Treatment and Management of White Spot Lesions

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Objectives:
- Review etiology and prevalence of white spot lesions
- Review structure of white spot lesions
- Review assessment methods
- Review methods of prevention
- Review treatment approaches

Remineralization
- Bleaching
- Microabrasion
- Restoration
- Future directions & Summary

White Spot Lesions & Orthodontics

Enamel white spot lesions (WSLs):
- Common finding with use of fixed orthodontic appliances
- Prevalence: varies up to 97%, depending on study
  - 2011: 73% of patients developed a new WSL during orthodontic treatment
  - 2016: 28% patients in private practice setting developed WSLs
- Most affected: Mx lateral incisors, canines; Mn canines, premolars

Etiology:
- Deficient oral hygiene → elevated plaque & cariogenic bacteria (S. mutans)
- Acidic environment tips de/re-mineralization balance toward demineralization
- Occurs rapidly: as early as two weeks after initial biofilm formation
- In typical WSL, enamel mineral content is reduced by 10-50%

Demineralization
Acid
PO₄³⁻ → Ca²⁺

Remineralization
Saliva
PO₄³⁻ → Ca²⁺

Characteristics of White Spot Lesions

- Early lesions: Shallow, uniformly demineralized
  - Have potential to spontaneously regress
- Mature lesions: Deeper & develop an intact surface layer due to remineralization
  - Subsurface region remains as porous body of lesion
  - Opaque, chalky-white appearance is due to scattering of light within subsurface, demineralized enamel
  - Refractive index of hydroxyapatite = 1.6; air = 1.0; water = 1.3
  - Once formed, remineralized surface layer presents obstacle for remineralization of deeper regions

In Vitro Assessments

- Micro-hardness
- Knoop diamond indenter
- Light or electron microscopy
- Ground sections
- Micro-CT

White Spot Lesions (WSLs)

- Result of localized enamel demineralization
- Etiology:
  - Deficient oral hygiene
  - Elevated plaque & cariogenic bacteria (S. mutans)
  - Acidic environment tips de/re-mineralization balance toward demineralization
  - Occurs rapidly: as early as two weeks after initial biofilm formation

In Vivo Assessments

- Bleeding and inflammation scores
- Bacterial count
- ATP-Driven Bioluminescence
- Spectrophotometrics

Alternative Assessments

- Gorelick Scale
  - 4 point scale
  - 1 = None
  - No WSL = 1
  - Slight WSL = 2
  - Excessive WSL = 3
  - WSL with cavitation = 4

- ICDAS (International Caries Detection and Assessment System)

- Laser Fluorescence (Diagnodent)
- KaVo (Kaltenbach and Voight), Germany
- Fluorescence related to bacterial metabolites

Alternative Assessments

- Quantitative Light-induced Fluorescence (QLF)
- Inspektor Research Systems, Netherlands
- Fluorescence related to mineral content

Visual Analogue Scale:
Rate improvement of white spots on multiple teeth

Before

After

0 = No improvement or worse
100 = White spot(s) completely disappeared
Objective Assessment

- WSL and total tooth surface area traced.
- % WSL = (Affected area/Total area) X 100

Traced white spot lesion

Traced total tooth surface

Prevention is ideal

- Many techniques/agents proposed
- Does anything really work?

Approaches Aimed at Minimizing Formation of WSLs

- Bonding agents that release ions to combat demineralization
  - “Bioactive Glass” adhesives
- Appliances less obstructive to maintaining good oral hygiene
  - Self-ligating orthodontic brackets

Bioactive Glass (BAG)

- Amorphous 3-D cross-linked matrix of SiO$_2$, CaO, P$_2$O$_5$, serving as a source of ions for bioactivity$^1$
  - Under acidic conditions => calcium ions leached from BAG
  - Leads to environment supersaturated with bioavailable calcium$^2$
  - Tested to see if protects against enamel demineralization

Bioactive Glass Formulations Tested, Compared to Transbond XT
- Varied in content of Silica, Calcium, Fluoride (none available in Transbond XT)
- Named based on content of Silica

<table>
<thead>
<tr>
<th>Sample</th>
<th>SiO$_2$</th>
<th>CaO</th>
<th>P$_2$O$_5$</th>
<th>Surface Area of BAG (m$^2$/g)</th>
<th>% Difference in bond (by weight)</th>
<th>Name of Adhesive</th>
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<tr>
<td>1</td>
<td>62</td>
<td>31</td>
<td>4</td>
<td>75</td>
<td>81.35%</td>
<td>BAG:Monomer</td>
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<td>65</td>
<td>31</td>
<td>4</td>
<td>144</td>
<td>83.54%</td>
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<td>3</td>
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<td>11</td>
<td>4</td>
<td>320</td>
<td>17.13%</td>
<td>BAG:Monomer</td>
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<tr>
<td>4</td>
<td>85</td>
<td>11</td>
<td>4</td>
<td>295</td>
<td>31.53%</td>
<td>Transbond XT</td>
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<tr>
<td>5</td>
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<td></td>
<td></td>
<td>n/a</td>
<td>Transbond XT</td>
</tr>
</tbody>
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1. Hench et al., Science 2006;17:967-78

Bonding Agent Study

A novel biomimetic orthodontic bonding agent for prevention of white spot lesions: an in vitro study of surface microhardness changes adjacent to orthodontic brackets

Lauren N. Manfred, John Mitchell, David Covell, Jennifer Crowe, Eser Tüfekçi

Angle Orthodontist 2013;83:97-103

1. Hench et al., Science 2006;17:967-78
Tooth Preparation Methods

- Extracted human 3rd molars (n=10/group)
- Window defined: confine bonding materials to under bracket base
- Lateral incisor bracket bonded

Demineralization & Testing

- pH Cycling\(^1\): 14 days, alternating 6 hours demineralizing solution & 18 hours remineralizing solution
- Sectioning: Embed in epoxy resin Sectioned with diamond saw
- Microhardness testing:
  - Duramin 5\(^*\) microhardness tester with Knoop diamond indenter
  - Apply 25 g force for 5 seconds
  - Measure width of the indentation

Microhardness Testing

- Indentations:
  - 3 distances from adhesive edge; 8 depths into enamel
  - Compare to microhardness under bracket (internal control)
  - Analyzed using 3-way ANOVA: microhardness vs. distance and depth

Outcomes

- 81 BAG-Bond
  - Highest surface area
  - Facilitates release of ions
  - Contains Fluoride
  - Contributes to formation fluorapatite
  - Overall: Highest bioactivity rate
  - Least change in enamel hardness

Interpretation/Clinical Viability

- Ion Release
  - Significant Calcium released into simulated body fluid\(^3\)
- Bond strength studies
  - Virginia Commonwealth Univ: Eser Tufekci & Cole Johnson\(^2\)
  - 81BAG-Bond had highest shear bond strength; well within acceptable clinical range
- Conclusions:
  - Use of adhesives combining bioactive glass into resin may help to reduce enamel demineralization & WSL formation

Can the type of orthodontic bracket impact oral hygiene and formation of white spot lesions?

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\(^1\) Toda & Featherstone J Dent Res 2008;87:224-27
\(^2\) Johnson et al, VCU Master's Thesis 2011
\(^3\) Brown et al, Angle Orthod 2011; 81:1014-20
Plaque and Bracket Ligation
Methods

Plaque retention by self-ligating versus elastomeric orthodontic brackets: Quantitative comparison of oral bacteria and detection using ATP-driven bioluminescence

Peter Pelligrini, Curt Machida, Tom Maier

Self-ligation vs. elastomers: A comparison of bracket archwire ligation technique on microbial colonization and white spot lesion formation

Tyson Buck, Curt Machida, Tom Maier
Orthodontics: the Art and Practice of Dentofacial Enhancement 2011;12;108-21

Study Design

• Bracket Bonding: 14 subjects, 50 lateral incisors (maxillary & mandibular)
  • 1/2: conventional brackets, 1/2: self-ligating brackets (GAC In-Ovation R)

• Assessments
  • Plaque collected: 1 week, 5 weeks and 1 year
  • Bacteria measured by blood-agar plating & ATP-driven bioluminescence
  • Assessment for white spot lesions: at start of Tx vs. 1 year later
    – Photographs, laser light fluorescence

Microbiology & ATP-Driven Bioluminescence

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Laser Light Fluorescence

• DIAGNODent* measurements recorded adjacent to brackets
  – Laser light causes fluorescence of enamel, proportional to amount of decay
  – Recorded highest reading (range: 0-99) from each of the four sides
  – Reading >4 considered WSL

Number of Bacteria: 1, 5 Weeks

Total bacterial measured from cell culture and by ATP-driven bioluminescence

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<td>2.05E+01 2.46E+00</td>
<td>3.10E+01 3.06E+00</td>
<td>2.56E+00 2.93E+00</td>
<td>3.04E+00 3.16E+00</td>
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Summary: Weeks 1 and 5, fewer bacteria associated with self-ligating compared to elastomeric- ligated brackets

Results consistent between cell culture and ATP-driven bioluminescence measurements

Number of Bacteria : 1, 5 weeks & 1 year

Orthodontics: the Art and Practice of Dentofacial Enhancement 2011;12;108-21

Total bacterial measured from cell culture and by ATP-driven bioluminescence

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Summary: After 1 year, no difference in number of bacteria associated with self-ligating vs. elastomeric- ligated brackets

ATP-driven bioluminescence correlates well with total oral bacteria numbers (Pearson correlations: r=0.90 to 0.91)
**DIAGNOdent vs. Visual WSL Assessments**

**Findings:**
- DIAGNOdent identified 5 of the 7 visual WSL
- Moderate sensitivity (0.71)
- More accurately identified absence visual/photographic WSL
- Good specificity (0.88)
- Limitation: small sample size of teeth having WSL (n=7)

**Findings consistent with previous studies:**
- Pinelli et al. 2002; Barberia et al. 2008:
  - Sensitivity = 0.72 - 0.79
  - Specificity = 0.73 - 0.87
- Kronenberg et al. 2009:
  - Visual evaluation of initial caries lesions superior to DIAGNOdent measurements when assessing WSL adjacent to orthodontic brackets

Barbera et al. A clinical study of caries diagnosis with a laser fluorescence system. JADA 2008;139:572-9

**Prevention & Treatment**

- Presentation switched to G Huang’s slide series, then returned to the slides below for completion of the presentation

**Microabrasion**

- Nonrestorative approach to treat enamel dysmineralization and demineralization
- Method:
  - Begin removal of affected enamel with fine diamond bur/high-speed, if needed
  - Complete removal using abrasive slurry, e.g., PERMA® compound (HC, silicon carbide abrasive), applied with rubber tip in slow-speed
  - Erodes and abrades enamel surface
  - Evaluate after 1 minute, repeat as needed
  - Average Tx time: 5 minutes
  - Apply neural sodium fluoride gel

* Premier Dental Products

**Restorative Tx: Resin Infiltration**

- “Micro-invasive” restorative treatment option involving penetration of a low viscosity resin into the body of the WSL with minimal removal of enamel
  - Method highlights:
    - Remineralized surface enamel removed with 15% hydrochloric acid etch
      - More effective than phosphoric acid
    - Subsurface demineralized enamel is exposed, increasing permeability
    - Demineralized lesion air dried, desiccated with ethanol
    - Infiltration resin applied: triethylene glycol dimethacrylate (TEGDMA) - based
      - Ideal characteristics to facilitate infiltration:
        - Low viscosity (low filler content)
        - Low contact angle to enamel (enhances capillary action)
        - High surface tension (helps draw resin into body of lesion)
    - Through capillary action, fills microscopic voids in demineralized enamel

4. Icon, DMG, Hamburg, Germany

**WHY THE DIFFERENCE SL vs. EL?**

**PELLEGRINI ET AL. 2009 (5 WEEKS):** EL BRACKETS > SL BRACKETS VS.

**BUCK ET AL. 2011 (1 YEAR):** EL BRACKETS = SL BRACKETS

1. Subjected for more time to oral environment - brackets and areas around brackets difficult to keep clean
2. Decreased patient compliance with increasing treatment time
3. Possibly SL brackets accumulate plaque?

**Conclusions:**
- 1. SL may hold some advantage if oral hygiene practices are good
- 2. Bracket type makes no difference if oral hygiene practices are less than ideal

**And when prevention fails ...**

- Remineralization of affected enamel (fluoride, MI Paste)
- Modifying surrounding enamel (bleaching)
- Removal of affected enamel (abrasion)
- Restoring affected enamel (composite, veneers)
Resin Infiltration Procedure
Icon® resin infiltration kit (DMG, Hamburg, Germany)
http://www.dmg-america.com/catalog/infiltrant/icon

Why HCl Etch?
Removes remineralized surface layer, increases permeability of lesion


HCl Etch & Resin Permeability
No HCl etch (C): * intact remineralized surface layer, no resin infiltration
HCl etch (R): Removal of remineralized surface layer, evidence of resin infiltration

Schneider et al. Imaging resin infiltration into non-cavitated carious lesions by optical coherence tomography. J Dentistry 2017;60:94-98

HCl Etch: Decreases depth of WSL
“Microabrasion effect”: Etch cycles progressively remove surface of lesion

15% HCl gel for 120 sec.
Mean: 37 ± 8 µm removed

Outcomes of Resin Infiltration
• Benefits of resin infiltration of white spot lesions: 1-4
  • Seals surface & arrests further progression of lesion
  • Reinforces remaining enamel structure
  • Penetrates body of lesion, masking opaque appearance
    – Refractive index of resin = 1.5
    – Similar to hydroxyapatite = 1.6
    – Light passing through resin and enamel has similar optical properties

• How well does resin infiltration work clinically?

Clinical Study of Resin Infiltration
“Minimally invasive resin infiltration of arrested white-spot lesions: A randomized clinical trial”

• Seth Senestraro, J Crowe, M Wang, A Vo, G Huang, J Ferracane, D Covell, Jr.
  • JADA 2013;144:997-1005

Comparison of side-by-side photographs via VAS rating

T2 = Immediate post-treatment of WSL
T3 = 8 weeks later

Senestraro et al., JADA 2013;144:997-1005

WSL Area Measurements

- Morphometric program (NIH Image J)
- WSL traced by investigator = WSL area (mm$^2$)
- Calculated % reduction of WSL for T2 & T3

Senestraro et al., JADA 2013;144:997-1005

Summary: Resin Infiltration Study

- Resin infiltration significantly improves the appearance of white spot lesions and reduces their size
- Appearance of WSL restored by resin infiltration was stable over the 8 week study period
- Results consistent with 6 month and 1 year post-treatment study using spectrophotometric color analysis
- Longer term studies still needed

Senestraro et al., JADA 2013;144:997-1005

Long Term Esthetic Stability of Resin Infiltration?

- Replicate passage of time using in vitro staining of teeth with various liquids
- “Effects of staining on white spot lesions treated with Icon resin infiltration”
  - Patra Alatsis (OHSU 2014)
  - Mentor: Jack Ferracane
  - Today, focusing on coffee

Senestraro et al., JADA 2013;144:997-1005
Tested Susceptibility to Staining

- **In vitro** study: Bovine incisors
  - Enamel demineralized: Acetic acid (50 mM, pH 4.95)
  - Two groups: 2 or 6 weeks exposure to demineralizing solution

Crown divided into 3 windows to assess staining:
1. Sound enamel (control): previously covered with varnish
2. Untreated WSL
3. ICON® treated WSL

  - 2 minute HCl etch cycles, repeated 3 times

Spectrophotometric Color Measurement

- CIE-L* a* b* system:
  - Lightness (L*: 0-100)
  - Green-red chromaticity (a*: -150 to +100)
  - Blue-yellow chromaticity (b*: -100 to +150)

- Color difference (ΔE) calculated:
  \[ \Delta E = (\Delta L^*)^2 + (\Delta a^*)^2 + (\Delta b^*)^2 \]

- Intraoral differences of ΔE > 3.7 are considered clinically noticeable*


Coffee Demineralized Stained ΔE: Enamel ΔE: WSL ΔE: ICON
2 weeks 1 week 11.9 ± 6.3 41.3 ± 8.6 17.1 ± 6.9
6 weeks 1 week 8.5 ± 4.1 35.7 ± 8.5 22.2 ± 8.5

Staining Results: 2 weeks demineralization

Relative to pre-stain resin or enamel, resin had greater change in color than enamel

Stain Location and Removal

- Ground sections: Stain confined to surface

  - Polishing: Borges and associates: \[ \Delta E \] improved
    - Aluminum oxide sandpaper discs; 4,000 grit, 20 sec.

  - Bleaching: Araújo and associates: Resin stained with coffee, bleaching able restore color
    - 16% carbamide peroxide gel; 4 hours/day for 21 days

<table>
<thead>
<tr>
<th>ΔE for ICON restorations</th>
<th>Borges et al. after stain</th>
<th>Borges et al. with polishing</th>
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<tbody>
<tr>
<td>Water</td>
<td>2.3 ± 1.7</td>
<td>2.1 ± 0.9</td>
</tr>
<tr>
<td>Red Wine</td>
<td>17.3 ± 2.7</td>
<td>14.7 ± 4.7</td>
</tr>
<tr>
<td>Coffee</td>
<td>21.3 ± 4.3</td>
<td>16.6 ± 4.3</td>
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Summary of Staining/Aging Studies

- Differences in staining of intact enamel vs. resin will likely occur over time
  - Staining will be less for WSL restored by resin infiltration compared to untreated WSL

- With resin restoration, stains are confined to surface layer
  - Able to remove stains with polishing
  - Reduce discoloration with bleaching
Differences in Esthetic Results Treating White Spot Lesions with Resin Infiltration

Evaluation of in vitro models for assessment of resin infiltration treatment of artificial enamel white spot lesions

Kaitlyn Darcy

- Evaluate three WSL simulation models on esthetic outcomes of a resin infiltration system (ICON®)
  1. Microbiological (S. mutans) demineralization
  2. Chemical demineralization (50 mM acetic acid)
  3. pH cycling (acetic acid/buffered CaCl2 solution)

- Evaluate two HCl etch protocols with resin infiltration

- Compare esthetic outcomes of resin infiltration

Methods

- Bovine incisors (n=54)
  - Chemical and physical properties comparable to human enamel
- Cover with acid-resistant nail varnish, except 7 x 15 mm window
- Subject to one of the 3 demineralization methods
  - 18 teeth/group
  - Resulted in lesions with varying structure and depth

Resin Infiltration

- Methods:
  - Demineralized area divided into incisal & gingival windows
  - Nail varnish stripe (red) in center preserved area of WSL as a control
  - Incisal & gingival halves randomly assigned to Icon etch protocols: 2X (4 min) or 4X (8 min) followed by resin infiltration
  - Color analysis: spectrophotometer
  - Structure assessed: ground sections using light microscopy and scanning electron microscopy

WSL Depth

WSL depth measurements: Bacterial method – deepest lesions (265 µm)
WSL Depth

WSL depth measurements:
- Bacterial method – deepest lesions (265 µm)
- Chemical demineralization (145 µm) & pH cycling (120 µm): no difference

Chemical Demineralization Lesion & 4X etch protocol
- Complete resin penetration of WSL
- Mean ΔE = 5 (similar to intact enamel)

Bacterial Lesion & 2X etch protocol
- Deep lesion & incomplete resin penetration of WSL
- Mean ΔE = 10 (less ideal color match - incomplete fill)
- Limitation of infiltration: etch or capillary transport of resin?

Tooth Structure Loss: 2X & 4X Etch Protocols

All groups:
- 4X etch cycles: greater loss than with 2X cycles (p<0.001)
- Loss proportional to etch time:
  - Bacterial: 60 µm/etch cycle
  - Chemical demin, pH cycling: 35 µm/etch cycle

Summary: In Vitro WSL Modeling Study

- Resin infiltration ranged up to 120 µm depth
- Each 2 minute etch cycle removes 35-60 µm of WSL surface (reducing overall depth of WSL)
- When infiltrating deeper lesions (>120 µm):
  - Incomplete resin infiltration
  - Leaves residual unfilled WSL
  - Poorer color match relative to adjacent enamel
- Conclusions:
  - Better results with shallower lesions
  - Keep etch cycles to minimum necessary
  - For successful resin infiltration of deeper WSL:
    - Relies on chemical erosion to remove remineralized layer and also to reduce depth of lesion
    - Resin infiltration fills remaining demineralized lesion, within limits

Future Considerations for Prevention & Treatment of White Spot Lesions

- Improved oral hygiene approaches/products
- Variations in orthodontic appliances:
  - Aligners
  - Lingual braces
- Management of white spot lesions before starting orthodontic treatment
- Antimicrobial sealants
- Use of ion-releasing bonding agents

Managing white spot lesions before starting orthodontic treatment

- E.g., 15 YO male, pre-Tx extensive cervical white spot lesions
- Consider resin infiltration before placing appliances: Shown to inhibit progression of caries 1-3
  - Seals surface, facilitates cleaning of tooth surface
  - Isolates any remaining microorganisms within lesions

Bonding to White Spot Lesions Restored by Resin Infiltration

Costenoble et al. Bond strength and interfacial morphology of orthodontic brackets bonded to eroded enamel with calcium-silicate-sodium phosphate or resin infiltration. Angle Orthod 2016; 86: 909-16

- Extracted human teeth, enamel demineralized using lemon juice
- Measured shear bond strength, compared to intact enamel:
  - If bracket bonded immediately to resin: no difference in bond strength
  - If bonding delayed 1 month, lower bond strength compared to intact enamel, no difference compared to ICON restored and immediate bonding

Costenoble et al. Bond strength and interfacial morphology of orthodontic brackets bonded to eroded enamel with calcium-silicate-sodium phosphate or resin infiltration. Angle Orthod 2016: 86: 909-16

Antimicrobial Coatings

- Toxic to particular bacteria
- E.g., products with trace element Selenium
  - Selenium: “micronutrient”
    - Cofactor for various antioxidant enzymes
    - Naturally occurring, varying concentrations in soils, foods
      - E.g., Brazil nuts common food source
    - Children exposed to high levels of Se systemically during tooth development, associated with tooth discoloration & increased risk of caries
    - Antimicrobial effect: Generates superoxide radicals, disrupts cell membrane & toxic to various bacterial species

Selenium Coatings in Medicine

- Potential to protect prosthetic devices against infection due to Staph aureus and other bacteria
- E.g., catheters, joint replacements, contact lenses

In vitro study of Se nanoparticle coating Biofilm: S. aureus cultured for 3 days
Confocal microscopy using stain for living cells (SYTO 9)

Selenium-Containing Coating: DenteShield™
Marketed previously: Select-Defense™ (Element 34 Technologies, Lubbock, Tx)
Currently: DenteShield™ (SelenBio, Austin, TX)

E.g., coating of exposed root surface

Known commercially as "selenbio.com/dental/"

Currently:
In-vitro evidence shows short-term inhibition of biofilms Needed:
Published clinical trials on long-term efficacy
Use of Ion-releasing Bonding Agents
Resin–Modified Glass Ionomer Cement

- Topic of 2018 AAO Annual Session presentation by Roberto Justus (Sunday, May 6)
- Continuous release of fluoride helps combat enamel demineralization
- Problem: Reduced bond strength
- Solution: Deproteinization (5% sodium hypochloride) prior to acid etch
  - Cleans organic debris from enamel surface for increased exposed enamel surface

Remineralization and Application of Amelogenin

- Protein involved in enamel formation
- Small peptides from amelogenin can initiate hydroxyapatite formation
- May be useful in treating WSL, hypersensitivity, and caries
- Still in an early stage of development

Peptide-Aided Remineralization for Treating White Spot Lesions

Hanson Fong, Mustafa Gungormus, Candan Tamerler, Greg Huang, & Mehmet Sarikaya

1 Materials Sci & Eng, 2 Orthodontics, 3Chemical Eng, and 4Oral Health Sciences, University of Washington, Seattle, WA 98195, USA

Summary: White Spot Lesions

- Prevention: Ideal approach
  - MI Paste and varnish may help protect enamel
  - Oral hygiene is important
  - Fluoride, fluoride, fluoride
- Treatment: Challenges remain
  - Remineralization
  - Bleaching/masking
  - Abrasion/erosion
  - Restoration
    - Resin infiltration restoration
    - Structure loss, long term?
    - Composites/veneers

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