Effects of Bleaching on Oral Hard Tissues and Dental Restorations

- Heinz Duschner
- Applied Structure- and Microanalysis
- Medical Faculty
- Johannes Gutenberg-University
- Mainz, Germany
Tooth Appearance – What We See

Light that returns to the observer

- **Intrinsic color of teeth**
  - not completely known
  - affected by dentin and scattering of tubules
  - enamel is translucent
  - carious enamel can scatter light (white spot) or contain chromagenes
  - longstanding exposure to chromogenes (tobacco) can produce intrinsic staining

- **Extrinsic discoloration**
  - factors – diet, smoking, calculus
Research Objectives

- Develop a fundamental understanding of the interaction chemistries of peroxides with hard tissues and dental restorations at the chemical, physical and ultra-structural level – applying state of the art techniques of analysis

- Determine dynamic range for safe and effective tooth bleaching – provide recommendations for clinical applications of whitening innovations

- Clearly differentiate effects of peroxides from delivery matrices in establishing conditions for safe and effective tooth bleaching
Principles of Research

- Techniques applied are state of the art – and applied in unique combinations to answer core questions

- Treatment conditions include direct simulations of clinical exposures – including dentifrice applications, salivary dilution etc. Treatments account for recommended use and overuse – that is ‘overbleaching’

- Substrates include diverse materials encountered in the oral cavity
Techniques Applied in Research –
Conventional Methods

- Hardness tester
- Fracture testing
- Profilometer
- Digital imaging
- VP-SEM + surface image
- CLSM-micro Raman
- Bond strength testing
Treatment Conditions –
Bleaching and Overbleaching

- Hydrogen Peroxide Concentrations in ‘Passive Matrix Base’: 5.3, 6.5, 9.0, 11.7, 13, 16 % H₂O₂

- Carbamide Peroxide 10 and 20 %

- Treatments simulating 1x – 5x clinical bleaching recommendations – test for OVERBLEACH (Critical to Unsupervised Use)
Testing Protocol
-in vitro- CWS Bleaching Cycling Regimen

- **Daily Treatments**
  - twice daily a 30 min peroxide gel exposure
  - wash and brush after bleach
  - overnight in whole human saliva

- **Bleaching Cycling Regimen**
  - 14 days bid 6 % peroxide
  - 14 days bid 13 % peroxide
  - 14 days bid 16 % peroxide
Testing Protocol
Measurements of Macroscopic Properties

- Tooth Color by Digital Image Analysis
  - *Fuji digital camera*

- Enamel and Dentin Hardness and Fracture Indices
  - *Buehler VHN hardness tester*

- Tooth Surface Roughness Index
  - *Taylor-Hobson profilometer*
Effects of Bleaching and Overbleaching on Tooth Colour

- L (BRIGHTNESS)

PLACEBO  |  CWS  |  NORMAL  |  CWS  |  OVERUSE

- b YELLOW

PLACEBO  |  CWS  |  NORMAL  |  CWS  |  OVERUSE
Enamel and Dentin Hardness Measures

Indent by VP-SEM

Indent by CLSM
Effects of Bleaching and Overbleaching on Enamel and Dentin Hardness

Meaningful bleach effects do not affect enamel and dentin hardness.
Enamel Fracture Sensitivity Measures

Measure of fracture lengths on microhardness indents
Effects of Bleaching and Overbleaching on Enamel Fracture Index

Meaningful bleach effects do not affect tooth fracture indices
Topography of Enamel, Dentin and Restorations

Environmental pressure electron microscopy (VP-SEM) for naturally wet specimens
Effects of Bleaching and Overbleaching on Enamel Surface Topography

CWS (overuse)  Placebo
Effects of Bleaching and Overbleaching on Dentin Surface Properties

CWS (overuse) Placebo
Effects of Bleaching and Overbleaching on Dentin Smearlayer

CWS (overuse) Placebo
VP-SEM Sensitivity for Assessing Surface Effects
Effect of Soft Drink on Enamel Surface

5 min diet Coke
CLSM / Raman Spectrometer / Spectrophotometer
Subsurface micro-Structure + micro-Analysis

Spectrophotometer

Leica TCS SP 2 XI
Confocal Laser Scanning Microscope

micro-Raman Spectrometer

3D non-destructive ultra-structural and micro-chemical analysis
CLSM / Raman-Spectrometry / Spectrophotometry Subsurface Imaging and Spectra-Uptake
Effects of Bleaching and Overbleaching on Tooth Ultrastructure

6% PEROXIDE

13% PEROXIDE

16% PEROXIDE
Effects of Bleaching on Enamel Ultrastructure
Effects of Bleaching on Dentin Ultrastructure
Characterization of Dental Tissues by Raman Spectrometry

SYNTHETIC APATITE CRYSTAL

\( \nu_1 \text{PO}_4^{3-} \)

\( \nu_2 \text{PO}_4^{3-} \)

\( \nu_3 \text{PO}_4^{3-} \)

\( \nu_4 \text{PO}_4^{3-} \)

DENTIN

\( \nu_1 \text{CO}_3^{2-} \)

\( \nu_1 \text{HPO}_4^{2-} \)

ENAMEL

\( \text{amide} \)

\( \text{C-H} \)
Effects of Bleaching and Overbleaching on Enamel Raman Spectra Signature

- 6 % PEROXIDE
- 13 % PEROXIDE
- 16 % PEROXIDE

$\nu_2PO_4^{3-}$, $\nu_4PO_4^{3-}$, $\nu_1PO_4^{3-}$, $\nu_3PO_4^{3-}$
Effects of Bleaching and Overbleaching on Enamel Subsurface Raman Spectra Signature

$\nu_{2}\text{PO}_4^{3-}$  $\nu_{4}\text{PO}_4^{3-}$  $\nu_{1}\text{PO}_4^{3-}$  $\nu_{3}\text{PO}_4^{3-}$

6 % PEROXIDE
13 % PEROXIDE
16 % PEROXIDE
Effects of Bleaching and Overbleaching on Dentin Raman Spectra Signature

- $\nu_2PO_4^{3-}$
- $\nu_4PO_4^{3-}$
- $\nu_1PO_4^{3-}$
- $\nu_3PO_4^{3-}$

6% PEROXIDE
13% PEROXIDE
16% PEROXIDE

APATITE CRYSTAL
Raman Spectra Signatures of pre bleach Tooth Tissues

DEJ
DENTINE
ENAMEL
ENAMEL SURFACE
Raman Spectra Signatures of post bleach Tooth Tissues

16 % PEROXIDE
Raman Spectra Signatures
Spectral Intensities

Integral of Raman Spectra

PRE BLEACH
16 % PEROXIDE
Effects of Bleaching on Tooth Optical Properties

Excitation: 488 nm
Emission 542 nm

PRE BLEACH
16 % PEROXIDE
Visible Tooth Changes

Chemical Reactions

Conversion Process

Darkly pigmented carbon ring structures

Lightly pigmented unsaturated structures

Hydrophilic non-pigmented structures

H₂O₂

Bleaching

Continue Bleaching

R – CH₂ – CH = CH – CH = CH – CH₂ – R

OH

OH


OH

OH

OH

OH

Effects of Bleaching on Restoration Topography and Hardness

- Porcelain
- Dental Gold
- Composite
- Amalgam
- Air Cured Ionomer
- Light Cured Ionomer

Initial vs. Post Bleach Hardness
Effects of Bleaching on Restoration Bond Strength

![Box plot showing the effects of bleaching on restoration bond strength. The x-axis represents different materials: control, Crest Whitestrips Re, Opalescence Gel, and Jade Paint On Perc G. The y-axis represents HAFTNEU values with N = 15 for each group.](image)
Effects of Bleaching on Restoration Microleakage

<table>
<thead>
<tr>
<th>Group 3 – penetration score, Crest Whitestrips Retail Gel</th>
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<tbody>
<tr>
<td>Tooth #</td>
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<td>Slide 1</td>
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Example for no penetration (grade 0)
Example for penetration < to ½ of enamel thickness (grade 1)
Example for penetration < to enamel-dentin-junction (grade 2)
Example for penetration < to base of the cavity (grade 3)
Effects of Bleaching on Nanoleakage Formation

Example for no dye penetration within the enamel-composite junction.

Example for little dye penetration (here 60 µm) within the dentin-composite junction. Left side reflecting mode, right side fluorescence mode.
Effects of Bleaching on Nanoleakage Formation

Materialien:
- Kontrolle
- Crest Whitestra Ret G
- Opalescence Gel
- Jade Paint on perc G
Conclusions
Enamel and Dentin Post Bleach Testing

- No CLSM evidence for adverse CWS bleach effects on morphology, micro-topography and sub-surface ultra-structure

- No micro-Raman evidence for adverse CWS bleach effects on enamel and dentin micro-chemical integrity

- Evidence for bleach effects on the background of micro-Raman spectra and on the autofluorescence of enamel and dentin which might be associated with post bleach colour changes (brightness, yellowness)

- No effects on Restoration Topography, Bond Strength as well as Micro- and Nanoleakage Formation
Investigators

University of Mainz, Germany
- Heinz Duschner
- Hermann Goetz
- Malgorzata Glukovska

University of Heidelberg, Germany
- Thomas Pioch

P&G Health Research Center, Cincinnati, USA
- Don White
- Kathy Kozak
- Jim Zoladz