNIM)	45
South African Bureau of Standards (SABS)	21
Swedish Planning and Rationalization Institute (Sara)	61

Specifications according to tests – which ones predict adverse clinical outcomes?

Static tests ?
Compressive (crushing) strength, e.g., 1h. & 24 h.
Tensile strength, e.g., 5 min.
Transverse strength, e.g.,1h. & 24 h.
(Flexure/bending/modulus of rupture)
Modulus of elasticity (Young's Modulus)
Shear modulus

Validity of a test
- Reproducible
- Known parameters
- Low C.V. (#samples)
- Calibrated devices

Dynamic tests ?
Compressive modulus
Tensile modulus
Bending modulus
Resilience
Fatigue
Fracture toughness

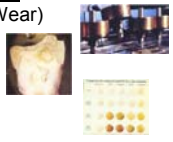


Specifications according to tests – which ones predict adverse clinical outcomes?

Other defined tests?
Flow (Creep), 3-24 h.
Dimensional change, e.g., 5 min. -24 h.
Polymerization- /Setting-...contraction/expansion
Hardness
Thermal expansion coefficient
Water solubility / - sorption

Validity of a test
- Reproducible
- Known parameters
- Low C.V. (#samples)
- Calibrated devices

Other undefined tests?
Abrasion resistance (Wear)
Adhesion
Surface roughness
Marginal leakage
«Retention strength»
Color stability



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Abrasion resistance (Wear)
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Surface roughness
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«Retention strength»

Validity of a test
- Reproducible
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"Neither dentists nor laboratory researchers have a clue as to what these tests say on possible clinical outcome in terms of predictability and longevity"

Dr. Siegward D. Heintze, Head of Preclinical Research, Ivoclar Vivadent. Dent Mater 2013.

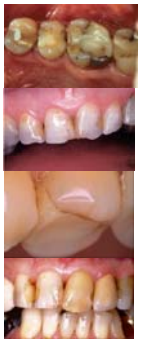
Evidence that specifications according to tests predict adverse clinical outcomes?

Weak - according to current leading content experts, although perhaps substantially inferior products may be identified

Restoration material and adverse outcome

undesirable performance

- Degradation
  - Bulk (/surface)
  - Interface (/margin)
- Material loss
- Fractures/cracks
- Rough surface
- Poor adaptation to tooth tissues
- Discoloration
  - Surface (/bulk)
  - Margin (/interface)

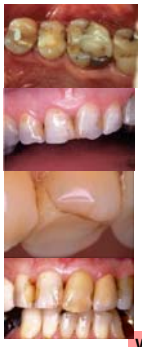


What are the predictors?

Restoration material and adverse outcome

undesirable performance **versus** **risk factor for:**

- Degradation
  - Bulk (/surface)
  - Interface (/margin)
- Material loss
- Fractures/cracks
- Rough surface
- Poor adaptation to tooth tissues
- Discoloration
  - Surface (/bulk)
  - Margin (/interface)



- Secondary caries
- Fractures
- Hyper-sensitivity
- Pulpal injury
- Antagonist extrusion
- Impaction/ periodontal disease
- Shade

What are the predictors?

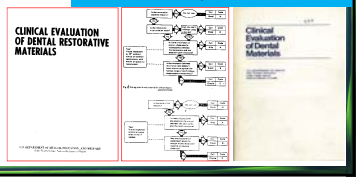
Why and how much are the risks inflated?

Desire to avoid adverse clinical outcomes by the development of standards for clinical practice and research

1920 1930 1940 1950 1960

ADA

- 1971: Cvar & Ryge, *"Ryge system"* US Dept. Health, Educ. & Welfare
- 1972: ADA Recommended standard practices for clinical evaluation of dental materials and devices
- 1973: ADA Guidelines for reporting clinical trials
- 1977: California Dental Association *"CDA system"*
- 1978: Clinical evaluation of dental materials. US Dept. Health & H.S.; 1980 - *"USPHS system"*



Desire to avoid adverse clinical outcomes by the development of standards for clinical practice and research

fdi

1977: Recommended format. Clinical comparison of several anterior and posterior materials.
1982: Recommendations for clinical research protocols for dental materials
1990: Good manufacturing practices, including quality assurance for dental materials

1920 1930 1940 1950 1960 1970

ADA

1981: Expansion of the ADA acceptance program: Composite resin materials for occlusal class I and II restorations
1986: Evaluation of dentin and enamel adhesive materials (r1991,r1994, r2001)
1989: Composite resins for posterior restorations (r1996, r2001)

Desire to avoid adverse clinical outcomes by the development of standards for clinical practice and research

2007: Hickel ea. Recommendations for conducting controlled clinical studies of dental restorative materials & criteria for evaluation of direct and indirect restorations including onlays and partial crowns.
2010: Hickel ea. Clinical criteria for the evaluation of direct and indirect restorations. Update

ISO/TC194 Clinical investigation of medical devices for human subjects - Good clinical practice

1920 1930 1940 1950 1960 1970 1980 1990 2000

ISO TC 106 Dentistry
SC1 Filling and restorative materials: 14 wgs
SC2 Prosthodontic materials: 20 wgs
SC3 Terminology: 4 wgs
SC4 Dental instruments: 10 wgs
SC6 Dental equipment: 8 wgs
SC7 Oral hygiene products: 4 wgs
SC8 Dental implants: 5 wgs
SC9 CADCAM: 4 wgs

Only test standards

2001-2008. Acceptance program guidelines for resin-based composites for posterior restorations & for dentin and enamel adhesive materials

Topics discussed in this presentation

- Dental caries, a brief review
- Restorative materials and the tooth-restoration interface
- The (cavity) "wall lesion" – what is in a word?
- Etiopathogenesis of secondary caries gained from in vitro research
  - Microleakage
  - Artificial caries-like lesions adjacent to restorations
- Secondary caries incidence in controlled clinical studies versus cross-sectional examinations

DENTAL CARIES, A BRIEF REVIEW

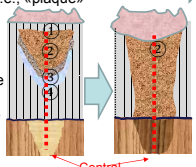
WHAT IS DENTAL CARIES?

Manifested in dental hard tissues by:
1. demineralization
2. white OR brown (spot) lesion
3. cavity ("cavitation")

Specific/Colloquial terms
- *active caries*
- *arrested caries*
- *caries lesion*
- *cavity*
- *chemical dissolution by microbes*
- *decay*
- *demineralization*
- *histologic caries*
- *inactive caries*
- *infected dentin*
- *radiographic caries*

Microbial biofilm i.e., «plaque» — time — «Cavitation»

Enamel demineralization (Microscopically*)
1 Surface zone
2 Lesion body zone
3 Dark zone
4 Translucent zone
(*change of optical birefringence»)

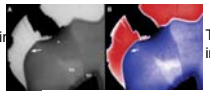


Lesion width in dentin ≤ enamel* (*some exceptions)

Central traversal line

Dentin sclerotization

Cellular changes in the pulp



Tertiary dentin in the pulp

Microradiograph: de Medeiros et al. J Microscopy 2012

Histopathology of enamel caries

Changes within the zones of a caries lesion

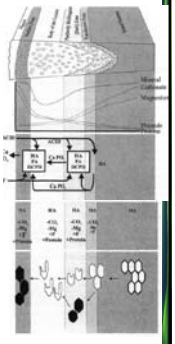
Relative pore structure of the 4 caries lesion zones

Relative concentrations of important ions. Selective loss of Mg and carbonate is illustrated together with concentration gradients of fluoride and protons from surface to interior.

Proposed phase changes in the surface zone and the positively birefringent zone following ingress of protons and fluoride and a net loss of mineral.

Net chemical changes detected at each stage of carious attack.

Diagrammatic representation of changes in enamel mineral crystal morphology within each zone to account for changes in pore structure.



Source: Robinson et al. 2000

Mineral loss detection methods

Laboratory methods

Destructive methods
- Chemical analysis
- X-sectional microhardness
- Optical birefringence (Polarized light)
- Confocal light microscopy
- " laser scanning microscopy (CLSM)
- Transverse microradiography (TMR)
- Microprobe analysis
- Energy-dispersive spectroscopy (SEM-EDX)
- Raman spectroscopy, and Fourier-transform infrared spectroscopy (FTIR)

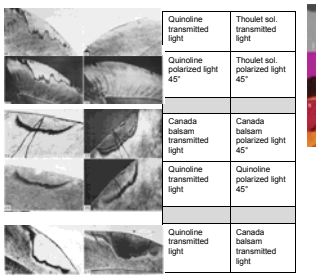
Non-destructive sequential methods
- Surface microhardness
- Iodine absorptiometry / penetration
- Longitudinal MR(LMR)
- Light scattering
- Wavelength-independent MR (WIM(T-WIM))

Intraoral methods
- Light-, infrared- or laser-induced fluorescence
- Electrical conductivity
- Computerized radiography +/- algorithms for automated detection of lesions
- Optical coherence tomography (OCT)
- Polarization-sensitive OCT (PS-OCT) in combination with near-infrared light

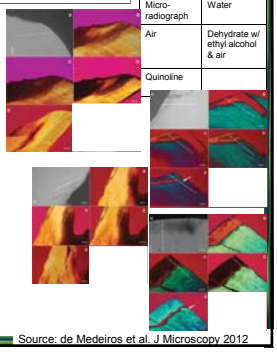
Variability
Discrimination threshold in dental tissues, resolution, time, costs & complexity

Enamel, Optical Birefringence* & Imbibition Media**

* Intrinsic (AKA crystalline) o.b. or anisotropy to light
& Form (AKA textural or structure) o.b. or anisotropy to light
** Effects depend on refractive index & molecular weight



Source: Darling et al. Arch Oral Biol 1961



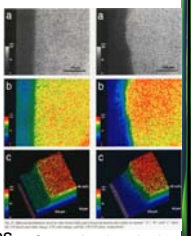
Source: de Medeiros et al. J Microscopy 2012

Creating caries-like lesions artificially in vitro

- Human and non-human, mainly bovine, teeth or tooth specimens
- Several approaches, some specifically tailored to create lesions in enamel or in dentin or in root cement.
- Two methods prevail,(1) an acidified medium with/without buffering & with/without pH-cycling; (2) an acidified broth containing usually some strain of *Streptococcus mutans*
- Mineral loss profiles of the surface and subsurface zones differ with method
- Differences can be large, e.g., at pH=5, a carboxymethyl cellulose gel (6%) causes ~33 volume % mineral loss in enamel per day, while an unstirred solution causes 13% & 26% volume % mineral loss in enamel per hour (with & without added fluorides respectively).
- The ultimate hope is to build the artificial mouth, or at least a steady state microcosm. In spite of some elaborate contraptions we have not succeeded yet to simulate the complexities of the intraoral ecology and microenvironment

Creating caries-like lesions artificially in situ

- Since early 90'ies. Used for multiple research objectives, e.g., assessing erosive or cariogenic potential of various substances, or, appraising the potential for remineralization following application of various oral care products on preconditioned specimens
- Human and non-human specimens
- Specimens mounted in a dental device worn by subjects for various periods
- Surface of the specimens often covered or machined to increase plaque retention
- Demineralization/erosion accelerated by repeat bathing of the device, e.g., caries, 4-8x / day in a 20% sucrose solution
- Demineralization differs from in vitro setups



Source: Arends et al. *Adv Dent Res 1997*

Are there any differences?

Artificial *caries-like* lesion
versus
Artificial *caries* lesion
versus
Clinical caries lesion

How is the disease entitled «Dental caries» defined by laypersons, basic scientists, dentists, clinical researchers and epidemiologists?

What is dental caries?

Essay

Essentialism and nominalism in medicine: logic of diagnosis in disease terminology

J G Scadding

Understanding of disease concept:
Essentialistic: The disease in itself exist, but our criteria for describing the disease change over time
Nominalistic: The actual signs and symptoms constitute the disease

Focus

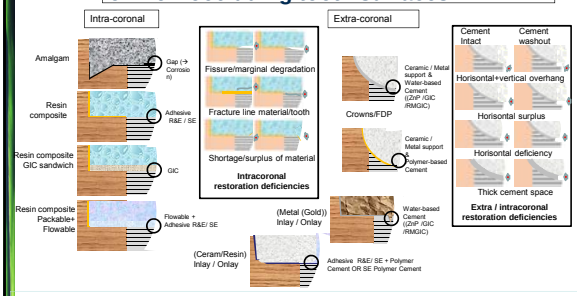
Dental caries paradigms in diagnosis and diagnostic research

Vibeke Baelum[1], Jens Heidmann[2], Bente Nyvad[3]

Topics discussed in this presentation

- ❑ Dental caries, a brief review
- ❑ Restorative materials and the tooth-restoration interface
- ❑ The (cavity) "wall lesion" – what is in a word?
- ❑ Etiopathogenesis of secondary caries gained from in vitro research
  - ❑ Microleakage
  - ❑ Artificial caries-like lesions adjacent to restorations
- ❑ Secondary caries incidence in controlled clinical studies versus cross-sectional examinations

Restoration:tooth interface morphologies on non-occluding tooth surfaces



Interface descriptors: «Margin(/-al)» - «adaptation» - «gap». Other terms are more specifically linked to:
Adhesive materials: «seal(/-ing)», **Amalgam**:«crevice»/«ditch», **Indirect restorations:** «discrepancy»/«fit»

Restoration:tooth interface morphologies on non-occluding tooth surfaces

Is it possible that the choice of term to describe the restoration-tooth interface influence clinicians' treatment decisions (perhaps unwittingly) ?

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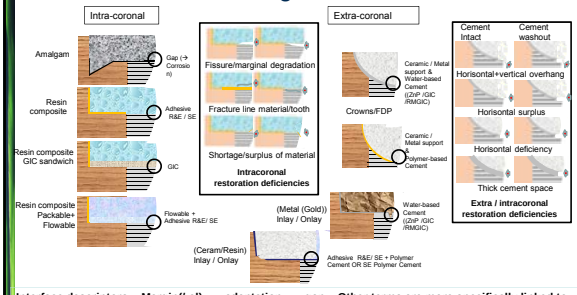

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Interfaces are never static, but in a complex dynamic equilibrium with substances and minerals in the saliva and in the more or less porous hard tissues of the tooth

Restoration:tooth interface morphologies on non-occluding tooth surfaces

Can fatigue degradation of the interface be simulated - influenced by compressive, tensile and shear stresses, salivary composition and amounts, shifting occlusal loads, dietary habits and oral cleanliness and possibly the individual's intra-oral bacterial profile – and will one test likely fit all materials?

Interface descriptors: «Margin(/-al)» - «ga… …are more specifically linked to:
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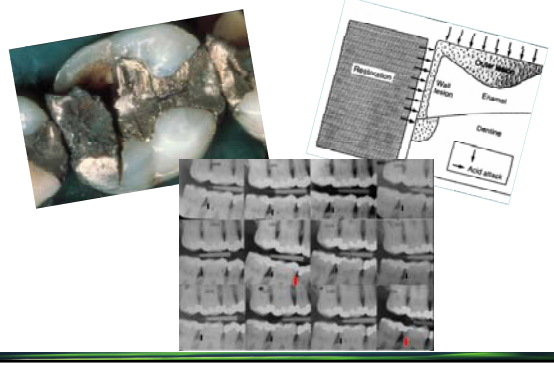
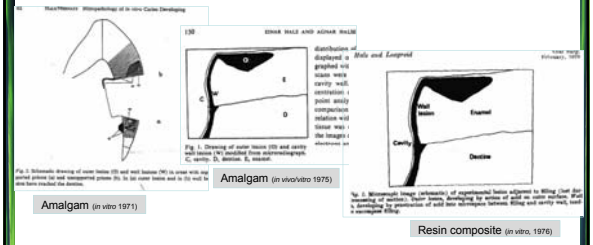
Etiopathogenesis of secondary caries – which one prevails?



The origin of the term «cavity wall lesion*»

*Hals & Nernæs, Caries Res 1971



M&M: Polarized light microscopy x60 & Quinoline imbibition

Cavity wall lesion: "tending to encompass filling..." "...usually without penetrating deeply into the tissue"

The depiction of the «wall lesion» originally

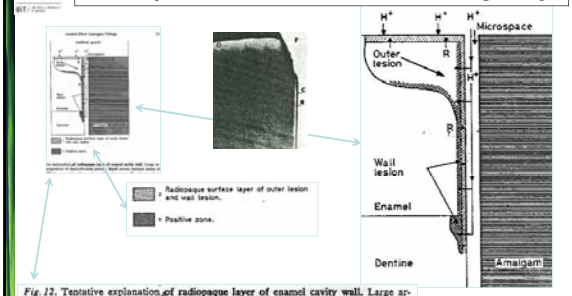


Fig. 12. Tentative explanation of radiopaque layer of enamel cavity wall. Large arrow indicates progression of decalcification process. Small arrows indicate attack of hydrogen ions (H^+) on enamel surface and enamel cavity margin. Reaction products of decalcification process (R, backward arrows) will precipitate in enamel surface and may do so in the enamel cavity margin as well.

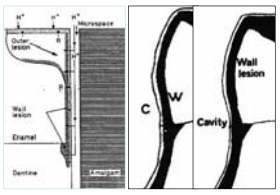
A tentative explanation for **a radiopaque layer of the cavity wall**

From: *Hals & Nernæs, Caries Res 1971

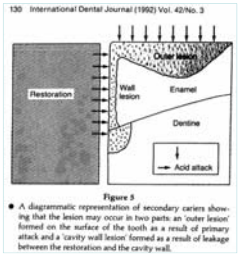
The original and the modified «wall lesion»

Depictions of a radiopaque layer of the cavity wall in original publications

A modified redrawing appearing ~10 years later - allegedly depicting "secondary caries "



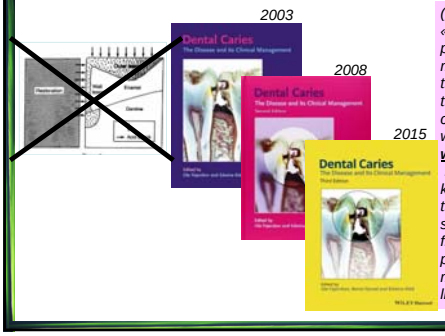
From:
Hals & Nernæs 1971
Hals & Halse 1975
Hals & Laegreid 1976



Kidd, Dental Update 1981
Kidd, Quintessence Publ., Co. 1989
Kidd, Toffenetti & Mjör. Int Dent J 1992

The end of the faith in «wall lesions»

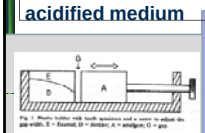
An etiopathogenetic theory which persisted for a decade before a "correction" was made in a 2003 cariology textbook



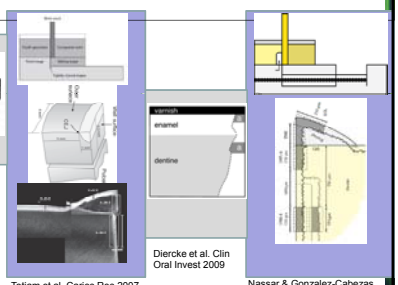
*(pp. 272): «…gaps will facilitate pathways for microorganisms, but this does not mean that these cause a caries reaction deep within the gaps, **as was once believed**. It should also be kept in mind that these are not empty spaces. They will be filled with proteinaceaous material from dentin liquid and saliva.»*

The re-emergence of use of the term «wall lesion» in laboratory experiments

The extent of demineralization as an effect of the distance between a specimen and a block of material placed in an acidified medium



Derand et al. Swed Dent J 1991

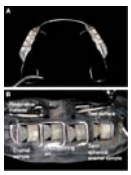


Totiam et al. Caries Res 2007

Diercke et al. Clin Oral Invest 2009

Nassar & Gonzalez-Cabezas Caries Res 2011

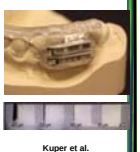
The re-emergence of use of the term «wall lesion» in *in situ* experiments



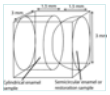
Lennon et al.
Eur J Oral Sci 2007

Thomas et al.
Caries Res 2007
& Oral Microbiol Immunol 2008

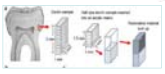
Van de Sande et al.
J Dent 2014

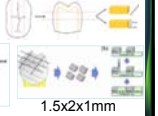


Kuper et al.
J Dent Res 2014
&
Montagner et al.
J Dent 2015



1.6 x3 x1.5mm



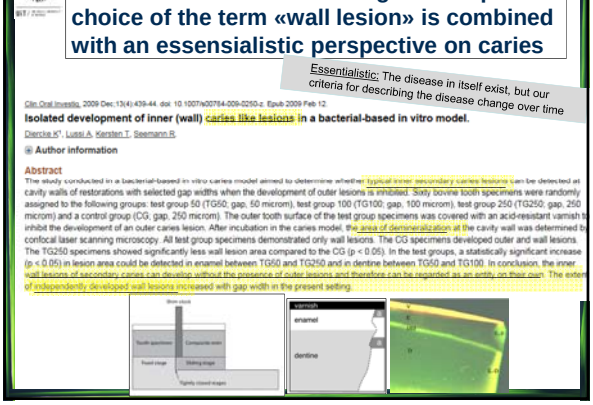


1.5x2x1mm

Specimen size

What is dental caries?

The risk of misunderstanding when a poor choice of the term «wall lesion» is combined with an essensialistic perspective on caries



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- Dental caries, a brief review
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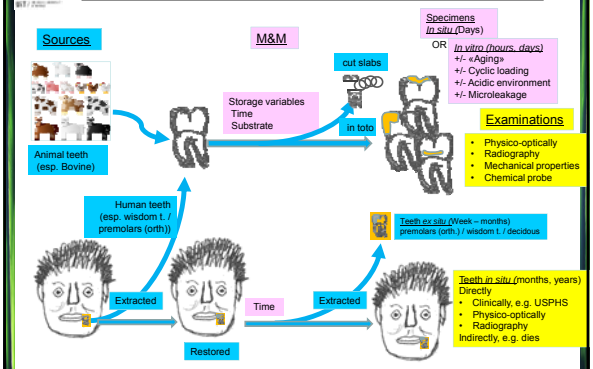
Overview of some experimental variables



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Further variables in microleakage experiments

Radioisotope (50'ies) e.g.
^{45}Ca
^{131}I
^{35}S
^{22}Na
^{14}C
^{32}P
^{86}Rb

Neutron activation (70'ies)
$^{55}Mg \rightarrow {}^{56}Mg$ (contaminants)

Dye penetration/ extraction, e.g.
Aniline dye
Basic fuchsin
Crystal violet blue
Eosin
Methylene Blue

(Fluorescent) penetration/ extraction, e.g.
Sodium fluorescein
Acriflavin
Auramine O
Rhodamine-B

Specimen variables
Tooth specimens & storage
Cavity dimension/C-factor & location (dent. permeability)
Margin location & isolation
Aging (Pre- OR in immersion)
Thermal cycling /°C /time / #
Mechanical loading N / #
pH cycling
Food-simulating solutions

Other methods
Air- / liquid pressure
Bacteria
Electrochemical
Fluid filtration
Moisture/«Percolation»

µCT

Chemical tracers
$AgNO_2$ ("nano-leakage") → hydroquinone developer

Dye variables
Concentrations & pH
Diameter/molecular weight
Tissue /material affinity
pH resistance
Time
Rinsing vz contamination
Sectioning/extraction 2D/3D
Identification & resolution
Quantification & analysis

Examples of variables in microleakage experiments

0.5% Basic Fuchsin, 24h (Cehreli ea 2013)

silver nitrate 50% w/v, 24 h. (Rengo ea 2012)

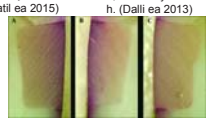
2%Rhodamine-B, 24h.+Vaccum (Patil ea 2015)

1% methylene blue, 24 h. (Patil ea 2015)

0,5% methylene blue, 24 h. (Dalli ea 2013)

0.5% Basic Fuchsin, 16 h. (Tantbirojn ea, 2011)

silver nitrate 50% w/v, 2 h. (Chandurkar ea 2012)



2% methylene blue, 48 h. (Arisu ea 2009)

Reviews on microleakage studies over last 4 decades

Author	Main conclusion
1968, Roydhouse	…of limited value …because many variables are not accounted for. Tests may demonstrate a potential, but not a clinical reality
1969, Loiselle et al.	…these tests eliminate the effect of pulpal hydrostatic pressure and plaque
1972, Going	…most methods fall scientifically short in providing quantitative data
1981, Jodaikin	…no direct comparison possible between in vitro & vivo due to many variables
1982, Shortall	… the results can be partly or totally influenced by the variations of the methodology applied
1992, Taylor & Lynch	…wide variations in methodologies are revealed
1991, Söderholm	…the relevance in a testing protocol for dentin adhesion must be questioned
2001, Raskin et al.	…results from different testing institutes could not be compared
2003, Raskin et al.	…results from different testing institutes are hardly reproducible
2007, Heintze	…it does not make sense to use this elaborate labor-intensive method
2007, Sarrett	…evidence for a direct relationship between poor marginal quality as promoter or primary cause for secondary caries is unlikely
2011, Schmid-Schwap al.	…not possible to make a quantitative synthesis due to study heterogeneity
2011 Heintze & Zimme	…dye penetration…do not correlate or correlate only partially with clinical findings
2012, Dennison & Sarr	…clinical evidence refute earlier conclusions that clinical microleakage leads to secondary caries
2012, Bayne	… no correlation of microleakage with any clinical event has ever been established
2013, Dietschi et al.	…the further use of this test method in the future should be strictly limited
2013, Heintze	…moderate evidence that dye penetration tests does not correlate with clinical data

Microleakage observations versus clinical observations

Clinical variable	Microleakage	Clinic
Incremental vs bulk filling	Less microleakage	Corroborate
Different curing approaches	conflicting results	?
Enamel vs dentin margins	Less microleakage	Corroborate
Light cured vs self-cured	Less microleakage	Corroborate
Matrix system	conflicting results	?
Primer solvent	Effect on dentin, not enamel	Corroborate
Incorrect cavity drying	More microleakage	Corroborate
Boxed cavity form	More microleakage than if rounded	Corroborate
Sharp margins	More microleakage than if beveled	?
Occlusal loading	More microleakage than if no loading	?
Thick flowable liner	Less microleakage in enamel (- dentin)	?
Adhesive brand	conflicting results	?
Flowable u. packable resin	conflicting results	?
rmGIC u. composite	conflicting results	?
Flowable u. rmGIC	conflicting results	?
Composite vs packable resin	Less microleakage in dentin	?
Etch-and-rinse vs self-etch	conflicting results	Corroborate
Single versus two layers	Less microleakage	Corroborate
Composite brand	conflicting results	?
Composite vs ormocer	conflicting results	?
Composite direct vs indirect	conflicting results	?

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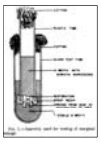
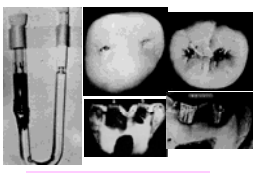
In-vitro caries-like lesions adjacent to restorations – Pioneer studies

Acidified broth

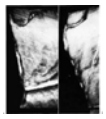


Mortensen ea. J Dent Res 1965



Ellis & Brown. J Dent Res 1967 & Atto et al. J Dent Res 1970

Acidified medium*



*Gelatin adjusted to **pH=4** by addition of lactid acid, imbibed 5 - 200 days

* Silverstone (1968)

First used by Hals & Nernaes, Caries Res 1971,

In-vitro caries-like lesions adjacent to restorations

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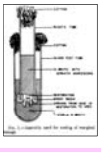

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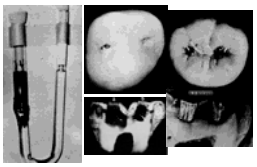
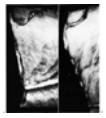


Ellis & Brown. J Dent Res 1967 & Atto et al. J Dent Res 1970

Cycling pH 4.7 ←→ 7

Common methodologies (Str. Mutans):
Dummer et al 1982
Fontana et al. 1996

Acidified medium*



*Gelatin adjusted to **pH=4** by addition of lactid acid, imbibed 5 - 200 days

* Silverstone (1968)

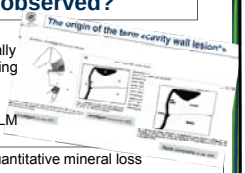
First used by Hals & Nernaes, Caries Res 1971, + ~30 papers, by e.g., Hals, Grieve, Kidd, Heintze, Zimmerman, Hicks, Donly and others)

Gelatin / gelatin gel or agar / methylcellulose

«Lesions» along restorations detected in PLM – what was actually observed?

Hals & Nernaes, 1971:

- Usually …a narrow subsurface defect …gradually encompassed the whole filling without penetrating deeply into the tissue"
- Wall lesions were seen only when imbibed in quinoline and not in air or water & only in the PLM



PLM is purely qualitative and does not provide quantitative mineral loss

Enamel

- Quinoline facilitates identification of caries due to pore size selectivity
- Penetration of ions into dental tissues change optical birefringence, e.g. corrosion products from amalgam such as oxides, sulphides and chlorides of tin, and to a lesser extent zinc and copper

Dentin

- Quinoline binds because of a «von Ebener phenol reaction» – i.e., a selective binding to collagen, and not due to pore penetration
- Dentin tubules demonstrates form bifringence due to their micrometer size
- Collagen displays form birefringence

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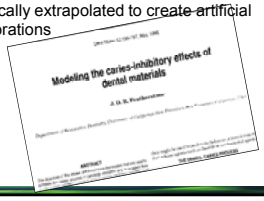
Effects of the acidified procedure on the restoration-tooth interface?

- Several strategies - often without consideration of likely negative effects on the restorative material and not occurring in reality intra-orally
- Restored teeth sometimes exposed directly after the setting time, i.e., not always synonymous with a fully hardened or polymerized material
- In aggressive media crevice corrosion cells are likely generated in the interface along metallic restorations, which lowers the pH further, and cements such as glass ionomers undergo profound surface erosion
- The adoption of methodologies for causing artificial caries-like lesions in enamel were perhaps too uncritically extrapolated to create artificial caries-like lesions adjacent to restorations

More common procedure today:
pH cycling: 4.4 ←→7 **

** Featherstone et al.1983/86



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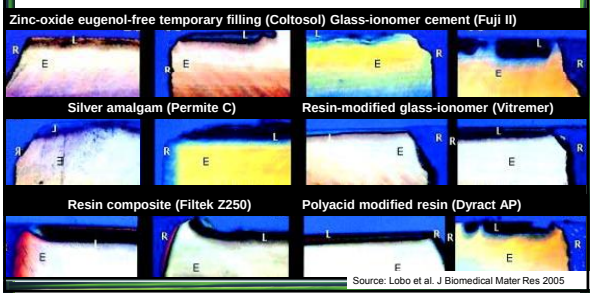
- The adoption of methodologies for causing artificial caries-like lesions in enamel were perhaps too uncritically extrapolated to create artificial caries-like lesions adjacent to restorations (Featherstone, 1996)
- Dentinal caries is not limited only to demineralization, but becomes heavily infected by mono- or multispecies biofilms, which is difficult to reproduce fully in vitro
- Confounder when the research focus is demineralization-remineralization of artificial caries-like lesions adjacent to restorations made from materials with alleged anticariogenic properties

Effects of the acidified procedure on the restoration-tooth interface?

Sa et al. 2004: "*Glass ionomers demonstrated significant anti-cariogenic properties when exposed to the chemical model. However, no significant anti-cariogenic properties were observed with the microbial caries model. In conclusion, …caution should be exercised when trying to extrapolate the results of in vitro studies to the clinical situation*"



Source: Lobo et al. J Biomedical Mater Res 2005

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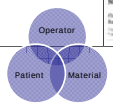
The replacement of dental restorations

Primary reason identified in:
1991:Secondary caries - 2001: Secondary caries - 2012: Secondary caries



Based on compilations of:

- Observational data from:
  - Cross-sectional studies of reasons for replacement of restorations, occasionally with true or estimated time since placement
  - Cross-sectional studies of restorations in situ, occasionally with true or estimated time since placement
  - Prospective & retrospective studies of patient cohorts or subgroup analyses of such
- Experimental studies, with variable internal or external validity reflected by study power, randomization, likelihood of confounding & risk of biases

Which estimates should we trust?

- Estimates of incidence & prevalence of secondary caries have ranged from insignificant to extensive. Scepticism have been voiced in both directions
- Potential biases that likely influences estimates is extensive
  - selection bias - performance bias - detection or assessment bias - attrition bias - reporting bias
- Typical examples: patient recruited amongst dental students and faculty; studies not conducted amongst GPs, lack of operational descriptive criteria or judgement of own clinical work; high number of patient dropouts especially amongst the unhappy ones; and the reporting of surrogate outcomes rather than patient-relevant ones
- Results based on clinical work in settings where cost per unit time is of nominal concern do not provide any indications on how the restorative material will perform when placed by the average dentists in mouths of their spectrum of patients during a busy workday.
- The data sampling method, patient demography as well as study methodology influence estimates - Is a quest for "overall" exact values meaningful from a scientific or clinical perspective?

When the «science» in evaluating «scientific research» becomes an exercise in nihilism

i.e.,
RCTs > 4 yrs &
<5% attrition/year

Only 6 / 4275 papers = 0,0019% was considered for grading of scientific evidence and conclusions

- In today's mobile world, the likelihood of a near-zero attrition is unrealistic.
- At what level does the attrition rate in a dental study become a concern with regard to restoration performance estimates?
- Good research ethics allow study participants at any time to drop out without having to explain why. Coercive offers is generally regarded as unethical.
- Are study participants who return for a follow-up clinical examination many years later in the same clinic representative of the general population when it comes to oral health attitudes and treatment behavior?

What are the alternatives for collecting data?

Health register data analyzed with Multi-level regression statistics (AKA hierarchical linear r., nested models r., mixed models r., random coefficient r., random-effects models r., random parameter models r.)

- UK: Burke & Lucarotti (80K+ adults)
- Finland: Vähänikkilä / Käkilehto /Suni (6K , 36K adults)
- USA: Bogacki / Coppola (300K / 1.500K adults)
- Norway: Dobloug & Grytten (64K adults)
- Brazil: Demarco & Correa (6K adolescents)

Pragmatic (real-life) studies, e.g., in Practice-based Research Networks

- Data on restoration performance obtained in cross-sectional studies reflect the good and the bad operators and oral health attitudes and practices of patients.
- However, how many dentists in real-life
  - prepare textbook-like cavities in teeth to receive the restoration?
  - handle and place restorative materials according to handling instructions?
  - ensure that their patients are motivated and enabled to prevent future caries?

CONCLUSIONS

Conclusions - 1/3 "caries wall lesions"

- It is doubtful whether caries can exist in the restoration-tooth interface independently of an outer enamel caries lesion.
- The term "wall lesion" including its variants is ill defined, has been, and is still being used indiscriminately.
- Stakeholders should avoid using this ambiguous label due to its connotation to an entity that does not exist per se.

Conclusions - 2/3, experimental data

- Microleakage experiments continue to emerge regardless of multiple reviews questioning the reliability and validity of the method.
- Several of the approaches used to generate artificial caries-like lesions are very aggressive. Remarkably little discussion has evolved about how these aggressive approaches create microenvironments that do not occur in reality. Corrosion- and biodegradation products may influence the biofilm qualitatively and quantitatively and it is difficult to replicate these variables in any ex vivo environment.

Conclusions - 3/3, clinical data

- Clinical data sampling method, patient demography as well as study methodology influences the incidence and prevalence estimates of secondary caries.
- Clinical results based on clinical work in settings where cost per unit time is of nominal concern do not provide any indications on how the restorative material will perform when placed by the average dentists in the mouths of their spectrum of patients during a busy workday.

One of the most gorgeous sites on Maui to watch sunrise & sunset: The Haleakala mountain:

If you plan to see the sunset on top of Haleakala mountain - An important safety message:

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What are your options?

1. Panic
2. If you have a satellite telephone:-Call the Hertz emergency centre in Florida and remember how to spell H-a-l-e-a-k-a-l-a before they can help you
3. Start walking down the 10.023 feet mountain in the dark
4. Hijack one of the 4 remaining cars on the parking lot or meet a good Samaritan

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5. Remove the battery in your remote controller – (non-validatet test)