Adhesive Systems: Enamel and Dentine Adhesion

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The word adhesion comes from the Latin word *adhaerere* ("to stick to").

Outline

- Adhesion - Definition
  - Advantages
  - Use in dentistry
- Adhesion to enamel and dentine - how?
- Adhesion generations
- Clinical case- discussion

Adhesive system

- Very hard to keep update with the developments in this area.
- These materials probably cause confusion in dental profession with respect to the protocol for use and the type of adhesion achieved.

The Role of Adhesion in Dentistry

- Retention of restorations
- Conservation of tooth structure
- Reinforcement of tooth structure
- Eliminate microleakage and its sequelae
- To join materials of dissimilar composition

Conditions for optimal adhesion

- Clean bonding surfaces
- Close contact between surfaces
- Large surface area
- Good wetting of adhesive
- Correct protocol for bonding
Advantages of Adhesion Techniques

- Expanded range of clinical treatments
- Conservation of tooth structure
- Reduction in microleakage
- Enhanced retention of restorations
- Reinforcement of tooth structure
- Repair of restorations
- Reduction in dentine hypersensitivity

Adhesion to Tooth Structure: Influencing Factors

- Enamel structure, composition, rod orientation
- Dentine structure and its transition, composition
- Smear layer, pellicle
- ‘Dentine Wetness’
- Polymerisation shrinkage of resin-based polymers
- Properties of the dental material
- Location and size of cavity
- Patient factors (erosion, parafunction, overbite, xerostomia)

What do we expect from a dental adhesive?

- High & consistent bond strength to enamel & dentin
- Quick & easy application
- Consistent product quality (no degradation)
- No postoperative sensitivity
- For universal use (direct + indirect restorations)

Enamel Composition

- 95-98% by weight inorganic component (hydroxyapatite)
- Crystalline structure is fairly constant at different levels
- Minor organic components
- Water (very low percentage)

Enamel Etching

- Untreated enamel is generally smooth and non-retentive and covered in a layer of pellicle
- Cut enamel surface has a ‘smear layer’
- Enamel etching creates a highly micro-retentive surface which is easily wetted by hydrophobic resin-based adhesives
- The adhesives penetrate the etched surface via capillary action and after polymerisation form resin tags which facilitate micromechanical adhesion
- Type I, in which there is predominant dissolution of the prism cores.
- Type II, in which there is predominant dissolution of prism peripheries.
- Type III, in which no prism structure evident.

Enamel: Etched Surface

Type I Pattern

Type II Pattern

Type III Pattern

Enamel Etching

- Generally, use of phosphoric acid concentration between 30-40%, an etching time of not less than 15 seconds - about 10μm of the enamel surface
- washing time of 10 to 20 seconds are recommended to achieve the most receptive enamel surface for bonding.

Factors Influencing Type of Etched Surface

- Type of etchant (organic/ inorganic acid)
- Etchant concentration
- Etching time
- Gel versus liquid etchant
- Rinse time/ method of application (self etching primers)
- Enamel instrumentation after etching
- Tooth type (deciduous/ adult)
- Prismless enamel
- Presence of contaminants
- Status of the enamel (fluorosis, hypoplasia, staining, amelogenesis imperfecta)

- Calcium dissolution and etching depth increase as the concentration of phosphoric acid increases until the concentration reaches 40%; at higher concentrations, a reverse effect is obtained.
- Most commercial enamel etchants have concentration between 30-40%. If less the dicalcium phosphate dihydrate precipitate forming is very difficult to wash off.

- An acid gel generally preferred over a liquid because its application is more controllable.
- Today this enamel-etching technique has proven to be a durable and reliable clinical procedure for routine applications in modern restorative.
Dentine Composition

<table>
<thead>
<tr>
<th>COMPONENTS</th>
<th>PERCENTAGE</th>
</tr>
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<tbody>
<tr>
<td>INORGANIC</td>
<td>~ 72%</td>
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<tr>
<td>Calcium, Phosphorus, CO₃-, Mg²⁺, Na⁺, Cl⁻, Ni, Ru, Pt, K, Si, Ag, Sn, Ti, W, Ru, Va, Zn</td>
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<td>ORGANIC</td>
<td>~ 18%</td>
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<tr>
<td>Collagen (glycine, alanine, proline, hydroxyproline)</td>
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<tr>
<td>Citrate</td>
<td></td>
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<tr>
<td>Lactate</td>
<td></td>
</tr>
<tr>
<td>Resistant Protein</td>
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<tr>
<td>Chondroitin Sulfate</td>
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<tr>
<td>Mucopolysaccharides</td>
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<td>WATER</td>
<td>~ 10%</td>
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</table>

Adhesion to Dentine

Predictable bonding to dentine is difficult to achieve

Problems to overcome include:
- Presence of smear layer
- Mineralised tissue
- Dentine tubular fluid and moisture
- Physico-chemical conditions (temperature, oxygen, atmospheric pressure)
- Outward flow of dentinal fluid via pulpal pressure
- Presence of a collagen matrix (not easy to bond to collagen)
- Dentinal pain- post-op sensitivity

Moisture on Dentine

Sources:
- Oral Humidity
- Triple Syringe
- Dentinal Tubules

The Smear Layer

- A layer of dentine, enamel shavings, organic matter, bacteria, blood products crevicular fluid and saliva which is formed during cavity preparation
- Bond strength to tooth structure ~ 2-3 MPa
- Can be altered or removed because it is not a very stable adhesion interface

Dentine Smear Layer
- Hydroxyapatite crystals
- Collagen fragments
- Blood
- Bacteria
Dentine Hybridisation

- Diffusion is the only mechanism whereby a monomer can pass across into demineralised dentine.
- The most important factor for dentine adhesion under clinical conditions is the permeation of resin into intertubular dentine.
- The chemical reactivity of collagen is quite low because any reactive functional groups (e.g., -COOH, -NH₂) are involved in covalent type bonding between peptides in the collagen fibres.

Hybrid Layer Formation
Resin Impregnated Dentine Layer (RIDL)

- Dentine etching
- Wash and dry surface
- Apply Primer
- Apply Adhesive Resin
- Light/Chemically activated polymerisation

Dentine Permeability

- Intratubular Permeation
- Intertubular Permeation

Hybrid layer
Background

- 1st and 2nd generations - the objective was to obtain a chemical adhesion between the adhesive and the smear layer. Unfortunately, the smear layer is superficially attached to the intact dentin surface, thus very poor results were obtained with these adhesives (Burke and McCaughey, 1995).
- 3rd generation - In the attempt to improve the bond strength of dentin adhesives, primer solutions were included that can alter the smear layer. (Nakabayashi et al., 1992, 1995)

~ Cont.

- 4th generation systems - the smear layer is totally removed by etching with organic acids, which is followed by application of primer and adhesive forming the hybrid layer (Nakabayashi et al., 1992, 1995)
  - basically composed of (1) an acid etching gel that is rinsed off;
  - (2) a solution of primers that are reactive hydrophilic monomers in ethanol, acetone, and/or water;
  - (3) an unfilled or filled fluid bonding agent.

4th Generation Adhesive System

- Etchant
  - Inorganic acid (e.g., 30-40% orthophosphoric, 2.5% nitric)
  - Demineralises enamel surface
  - Dissolves smear layer
  - Demineralises dentine

- Primer
  - Actual adhesion promoter, initiates hybrid layer formation
  - Contains hydrophilic monomers (e.g., HEMA), organic solvent (e.g., acetone or alcohol) and water.
  - Solvents displace water in dentine and allow monomers to permeate the demineralised intertubular dentine, peritubular dentine and the tubules themselves.
  - The hydrophobic end of HEMA allows chemical compatibility with the supralayer of adhesive resin applied. The hydrophilic end of HEMA is compatible with the dentinal moisture.

Adhesive Resin

- Also called bonding resin/dentine adhesive
- Composition:
  - Hydrophilic monomers (e.g., HEMA, TEGDMA)
  - Hydrophobic monomers (e.g., Bis-GMA, UDMA or others)
  - Camphorquinone (light cure)
  - Stabilisers
  - Silanated microfillers (fluoride source/radiopacity/reduction in shrinkage, elasticity-stress relief)

Fifth generation

- Etchant and primer applied as one solution or primer and adhesive resin applied as one solution.
- Create hybrid layer
- Still a lot of debate going on about whether these combination system actually improve the bond strength to tooth structure
- Ex: Exite, Integra Bond, One Step, Optibond SOLO Plus
- **Sixth generation**
  Etchant/primer and adhesive applied as one solution which is not wash off.
  Ex.: Promp L - Pop, One-Up Bond

- Still a lot of debate going on about whether these combination system actually improve the bond strength to tooth structure
Excite®
- Excite is an ethanol-based total etch adhesive
- The one-bottle system simplifies the application

AdheSE®
- AdheSE is a 2-step self etching and light curing dental adhesive

Self etch adhesives
- No separate etching & rinsing necessary
- Faster application
- Simultaneous etching & resin infiltration
- Reduced postoperative sensitivity

Composition of self etching primers
- Acidic monomer
- Crosslinking monomer
- Solvent: Water based
- Photoinitiators Stabilizers

Smear layer
- Dentin surface after cavity preparation
- Smear layer covers the dentin, blocks tubules

Primer application
- Dissolves the smear layer
- Decalcifies underlying dentin
Dentin hybridization

- Dentin decalcification
- Exposed collagen fibrils
- Resin infiltration
- Resin tag formation
- Crosslinked monomers

Advantages of 2-step systems

- Uniform layer thickness
- Complete sealing of dentin
- No postop. sensitivity
- High + consistent bond strength

2-step adhesive systems are more predictable + superior

AdheSE Light Curing

1. Primer
2. Bond

- Self-etch adhesive for direct light curing composites and compomers
- Self-etch adhesive for dual- or self-curing core build-up materials (bonding component must be light cured before)

1. Primer:
- Phosphonic acid ether acrylate
- Hydrolytically stable bisacrylamide
- Water (pH 1.6)
- Initiators and stabilizers

2. Bond:
- Bis-GMA, GDMA
- HEMA
- Highly dispersed silica filler
- Initiators and stabilizers

Additional components

- Activator
  - Helps to chemically polymerise the primer
  - Contains sulfinic acid and a photoinitiator such as camphorquinone
- Catalyst
  - Promotes chemical polymerisation of the adhesive resin
  - Contains a peroxide chemical initiator plus BiS-GMA and HEMA
AdheSE Dual Curing

1. Primer
2. Bond
3. DC Activator

- Adhesive cementation of indirect metal-free (all-ceramic or polymer) restorations
- Adhesive cementation of metal-free posts

AdheSE DC Activator is mixed 1:1 with the Bond

→ AdheSE becomes now Dual Curing

The right side of the new pad has been designed to mix DC Activator with the Bond in a 1:1 ratio.

SBS on different dentin conditions

<table>
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<tr>
<th>Dentin Condition</th>
<th>Dry</th>
<th>Moist Wet</th>
<th>Dentin Condition</th>
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Prompt TM L-Pop TM Self-Etch Adhesive

6th generation adhesive system

1. Press
2. Fold
3A. Press
3B. Spin applicator to mix adhesive

Easier to activate for a more consistent, reliable mix
- New indentation makes it easy to see that material has moved from one chamber to the next
- Allows you to etch, prime and bond in a single step — all in seconds
- Innovative and convenient unit-dose L-Pop delivery
- Cures with any light source — halogen, laser, plasma or LED
GC G-BOND: One Component, One Coat Bonding System for Light-Cured Composites

- G-BOND is a NEW revolutionary 7th Generation (single component) adhesive
- The unique combination of phosphoric acid ester monomer and 4-MET adhesive technology creates superior etch and adhesion to enamel in addition to providing chemical and mechanical seal to dentin – referred to as the Nano Interaction Zone.
- Etch, desensitize, prime and bond for 20 seconds.
- Ideal for bonding light-cured composites, compomers and dual-cured cements and core build-up materials (light-cure mode) to tooth structure.

iBond - 7th generation
- The iBond-revolution: etching, priming, bonding and desensitizing, all in one step.
- iBond has to be added to the All-In-One-Adhesive group.
- All adhesive treatment steps are included in one component.
Choosing an adhesive system

- The clinical situation (e.g., placement of direct or indirect restoration)
- Cavity depth
- Ease of use
- Reliability/performance record

With respect to dental materials and operative techniques – remember the biological principle involved in their clinical application and potential biological effect.

- Follow the usage instructions carefully, no short cut.
- Always aware of the limitation of technique and materials

References

- Acknowledgement
- Tom Berekally lectures and notes (Uni Adelaide-Prosthodontist)
- Ivoclar, GC and 3M ESPE product information
Thank you