Isn’t the dental pulp a topic for Endodontics?

“The treatment phase of restorative dentistry is or should be, more involved than endodontics with the structure, function, tissue reactions, and potential healing capacities of dentin and pulp. All caries prophylactic measures and treatment phases of restorative dentistry should be considered ‘preventive endodontics.’”

Mjör IA. Quint Int 2001

Dentin

- Derived from odontoblasts
- Newest layer of dentin always on pulpal surface
- Formation continues throughout life

Dentin Anatomy & Physiology

- Derived from odontoblasts
- Newest layer of dentin always on pulpal surface
- Formation continues throughout life

Odontoblastic process

Enamel

Dentin

Pulp

N. B. Cook, DDS, MSD
**Primary Dentin**

- Dentin forming initial shape of tooth
- In permanent teeth, completed 3 years after tooth eruption

**Secondary Dentin**

- Low rate deposition continuing after primary dentin is formed.
- Different directional pattern from primary dentin, more irregular
- Forms on internal aspect of pulp chamber

**Dentin Matrix**

- Calcified Portion
- Uncalcified Portion

**Calcified Portion**

- Organic - mainly collagen
- Inorganic - hydroxyapatite
- Water

**Uncalcified Portion**

- Dentinal tubules
  - odontoblastic fibers (Tome’s)
- fluid

**Distance from pulp (mm)**

<table>
<thead>
<tr>
<th>Distance from pulp (mm)</th>
<th>Mean Number of tubules (1000/mm²)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pulpal Wall</td>
<td>45</td>
</tr>
<tr>
<td>0.1-0.5</td>
<td>43</td>
</tr>
<tr>
<td>0.6-1.0</td>
<td>38</td>
</tr>
<tr>
<td>1.1-1.5</td>
<td>35</td>
</tr>
<tr>
<td>1.6-2.0</td>
<td>30</td>
</tr>
<tr>
<td>2.1-2.5</td>
<td>23</td>
</tr>
<tr>
<td>2.6-3.0</td>
<td>20</td>
</tr>
<tr>
<td>3.1-3.5</td>
<td>19</td>
</tr>
</tbody>
</table>

(Pathways of the Pulp, 6th ed.)
### Dentin Permeability

- Movement of fluids through dentin
- Related to thickness of dentin, and diameter and number of tubules
- Pulpal fluid has slight positive pressure (5 - 20 mm Hg)

---

(Pathways of the Pulp, 6th ed.)

---

(Dentinal tubules)

---

James K. Avery, University of Michigan, School of Dentistry, 1987
Clinical Implications
• ↑ Permeability
  – ↑ fluid flow (bonding)
  – ↑ access to pulp (chemical & bacterial)
  – ↑ tooth sensitivity (hydrodynamic theory)

Functions of the Pulp
• Formative
• Nutritive
• Sensory
• Protective
  Review in Chapter 1 (Summitt)

Pulpal Reaction
• Inflammatory response to noxious stimuli
  – Bacteria and endotoxins
  – Physical, chemical, & thermal irritation from restorative procedures

Stressed Pulp Syndrome
• Pulp is stressed during every restorative episode
  • Stressful effects are additive
  • Repeated insults decrease pulp’s ability to tolerate injury

Effects of Aging
• Young Pulps
  – Highly cellular, low fiber
• Old pulps
  – Increased fibrous component
  – Low number of cells
  – Decreased nerve fibers and neuropeptides
  • Therefore, reparative capability of older pulps is decreased.

Effects of Aging
• However; aged teeth are generally:
  – less sensitive
  – protected by sclerotic and tertiary dentin
  – Low dentin permeability
Pulpal Response to Dental Procedures

Opportunities to Protect the Pulp
- Tooth Preparation
- Tooth Restoration

Goal during restorative process:
Maintain the health of the pulp

Natural Defenses

Remaining Dentin Thickness (RDT)
- Remaining dentin thickness (prep to pulp) is single most important factor in protecting pulp from insult
  - 0.5mm reduces effect of toxins 75%
  - 1.0mm reduces effect of toxins 90%
  - 2.0+mm little pulpal reaction

Remaining Dentin Thickness
- Thicker dentin, better insulator
- Thicker dentin, better buffer
- Greater permeability in deep preps

Smear Layer
Reparative Dentin (tertiary dentin)

- Response to moderate level irritants: attrition, abrasion, erosion, trauma, moderate-rate caries lesions, operative procedures, etc.
- Localized dentin deposit on wall of pulp cavity

Reparative Dentin (tertiary dentin)

- Variable tubular structure "barrier effect"
- Low permeability
- 1 month to detect microscopically
- 7-8 weeks to get 70μm thickness (Stanley)

Sclerotic Dentin

- Mineral crystallization within tubules
- Result of aging or mild irritation
- Progresses from DEJ toward pulp

Local Anesthetic

- 2% Lido w/ 1:100K epi - blood flow reduced (infiltration / IA block)
- pulpal blood flow ceases for 30 min. with ligamental injection

The Dental Pulp during Tooth Preparation

- Dentinal Tubule
- Peritubular Dentin
- Intertubular Dentin
Local Anesthetic

- Direct relationship between length of flow cessation and concentration of vasoconstrictor used
- Prolonged reduction in oxygen transport can alter pulpal response to injury

Thermal Injury

- Heat is primary cause of pulpal damage during restorative procedures
- Deep prep worse than shallow

Thermal Injury

- Main pulpal damage in 1-2mm radius of dentin being cut
- Tooth “blushing” during prep attributed to frictional heat

Thermal Injury

- 4 °F increase - minimal reaction
- 10 °F increase - partial odontoblast destruction, 15% of cases showed pulpal necrosis

Thermal Injury

- 20 °F increase - complete odontoblastic destruction, 60% of cases did not recover
- 30 °F increase - necrotic pulp

Instrumentation and Pulpal Temperatures

- 1800-10,000 rpm’s, no coolant → 5-22 °F increase
- 1800-10,000 rpm’s, air coolant → 1 °F increase
**Instrumentation and Pulpal Temperatures**

- 250,000-300,000 rpm’s w/ air → 4-7 °F decrease
- 250,000-300,000 rpm’s w/ water spray → 8-9 °F decrease

**Instrumentation**

- Speed and type of coolant

**Instrumentation**

- Large vs. small burs

**Instrumentation**

- Pressure on rotary instruments
  
  Pressure applied has greater effect on temperature than does rotational speed

**Instrumentation**

- Carbide vs. steel burs

**Instrumentation**

- Carbide burs
  - better for cutting ductile materials such as dentin, metal alloys, amalgam removal
  - better for end cutting, intracoronal cavity preparation
Diamond burs / stones

Diamonds produce more temperature rise than do carbide burs

Crown Preparation

• Incidence of pulp necrosis
  – full crown preparation 13.3%
  – partial veneer restoration 5.1%
  – unrestored control 0.5%
  (Felton, 1989)

Instrumentation

• Diamond burs
  – better for cutting brittle materials (e.g. enamel, porcelain)
  – better for extra-coronal cavity preparation, beveling enamel margins, enameloplasty

Other Potential Heat Sources

• Light curing of resins
  \[2.9 - 7.8^\circ C\] (Hannig, Dent Mater, 1999)

• Resin finishing & polishing
  Max. 4000 rpms (dry), 10000 rpm’s (wet) (Briseno, Quintessence Int, 1995)

• Amalgam polishing
  (Class V amalgam, rubber brownie point) 15000 rpm’s, 60 gms force → pulpal damage in 15 seconds. (Hatton, Am J Dent, 1994)
  Continuous polishing, high velocity → pulpal temp increased more than 20\(^{\circ}C\) in 30 seconds. (van Amerongen, J Prosthodont Dent, 1990)

• Fabrication of provisionals
**Electrosurgery**

- Contact enamel with probe → little to no pulpal reaction
- Contact metallic restoration → adverse and often severe reaction
  - More severe reaction with ↑ contact time (>0.4sec) and ↓ dentin thickness between restoration and pulp

**Desiccation of Dentin**

- Rapid outward fluid movement
- Continuous air drying can aspirate odontoblasts into tubules
- Dentin desiccation from air blasts and cutting procedures has limited pulpal effect

**“Pulp-friendly” Prepping**

- Preserve tooth structure
- Adequate air-water spray
- Light pressure
- Sharp burs
- Do not overdry

**Instrumentation**

- Hand Instruments

**Desiccation of Dentin**

**Pulpal Response to Restorative Materials**
**Commonly Used Cytotoxic Clinical Materials**

- eugenol
- formocresol
- glutaraldehyde
- HEMA
- Bis-GMA
- UDMA

**Dental Materials**

- Acid etching
- Bonding agents
- Dual-cure resin cements

**Dental Materials**

- Acid etching
- Bonding agents
- Dual-cure resin cements
- Dental cements

**Dental Materials**

- Acid etching
- Bonding agents
- Stanley
- Brannstrom
### Dental Materials

- Composite resins
- Dental amalgam
- Gold


### Pulpal Response to Dental Materials (summary)

- Inflammatory reactions to dental materials tend to be mild and transitory
- Significant pulpal responses occur more as the result of infiltration of bacteria or their toxins.

### Liners and Bases

**Classification System**

- According to Function
  - Sealers
  - Liners
  - Bases

### Classification

**Cavity Sealers**

- Protective coating / barrier to leakage (all leak)
- Applied to ALL WALLS
  - Varnish: natural gum or rosin in organic solvent (dentin permeability ↓ 69%)
  - Resin Bonding System: etch, hybrid layer, bifunctional molecule

**Cavity Liners**

- Thickness <0.5mm
- Physical barrier or therapeutic effect
- Usually only applied to dentin walls near pulp
  - Calcium Hydroxide
  - Glass Ionomer (Vitrebond, Lining LC)
**Classification**

- Cavity Bases
  - Replace missing dentin
  - Used for build up and/or block out
    - Zinc Oxide-Eugenol
    - Zinc Phosphate
    - Glass Ionomer

**What to use and when?**

**Post-Op Sensitivity**

- **Theories**
  - Theory of Thermal Shock (thermal diffusion)
  - Theory of Pulpal Hydrodynamics

**Thermal Diffusivity**

<table>
<thead>
<tr>
<th>Material</th>
<th>Thermal Diffusivity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pure gold</td>
<td>119.0</td>
</tr>
<tr>
<td>Amalgam</td>
<td>9.6</td>
</tr>
<tr>
<td>Comp. resin</td>
<td>0.675</td>
</tr>
<tr>
<td>Porcelain</td>
<td>0.64</td>
</tr>
<tr>
<td>Enamel</td>
<td>0.469</td>
</tr>
<tr>
<td>ZOE</td>
<td>0.389</td>
</tr>
<tr>
<td>Zn phos.</td>
<td>0.290</td>
</tr>
<tr>
<td>Compound</td>
<td>0.226</td>
</tr>
<tr>
<td>GIC</td>
<td>0.198</td>
</tr>
<tr>
<td>Dentin</td>
<td>0.183</td>
</tr>
<tr>
<td>Acrylic resin</td>
<td>0.123</td>
</tr>
<tr>
<td>Porcelain</td>
<td>0.64</td>
</tr>
</tbody>
</table>

-Craig RG. Restorative Dental Materials, 10th ed. 1997; Mosby.

**Thermal Diffusion**

- no need for base under resin composite
- base should be 0.50 – 0.75mm thick
- should have high modulus of elasticity
- ↑ base thickness → ↓ Fx resistance of amal


-Trowbridge et. al. (1980) showed in 16 teeth that pain fibers (A-delta) are activated before it was possible for the temperature change to diffuse through dentin near the fibers
Hydrodynamic Theory
(Brannstrom et al.)

- Rapid movement of fluid in the dentinal tubules results in deformation of the mechanoreceptor nerve endings.

Hydrodynamic Theory

Causes of fluid movement
- Intrapulpal pressure
- Desiccation
- Cold
- Heat
- Negative pressure
- Hydraulic pressure
- Osmotic gradient
- Mechanical instrumentation

Hydrodynamic Theory

• Most widely accepted explanation for tooth sensitivity
• Numerous controlled clinical trials have failed to show decreased post-op sensitivity with resin bonding under amalgams

Gordan, et al., Oper Dent 1999; 24:377-83
• 90 class 1 and class 2 amalgams
• Lesion depth: equal numbers of lesions in outer, middle and inner third of dentin
• Test groups:
  - No liner
  - 2 coats Copalite
  - Dentin adhesive resin liner
  - Resin modified glass ionomer liner
• Patient complaints of sensitivity

Sealers, Liners, & Bases

• Under Amalgam
  - Generally no sealers, liners, or bases
  - GI liner in deep areas close to pulp
  - If less than 0.5 mm dentin remaining (you can see pink through dentin), Ca(OH)₂ (dycal) on deep area, cover with glass ionomer liner

Gordan, et al., Oper Dent 1999; 24:377-83
• Results:
  - No clinical or statistically significant difference between lesion depth or dentin treatment.
  - When teeth were sensitive, copal varnish and resin lined teeth remained sensitive longer than glass ionomer or no liner teeth.
Initial vs. Replacement Restorations

Sealers, Liners, & Bases

• Under Resin Composite
  – Generally no liners or bases. Bonding agent is the sealer.
  – GI liner in deep areas close to pulp
  – If less than 0.5 mm dentin remaining, Ca(OH)₂ (dycal) on deep area, cover with glass ionomer liner

Sealers, Liners, & Bases

• Under Resin Composite (posterior)
  – Some advocate flowable composite liner
  – Prefer glass ionomer liner

Pulp Exposure

• Pulpal injury primarily due to bacterial contamination
• Mechanical or carious exposure?
• Rubber dam used?

Pulp Capping

• Endodontic treatment designed to maintain pulpal vitality
• Formation of reparative dentin (dentin bridge)

Pulp Capping Requirements

• Pulp must be vital, no history of spontaneous pain
• No lingering pain to cold/hot testing
• No periradicular lesion on radiograph
**Pulp Capping Requirements**

- Must be able to place a well-sealed restoration
- Rubber dam isolation
- Consider how tooth is to be used in treatment plan

**Indirect Pulp Caps**

- Indirect pulp cap is preferred
  - Protective thickness of dentin remains over pulp
  - Because RDT is directly related to odontoblast survival, reparative dentin formation is enhanced
  - Less chance for infected debris to get into the pulp causing inflammation

**Indirect Pulp Cap Procedure**

1. Anesthesia, Isolate with rubber dam
2. Prepare tooth for final restoration leaving demineralized dentin only immediately adjacent to pulp.
3. Caries detecting dye?
5. Calcium hydroxide placed over remaining demineralized dentin. This is always sealed with a glass ionomer liner.
6. Place restoration.
7. Monitor pulp vitality.

**Direct Pulp Capping**

- Traditionally performed with Ca(OH)$_2$
- Renewed interest in pulp capping using **Mineral Trioxide Aggregate** (MTA) (similar to Portland cement)

**Direct Pulp Capping**

- Only works under ideal conditions
- A bacteria free environment required
- Small mechanical exposure on otherwise healthy pulp
- Aged pulps have less healing capability
- Increased bleeding associated with increased likelihood of failure.
Direct Pulp Cap Procedure

- Achieve hemostasis
- Place calcium hydroxide (or MTA) over exposure
- Seal calcium hydroxide (or MTA) with glass ionomer liner
- Placed well-sealed restoration
- Monitor pulp vitality

Quiz

A B

- Primary Dentin
- Secondary Dentin
- Tertiary Dentin
- Reparative Dentin
- Sclerotic Dentin

During restorative procedures, what is the primary cause of pulpal damage?

Heat
Which case is more likely to have post-op sensitivity following the placement of an amalgam restoration?

a. Conservative MO amalgam on previously unrestored tooth #3.

b. Large MODL amalgam replacing previous large amalgam.