Problem solving in Dentistry:

Applying color theory in clinical practice

Asbjørn Jokstad
Institute of Clinical Dentistry, University of Oslo, NORWAY
1. Discolored teeth - etiology
2. Materials
   - Esthetic Restorative Materials
   - Shade guides characteristics
3. Shade matching
   - Digital systems
   - Procedure for matching & communication
The color of teeth?
Tooth Color

- Munsell values
- CIE 1976 L*a*b
- Tristimulus values X, Y, Z
- CIE chromaticity values Y(%), x, y

??!
# Tooth Color, CIE 1976 L*a*b

<table>
<thead>
<tr>
<th>Average</th>
<th>L</th>
<th>a</th>
<th>B</th>
<th>Method</th>
<th>n</th>
<th>Y</th>
<th>r</th>
<th>Author</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Vitro</strong></td>
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<td></td>
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<tr>
<td>72-1-16</td>
<td>56-83</td>
<td>-.7-4.6</td>
<td>4.4-26.</td>
<td>Spectrophotometer</td>
<td>9</td>
<td>5</td>
<td>5</td>
<td>O'Brien et al.</td>
</tr>
<tr>
<td>48-61</td>
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<td>Spectrophotometer</td>
<td>2</td>
<td>0</td>
<td>9</td>
<td>Horn et al.</td>
</tr>
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<td><strong>Vivo</strong></td>
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<td></td>
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<td></td>
</tr>
<tr>
<td>63-73</td>
<td>2-9</td>
<td>12-20</td>
<td></td>
<td>Colorimeter</td>
<td>8</td>
<td>7</td>
<td>0</td>
<td>Hasegawa et al.</td>
</tr>
</tbody>
</table>

\[ \Delta E^* = 8 \] (1 - 15)

\[ \Delta E^* = 4.5 \]
The proportional contribution of enamel, dentin, pulp, gingiva and mucosa to the spectral reflection from the tooth in isolation remain uncertain.

In general, dentin contributes the most as it is more chromatic than enamel.

Enamel is very translucent and more grey-blue than dentin.
In addition to ground color, other internal structures will produce optical phenomena:

- Enamel: Perikymata, Infractions, Retzius-lines, Hunter-Schreger lines, enamel lamellas, hypoplasia, thickness and composition
- Dentin: Dentin canal obliteration, enamel-dentin-transition, thickness and composition
- Pulp: Secondary dentin and size

Contact points, size and location and embrasure form and size

Location of the enamel-cement transition buccally and proximally
Definitely not Realistic!
Tooth color

There is lack of longitudinal studies on how much teeth discolored with age.

The evidence that teeth may be related to ethnic group is weak.

A reliable and valid measurement system of tooth color remains to be developed.

Nobody have attempted to correlate tooth color with any demographic data.

Age-related increased opacity and perceived darkening is due to following deposition of calcium-phosphates in enamel and in peritubular dentin, loss of enamel surface due to wear, and increased secondary dentin and gradual obliteration of the pulp.
Discolored teeth – extrinsic, etiology

Nathoo 1997

N1-type colored material (chromogen) binds to the tooth surface. The color of the chromogen is similar to that of dental stains caused by tea, coffee, wine, chromogenic bacteria, and metals.

N2-type colored material changes color after binding to the tooth. The stains actually are N1-type food stains that darken with time.

N3-type colorless material or prechromogen binds to the tooth and undergoes a chemical reaction to cause a stain. N3-type stains are caused by carbohydrate-rich foods (eg, apples, potatoes), stannous fluoride, and chlorhexidine.
Discolored teeth – intrinsic, etiology

1. Hereditary defects

Dentinogenesis imperfecta. Teeth are relatively normal at eruption. With time, they become more and more translucent, and yellow, pink, brownish or grey-brown. The enamel may chip off with subsequent heavy discoloration of the exposed dentin.

Amelogenesis imperfecta. Two categories have been described:

Hypoplastic: Teeth are smooth and glossy. The color is orange, reddish or brown.

Hypomineralised. The color can vary between bone white, yellow, red and black. The enamel may chip off later.
Discolored teeth - etiology

2. Toxic effects during tooth development
Fluorosis: Due to high intake of fluorides. The surface may range between small opaque white spots to extensive yellow-brown areas.
2. Toxic effects during tooth development

Fluorosis: Due to high intake of fluorides. The surface may range between small opaque white spots to extensive yellow-brown areas.

Tetracycline: Due to a chemical complex between the medicament and ameloenamel proteins. Even a short one-week cure can cause marked discoloration. The color can vary between light to dark yellow, and give a characteristic fluorescence in UV light. The teeth are usually very dark cervically due to the thin enamel.
Discolored teeth - etiology

1. **Hereditary defects**: Dentinogenesis imperfecta. - Amelogenesis imperfecta

2. **Toxic effects during tooth development**: Fluorosis - Tetracycline

3. **Trauma**: In the early phase following a trauma, a discoloration can sometimes be observed due to internal bleeding in the pulp, with retention of porphyrines and iron in the dentine. The discoloration may be reversible or remain, even if the pulpa remains vital.

4. **Pulp necrosis**: Results usually in a tooth discoloration, but not always.

5. **Other reasons**: Can be degradation products from metallic restoratives, seldom bleeders’ diseases, surface erosions and unknown reasons, possibly related to some childhood illness. One such known relationship is hepatitis over a long period.
<table>
<thead>
<tr>
<th>TYPE OF PRODUCT OR METHOD</th>
<th>ACTIVE AGENTS</th>
<th>INDICATIONS FOR USE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Internal Bleaching—In-Office or Walking</td>
<td>Na perborate or 35 % hydrogen peroxide</td>
<td>Endodontically treated teeth</td>
</tr>
<tr>
<td>External Bleaching—In-Office One to Three Visits</td>
<td>30 - 38 % hydrogen peroxide, alone or with heat or light</td>
<td>Single or multiple disColored teeth</td>
</tr>
<tr>
<td>Custom Bleaching Trays Worn by Patient Daily for Two to Six Weeks</td>
<td>10 % carbamide peroxide</td>
<td>Multiple teeth and entire arches, most effective for yellow or brown discoloration; may be effective for tetracycline staining with longer use</td>
</tr>
<tr>
<td>Brushing With Whitening Toothpaste</td>
<td>Abrasives</td>
<td>Surface staining</td>
</tr>
<tr>
<td>Microabrasion Followed by Neutral Sodium Fluoride Applications</td>
<td>Abrasives and HCl up to 36 %</td>
<td>Isolated brown or white discolorations of shallow depth in enamel</td>
</tr>
<tr>
<td>Microabrasion Followed by Custom Tray Bleaching</td>
<td>Abrasives and acid; 10 % carbamide peroxide</td>
<td>White discoloration on yellowish teeth</td>
</tr>
</tbody>
</table>
Esthetic Restorative Materials
Dental Materials

Presently, there are no spectrophotometric quality control of materials with minimum criteria of performance among the direct plastic materials. Composite resins possess the best optical-physical properties regarding esthetics.
New products

Opaque Dentin

Regular Body

Translucent Enamel

=Miris

=Vit-l-escence

=Matrixx

=Esthet-X

=Enamel plus HFO
Shade Selection

Enamel

Body

Dentin
Dental Materials - composites, clinical observations

- Most materials become more opaque and lighter after a while intraorally, due to water uptake
  - This varies markedly among different materials
- Chemically polymerised composites discolor more into yellow than the light polymerised due to the polymerisation chemicals in the resin
- Chemically polymerised composites with microfillers discolor more compared to those with macrofillers.
Dental Materials - composites, laboratory observations

1. Color Stability, in 60/80°C Water
2. Color Stability, Xenon light
3. Stain Resistance, in 37/80°C Coffee
4. Stain Resistance, in 37/80°C Tea
**Principles - preparation**

- The thickness of a restoration / veneer is critical to obtain a correct reflection spectrum and thus acceptable shade.
- Not removing enough tooth substance will either result in poor esthetics or to overcontouring with risk for subsequent gingival recession. This is especially critical cervically.
Principles – composite materials properties

- Light polymerised composites become less colorful after polymerisation, with microhybrids becoming darker and microfills becoming lighter after polymerization.
- Light-curing cause an increase in translucency of microhybrids and a reduced translucency in microfills.
Principles – composite materials, effects

- When placing a microfill composite the shade of unpolymerised material should be slightly more yellow/chromatic than the tooth before placement.
- The surface structure influences the appearance of shade. A highly polished surface appears lighter than a rough surface with a similar color.
- Special optical effects in composite restorations created by using intensive colors must always be veneered by a translucent composite.
<table>
<thead>
<tr>
<th>Producer</th>
<th>Materials</th>
<th>Shade</th>
</tr>
</thead>
<tbody>
<tr>
<td>3M ESPE</td>
<td>Composite / Hybrid</td>
<td>VITA/ Biodent / Own</td>
</tr>
<tr>
<td>Bisco</td>
<td>Composite / Hybrid</td>
<td>VITA</td>
</tr>
<tr>
<td>Coltène</td>
<td>Composite</td>
<td>VITA</td>
</tr>
<tr>
<td>Dentsply</td>
<td>Composite / GIC / Hybrid / Ceram / Prefabricated teeth</td>
<td>Biodent/ VITA/ Own</td>
</tr>
<tr>
<td>Discus</td>
<td>Composite</td>
<td>Own</td>
</tr>
<tr>
<td>DMG</td>
<td>Composite / Hybrid / GIC</td>
<td>VITA</td>
</tr>
<tr>
<td>Ducera</td>
<td>Ceram</td>
<td>Biodent / VITA</td>
</tr>
<tr>
<td>GC</td>
<td>Hybrid / GIC / Ceram</td>
<td>VITA</td>
</tr>
<tr>
<td>H Kulzer</td>
<td>Composite / Hybrid / Prefab teeth</td>
<td>Biodent/VITA</td>
</tr>
<tr>
<td>Jeneric</td>
<td>Composite / Ceram</td>
<td>Bioform/VITA</td>
</tr>
<tr>
<td>Kerr</td>
<td>Composite</td>
<td>VITA</td>
</tr>
<tr>
<td>Shofu</td>
<td>Ceram</td>
<td>VITA / Vintage Halo</td>
</tr>
<tr>
<td>Ultradent</td>
<td>Composite</td>
<td>VITA</td>
</tr>
<tr>
<td>VITA</td>
<td>Ceram / Prefabricated teeth</td>
<td>VITA</td>
</tr>
<tr>
<td>Vivadent</td>
<td>Composite / Ceram</td>
<td>Chromascop/VITA/ Own</td>
</tr>
</tbody>
</table>
Shade guides from the different producers may often differ markedly from the original VITA-shade.
Shade guides

- Shade guides from the different producers may often differ markedly from the original VITA-shade.
- Large deviations between supposedly similar tooth shades from the same producer is not uncommon.
- Custom-made color shades using the actual restorative material is claimed to be better than using a standard color shade.
- Some tooth shades change following immersion in disinfectants. Keep away from chlorine-containing solutions.
Shade guides
1. Porcelains do not match the shade guides that they are being compared to
2. Shade variations occur between different die lots of porcelain from the same manufacturer and between shade guides ($\Delta E^* = 2$)
3. Shade guide tabs are 4-5 mm thick compared to the thin 1.5 mm piece of porcelain used for the restoration
4. Shade guides are not always made with fluorescent porcelain, which causes inconsistencies in color matching
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2. Shade variations occur between different die lots of porcelain from the same manufacturer.
3. Shade guide tabs are 4-5 mm thick compared to the thin 1.5 mm piece of porcelain used for the restoration.
4. Shade guides are not always made with fluorescent porcelain, which causes inconsistencies in color matching.
5. It is difficult to predict the final shade after the layering of opaque, dentin and enamel.
7. Shade tabs are condensed differently than porcelain used for final restorations.
Bioform -> Biotone -> Trubyte
Bioblend -> Portrait IPN

White-red | Yellow | Orange | Brown-Red | Brown-Grey
1990; Vivadent -> Kerascop
Reddish-brown  Reddish-Yellow  Grey shades  Reddish-Grey

 +/- neck?
 Changed in the mid-seventies
 A3.5 & D4 added in 1980
 B1 & D1 sometimes excluded
VITA 3D-MASTER

With & Without neck Colors
Shade Matching

Digital

Analogue
Digital Shade Matching Systems

Alternative 1. Objectively match shades from natural dentition with standard shade guides and incisal shades. Record with a digital or video camera and analyse or send to technician.
Digital Shade Matching Systems

Alternative 2. A hand held optic device with dual light source connected through fiber optics to a spectrophotometer.
Digital Shade Systems

- Dental Color Analyser (clearlight.com/~aei)
- Metalor-ikam system (metalor-ikam.com)
- Pocketspec (Pocketspec.com)
- ShadeVision /ShadeRite (X-Rite.com)
- Shadescan (Cynovad.com)
- Spectroshade (mhtint.com)
- ShadeEye NCC (Shofu.com)
Digital Shade Systems - Benefits

- Improved communication between dentist and lab
- Can integrate with
  - Intra-oral camera
  - Digital Camera
  - Image enhancing software
  - Mouth Simulator
  - Printer
Cosmetic Imaging Systems

1. Vipersoft 3.1
   Integra Medical
2. Digital Dentist
   Digident
3. Image FX 4.0
   SciCan
4. Smile-Vision Cosmetic Imaging System
   Smile-Vision
Prize

Systems may be subject to external variables

- Filters and bulbs breakdown
  - Heat
  - Length of time in use
- Algorithms
  - Attempt to fill in the gaps
- Single light source
  - Can create reflection and glare spots
Analogue Shade Matching Systems

A handheld optic device viewed in split image with a light source projected through variable filters
Before you start...

1. Have the patient remove lipstick or bright makeup
2. If patient is wearing bright clothing, drape him or her with a neutral colored cover, i.e. light blue or light gray
3. Keep a surface with a neutral color nearby
4. Clean the teeth if doubt of extrinsic discoloration
5. Don't recline your patient – keep at eye level
6. Do not wear glasses that changes with light
Fixed Prosthetic Dentistry-
shade selection

... right environment

1. Do not use direct lights. Lighting should be in the most natural light possible. Incoming light may be altered if the window in your operatory has a lot of greenery around it

2. Compare your shade selection under varying conditions such as with lip retraction versus lip down and when the patient moves their head in different directions or lighting angles

3. Have also your patient press their tongue against the lingual surface, when doing an anterior tooth restoration
Light sources

Fluorescent   Natural daylight Incandescent

The same teeth look different under different light sources
Fixed Prosthetic Dentistry-
shade selection

... right time

1. Select the shade at the beginning of the session before the tooth becomes dehydrated and your eyes fatigued

2. An impression and the use of rubber dam will cause lighter teeth. Retraction cord may influence the tooth color both ways. Anaesthetics too?

3. The canines are a good for selecting shade as they have the highest chroma of the dominate color of the teeth

4. Once the tooth is fully prepared, use your guide to select the shade of the dentin in the tooth’s body
Important:

1. The first impression is usually the most accurate in shade selection

2. It is important to avoid fatiguing the eyes. Do not stare for >3-10 secs. Gazing at a neutral color, e.g. blue or grey for approx. 30 seconds will help to cleanse and refocus the eyes.
Fixed Prosthetic Dentistry-
shade selection

... the process ...

1. Place the shade tab parallel to the facial surface of the teeth, not in front or behind

2. Arrange each tab on the guide so that the incisal edge is facing out or away from the tab holder. Since incisal shading has the greatest influence on value, it is helpful to position the incisal area of the tabs closest to the teeth you are shading. This will also help avoiding color choice being influenced by the hue area of the tab

3. Always select the value reading first. It may help to squint

4. Now that the value reading has been taken, use your hue guide to select the color reading
Fixed Prosthetic Dentistry-
shade selection

... finalising

1. Make your final shade selection after comparing your selections with those of a staff member and/or ask the patient's opinion on your choice

2. Make a mental note of morphological details

3. If unable to match, choose a lower chroma and higher value

4. Take photo with shade tab if possible
Communication is often impaired because handwritten Rx’s are often poorly specified
Communication with lab

- Color characteristics:
  - conventional thirds,
  - no apparent thirds,
  - only the cervical or central 1/3 differ

- Translucency:
  - Diffuse translucency over the whole surface
  - incisally
  - translucent both incisally and proximally
Communication with lab

Get as detailed as possible with characterization.
Every piece of information helps:

- Surface texture
- Glaze
- Translucency
- Wear
- Proximal view with incisal/thickness of enamel
- Any unique color characterizations of the dentine
Topics covered

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Thank you for your kind attention.