INTRODUCTION:

A. Historical Development:

1. Hybrid Cement of Silicate and Polycarboxylate:
   a. **Silicate Cements**: FLUORIDE RELEASE, Good Esthetics

   ![Diagram of Silicate Cements](image)

   - **Silicate Cements**: 
     - **Si, Na, F, Ca, Al, H₂O, H₃PO₄, Al, Zn**, 
     - **Ca²⁺**, **Al³⁺**, **F⁻**, **Si⁺⁴**, **H⁺**, 
     - Glass particle Etched periphery
     - Ca, Al, Na, Zn Phosphates and Fluorides

   b. **Polycarboxylate Cements**: ADHESION, Biocompatibility

   ![Diagram of Polycarboxylate Cements](image)

   - **Polycarboxylate Cements**: 
     - **ZnO**, **H₂O**, **PAA**
     - **HOOC**, **COOH**, **HOOC**
     - **-OOC**
     - **Zn²⁺**, **Zn²⁺**, **COO⁻**, **-OOC**
     - Residual ZnO

   - Zinc polyacrylate gel

2. First Product = ASPA
   a. **Aluminosilicate POWDER** (from Silicate Cement)
   b. **Polyacrylic Acid LIQUID** (from Polycarboxylate Cement)

   ![Diagram of ASPA](image)

   - **Si, Na, F, Ca, Al, H₂O, PAA**, 
   - **H⁺**, **Ca⁺²**, **Al⁺³**, **F⁻**, **Si⁺⁴**, 
   - Glass particle Etched periphery
   - Ca and Al crosslinked polyacrylate gel

   **REACTANTS**  **PRODUCTS**

B. Definitions and Terminology:

1. **Glass Ionomer**: "glass" refers to the glassy ceramic particles and the glassy matrix (non-crystalline) of the set material, while "ionomer" refers to ion-crosslinked polymer.

2. **Polyalkenoic or Polyalkenoate**: refers to polymer chain which incorporates alkenoic monomers such as acrylic acid, tartaric acid, maleic acid, etc.

3. **F-Release**: refers to release of fluoride ions but their is no implication as to the source of the ions-- and they are many possibilities. The confusion for current systems is that if the F does not come from the traditional GI matrix, then some people say that the system is not a "true" GI (but that point is irrelevant).

4. **Multiple-Cure**: refers to multiple curing mechanisms possible with resin-modified systems--the terminology was first introduced in 1992 by 3M for their Vitremer product because it underwent the (1) traditional GI chemical setting reaction, (2) a self-cured polymerization reaction, and a (3) light-cured polymerization reaction.
C. Evolution of Glass Ionomer Products:

1A. Conventional GI (original product appeared in 1972):
   a. Refinements to avoid technique sensitivity (pre-capsulated)
   b. Liquid Modifications: Itaconic Acid, Maleic Acid, Tartaric Acid

1B. Metal-Modified GI (circa 1980):
   a. Admixed Amalgam Alloy Particles: Ag-Sn Additives (MIRACLE MIXTURE)
   b. Reinforcing Fillers: Ag-Pd Additives, TiO₂ (CERMET GI)

2. Resin-Modified GI (circa 1988) -- (RMGI, RM-GIC, Hybrid GI, Light-Cured GI):
   a. Powder/Liquid Hand Mixed Versions
   b. Pre-capsulated Auto-Mixed Versions

3. Pre-reacted Glass Ionomers (circa 1990, 2001) -- (F-PRG, GIOMERS)

4. Compomers (circa 1996) -- (Fluoride Ion-Releasing Composites):
   a. Powder/Liquid Hand Mixed Versions
   b. Pre-capsulated Auto-Mixed Versions

5. A.R.T. Materials (Resin-Reinforced Glass Ionomers)
D. Convergence of compomers and composites:

E. Classification Grid for Glass Ionomers:
STRUCTURE

A. Chemistry:

1. GIC:

   Continuous Phase:
   Acid Functional Polymer Solution = 50 w/o AA-MAA-IA-TA polymer + 50 w/o water

   Dispersed Phase:
   (Finely ground F-Al-Si-Glass) (Higher Al/Si ratio than silicate cem)
   29.0 w/o SiO₂
   34.2 w/o CaF₂
   16.6 w/o Al₂O₃
   7.3 w/o AlF₃
   9.9 w/o AlPO₄
   3.0 w/o NaF

2. RMGI (GIC + VLC Monomers):

   Continuous Phase:
   Same as GIC but VLC chemistry added
   LC Monomer, Oligomer, and/or Polymer

   Dispersed Phase:
   Same as GIC

B. Setting Reactions: (2 Rx's for monomer; 2-step Rx for cement; Si matrix Rx)

1. GIC:
   (Exothermic; amorphous matrix)
   Reaction occurs in stages:
   Mixing: initial contact of L and P
   Working: ions from powder by dissolution
   Initial Setting: Ca⁺² ion xlinked polymer gel
   Final Setting: Al⁺³ ion xlinked polymer gel
   Al⁺³ ions replace Ca⁺² ions over 1-3 days

2. RMGI:
   (Monomer/oligomer reactive groups)
   (Self-cured; Light-cured; Dual-cured)
   Reaction occurs in stages:
   Mixing: initial contact of L and P
   Working: ions from powder by dissolution
   Initial Setting: Ca⁺² ion xlinked polymer gel
   Final Setting: Al⁺³ ion xlinked polymer gel
   Al⁺³ ions replace Ca⁺² ions over 1-3 days

C. Manipulation and Technique Requirements:

1. GIC:
   (Reaction Control: chilled components)
   Cavity Preparation:
   Isolate preparation
   Pre-clean E+D with pumice/water
   Debride E+D with citric, PAA, EDTA
   Completely dry cavity preparation
   Dycal for deep preparations
   Powder and Liquid Mixing: (Manual)
   Mix in small area, 2-3 increments
   Completely mix <45 s
   Use P/L = 1.0 (cem), 3.0 (rest, base)
   Placement and Setting:
   Avoid water contact
   Do not use after lose gloss
   Protect surface with varnish for 24 h
   Finishing and Polishing: (Restorations):
   Do not attempt for 24 hrs
   Procedures similar to composites
   Do not DESICCATE

2. RMGI:
   (Reaction Control: VLC or auto-cure)
   Cavity Preparation: Same but use primers
   Mixing: Same or precapusulated
   Placement and Setting: Same
   Finishing and Polishing: Immediate
PROPERTIES

A. Depend on Applications: (* = major)
1.* Cement (ADA Type I)
2.* Liner / Base
3.* Filling Material - Class III, V, II (ADA Type II)
   Root Caries
4.* Core for Crown
   Foundations
5. (Tunnel Preparations)
6. (Sandwich Prep)
7. Retrograde Filling Material
8. (P/F Sealants)

B. Examples of GI Properties (Conventional Materials):
1. Type I: Permanent Cementation (Conventional Materials)
   a. Low P/L Ratio  = 1.00-1.25
   b. Moderate Strength = 12,500 psi CS (900 psi DTS)
   c. High Solubility  = 1.25%
2. Type II: Permanent Filling Material (Conventional Materials)
   a. High P/L Ratio  = 2.00-3.00
   b. High Strength  = >20,000 psi CS (400 psi DTS)
   c. Low Solubility  = 0.4%

C. Clinical Properties:
1. Strength:
   a. Conventional cement is strongly hydrophilic during first hour
   b. LC versions are about 2/3rds set immediately
2. Adhesion: P/L ratio governs balance bonding vs solubility
   a. Conventional cement chelates enamel and dentin
   b. Base metal alloys (or zinc or tin plated alloys) can be chelated
   c. Better bonding if surfaces acid etched and treated with primers
3. Biocompatibility:
   a. Conventional cement: pulpal irritation from initially high acidity (pH <=3)
      LC Version: Less acidity
   b. Good biocompatibility from set materials
4. Fluoride Release:
   a. Decreases dramatically after 24-72 hrs
   b. Decreasing release for first month; Low release for 1-6 months
   c. No clinical studies to demonstrate that imp product differences
FLUORIDE RE-CHARGING OF GLASS Ionomers

A. Introduction:
   1. Fluoride release exponentially decays to low levels (0.5-2.0 ppm typically)
   2. Re-charging = F absorption from other sources into GI materials for re-release later
   3. Re-charging -- occurs when F can readily diffuse from high-to-low concentrations

B. Re-charging strategies:
   1. Use daily fluoride rinses to provide F source for re-charging
   2. Use F toothpastes for re-charging
   3. Use topical fluorides for re-charging

C. Properties:
   1. High F concentration produces immediate increase in F levels of restorations
   2. Once re-charging source is removed, re-release immediately begins
   3. High F release occurs for short period of time and quickly goes back to original level
      (Typically release to normal levels in 1-2 days)
   4. Value of F re-charging has never been demonstrated clinically
COMMERCIAL EXAMPLES

A. Conventional GIC:
1. ASPA (Caulk/Dentsply)   -- No longer available
2. Chembond (Caulk/Dentsply)   -- No longer available
3. G-C Fuji I (GC Chemical)   -- Cement
4. G-C Dentin Cement (GC Chemical)   -- Liner
5. Ketac-Cem (3M-ESPE)   -- Cements
6. Ketac-Bond (3M-ESPE)   -- Liner/Base
7. Zionomer Liner (Denmat)   -- Liner
8. Ionosit (DMG)   -- Base / Liner
9. Zionomer Cement (Denmat)   -- Cements
10. Ketac-Fil and Ketac-Molar (3M-ESPE)   -- Filling Matl
11. Core Zionomer (Denmat)   -- Core
12. Chem-Flex (Dentsply-DeTrey)   -- Filling Mtl
13. Vitrebond (3M-ESPE)   -- Liner/Base
14. Vivaglass Liner (Ivoclar/Vivadent)   -- Liner/Base
15. Meron AC (VOCO)   -- Cement
16. Alpha-Fill (DMG-Hamburg)   -- Filling Mtl

B. Metal-Modified GI Filling Material (CERMETS):
1. Ketac-Silver (3M-ESPE)   -- Filling Mtls, Cores
2. Miracle Mix (GC Chemical)   -- Filling Mtls, Cores
3. Fuji II and Lumi-Alloy (GC Chemical)   -- Filling Mtls, Cores
4. Chelon-Silver (3M-ESPE)   -- Cores
5. Argion Molar and IonoFil Molar (VOCO)   -- Filling Mtl
6. Alpha-Silver (DMG-Hamburg)   -- Cores, Primary Teeth

C. RESIN-MODIFIED GLASS IONOMERS (RMGI):
1. Light Cured Zionomer (Denmat)   -- Liner
2. Light Cured GC Dentin Cement (GC)   -- Liner
3. Rely-X ARC (Vitremer) (3M-ESPE)   -- Filling Inlays, Crowns, Bridges
4. Fuji Duet (GC) and now Fuji Plus   -- Filling Inlays, Crowns, Bridges
5. Advance (LD Caulk)   -- Filling Mtl
6. Principle (LD Caulk)   -- Filling Mtl, Core Build-Ups
7. Fuji II LC (GC America)   -- Filling Mtl
8. Fuji II LC Core (GC)   -- Core
9. Geristore (Den-Mat Corporation)   -- Filling Mtl
10. Variglass VLC (LD Caulk)   -- Filling Mtl
11. Vitremer (3M-ESPE)   -- Filling Mtl, Core Build-Ups
12. Photac-Fil (3m-ESPE)   -- Filling Mtl
13. FujiCem (GC America)   -- Cement

D. GIOMERS (GIC Modified Composites):
1. Reactmer (Shofu)   -- Filling Mtl

D. COMPOMERS (Resin-Reinforced) GIC Filling Materials:
1. Dyract, AP, Flow (LD Caulk)   -- Filling Mtl
2. F2000 (3M-ESPE)   -- Filling Mtl
3. Hytac (3M-ESPE)   -- Filling Mtl
4. Elan (Kerr)   -- Filling Mtl
5. PrimaFlow S and Luxat Compomer Plus (DMG)   -- Filling Mtl
6. Compoglass F (Ivoclar/Vivadent)   -- Filling Mtl
7. Principle (Dentsply)   -- Cement
8. PermaCem (DMG-Hamburg)   -- Cement
### IMAGES OF COMMERCIAL PRODUCTS:

<table>
<thead>
<tr>
<th>Product Name</th>
<th>Usage and Applications</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>ESPE Ketac Cem (GIC)</strong></td>
<td>-- Crown and Bridge Final Cementation</td>
</tr>
<tr>
<td><strong>GC MiracI Mix (Metal-Modified GIC)</strong></td>
<td>-- Cores</td>
</tr>
<tr>
<td><strong>3M Rely-X ARC (RMGI)</strong></td>
<td>-- Crown and Bridge Final Cementation</td>
</tr>
<tr>
<td><strong>Dentsply Dyract AP (Compomer Restorative)</strong></td>
<td>-- Class I, II, III, IV, V</td>
</tr>
<tr>
<td><strong>Shofu Reactmer (GIOMER)</strong></td>
<td>-- Restorations</td>
</tr>
<tr>
<td><strong>ESPE Hytac (Compomer Restorative)</strong></td>
<td>-- III, V, Primary Teeth, Base or Liner, Cervical Erosions/Abrasions</td>
</tr>
</tbody>
</table>
A. Introduction: (http://www.whocolab.odont.lu.se/expl/artintrod.html, Jo Frencken)
   1. Historical Development (circa 1989)
      a. ART materials designed as temporary restorations for 3rd world countries
      b. Goals = caries control, replacing missing tooth structure, function
      c. First tested in central African countries
      d. Currently used in SE Asia, India, and Africa --- but also in 1st and 2nd world
   2. Definition: ART = approach includes both prevention and treatment of dental caries. ART procedure is based on excavating and removing caries using hand instruments only and then restoring the tooth with an adhesive filling material (glass-ionomer).

3. Excellent success as a temporary restorative material
   a. Expanded applications -- replacement for ZOE and composite temporaries
   b. Application as short term restorations for primary teeth
   c. Use as standard primary tooth restoration as alternative to composite

B. Composition:
   1. Variations: GIC or RMGI (normal FAS glass or higher-than-normal-F glass)
   3. Varying consistencies: flowable, normal, packable

C. Properties:
   1. Generally no different than GI or RMGI -- not designed as permanent restoration
   2. Clinically acceptable as long as not very high stress
   3. No clinical evidence of efficacy in caries reduction -- only in caries control

D. Commercial Examples:
   1. Fuji IX (GC)
MULTIPLE CHOICE STUDY QUESTIONS FOR GLASS Ionomers:

What is the POWDER component in GICs (traditional glass ionomers)?
   a. Zinc oxide
   b. Silica
   c. Lithium aluminosilicate
   d. Aluminosilicate glass
   e. Alumina

What is the LIQUID component in GICs (traditional glass ionomers)?
   a. Polyacrylic acid
   b. Polymethacrylic acid
   c. Polymethyl methacrylate
   d. BIS-GMA polymer
   e. Phosphoric acid

Which one of the following has NOT been used as part of the GIC liquid composition?
   a. Acrylic acid
   b. Tartaric acid
   c. Maleic acid
   d. Citric acid
   e. Itaconic acid

Which one of the following has NOT been used to modify the GIC powder composition?
   a. Aluminosilicate glass
   b. Amalgam alloy particles
   c. Ag-Pd particles
   d. TiO₂ particles
   e. Alumina

How is F ion released from a cured GIC?
   a. Intraoral fluids dissolve it out of the glass particles
   b. CaF₂ salts dissolve and release the fluoride
   c. Fluoride ions in the matrix are released
   d. Sodium fluoride salts release the fluoride
   e. Acid in the oral environment dissolves the residual glass

What causes the initial setting reaction in a GIC?
   a. Release of fluoride ions from the aluminosilicate glass
   b. Crosslinking of polyacrylic acid polymer chains by aluminum ions
   c. Loss of water from the matrix phase
   d. Crosslinking of polyacrylic acid polymer chains by calcium ions
   e. Crystallization of the dissolved salts from the powder particles

What causes the final setting reaction of in a GIC?
   a. Release of fluoride ions from the aluminosilicate glass
   b. Crosslinking of polyacrylic acid polymer chains by calcium ions
   c. Crosslinking of polyacrylic acid polymer chains by aluminum ions
   d. Loss of water from the matrix phase
   e. Crystallization of the dissolved salts from the powder particles

What produces chemical adhesion to tooth structure for a GIC?
   a. Chelation of polyacrylic acid with calcium ions
   b. Chelation of polyacrylic acid with aluminum ions
   c. Reactions of the fluoride ions with hydroxyapatite
   d. Precipitation of calcium phosphate from the dissolved powder
   e. Precipitation of calcium oxide
Contaminated or overly wet tooth surfaces interfere with the:
   a. Adaptation of the cement for chemical bonding
   b. Initial setting reaction
   c. Final setting reaction
   d. Release of fluoride ion
   e. Color of the final cement

Which one of the following is key during the first 24 hours for conventional GIs?
   a. Protection against contact with moisture
   b. Protection against intraoral acid contact
   c. Protection from ultraviolet radiation
   d. Protection against salivary protein contact
   e. Protection against fluoride release

What is the time of maximum fluoride release RATE out of the cement?
   a. During the first few minutes
   b. During the first 24 hours
   c. During the first month
   d. During the first year
   e. After the first year

Which one of the following is NOT a major use for glass ionomers?
   a. Class V filling material
   b. Liner
   c. Base
   d. Cement
   e. Tunnel preparations

Which application takes best advantage of chemical adhesion of glass ionomers?
   a. Class V filling material
   b. Liner
   c. Base
   d. Cement
   e. Tunnel preparations

Which application takes best advantage of the fluoride release of glass ionomers?
   a. Liner
   b. Base
   c. Root caries restorations
   d. Retrograde filling material
   e. Core

Which one of the following has the most influence on the final mechanical and chemical properties of conventional GI cements?
   a. Fluoride content of the aluminosilicate glass
   b. Mixing technique
   c. Powder-to-liquid ratio
   d. Acidity of the mixture
   e. Reaction exotherm

What is the mechanism of reinforcement of metal-modified GIs?
   a. Addition of stronger powder particles
   b. Addition of particles which can be chelated by matrix
   c. Addition of particles which can dissolve and affect reaction
   d. Addition of particle that accelerate fluoride release
   e. Addition of insoluble particles
What is the major difference between chemically-cured and light-cured (LC) GIs?
- a. LC produces second matrix
- b. LC version has no acid-base reaction
- c. LC versions accelerate release of F from aluminosilicate glass
- d. LC eliminates all moisture sensitivity of material
- e. LC version increases adhesion to tooth structure

Which one of the following is not part of a "multiple-curing" GI system?
- a. Ca++ ion crosslinking of acid-functional polymer chains
- b. Al+++ ion replacement of Ca++ crosslinking
- c. Visible light polymerization of matrix monomers into polymer
- d. Chemical curing of matrix monomers into polymer
- e. F ion crosslinking of polymer chains

Which one of the following materials is a traditional glass ionomer cement?
- a. Vitremer cement
- b. Fuji II
- c. Advance
- d. Dyract
- e. Kétac-Cem

What is the term used for glass ionomers that are very similar to composites?
- a. Hybrid ionomers
- b. Compomers
- c. Hybrid composites
- d. Giomers
- e. Glass ionomer modified composites

ART is the acronym for which of the following?
- a. Advanced Resistance Technique
- b. Atraumatic Restorative Technique
- c. Advanced Restoration Therapy
- d. Assisted Re-Enameling Technology
- e. Archive of Restoration Technologies

What is the primary goal of ART?
- a. Prevention and treatment of dental caries with minimal instrumentaion
- b. Delivery of F from restorations for patients at high risk to dental caries
- c. Relief of patient pain
- d. Alternative to dental amalgam restorations
- e. Inexpensive dentistry

Which of the following re-charging sources is the most effective?
- a. Topical fluoride treatments
- b. Daily fluoride mouth rinses
- c. Fluoride-containing toothpastes
- d. Ice tea
- e. Fluoride supplements

How long does re-charging of glass ionomer materials effect F-release?
- a. 1-2 minutes
- b. 1-2 days
- c. 1-2 weeks
- d. 1-2 months
- e. 1-2 years