Restorative Composite Resins

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Overview

- Direct restoratives
  - – composition
  - – classification
  - – performance factors
- Flowable
- Packables

Composite

- Material with two or more distinct substances
  - metals, ceramics or polymers
- Dental resin composite
  - soft organic-resin matrix
    - polymer
  - hard, inorganic-filler particles
    - ceramic
- Most frequently used
  - esthetic-restorative material

Leinfelder 1993

History

- 1871 – silicates
  - alumina-silica glass & phosphoric acid
  - very soluble
  - poor mechanical properties
- 1948 - acrylic resins
  - polymethylmethacrylate
  - high polymerization shrinkage

Rueggeberg J Prosthet Dent 2002

History
(cont.)

- 1962 – Bis-GMA
  - stronger resin
- 1969 – filled composite resin
  - improved mechanical properties
  - less shrinkage
  - paste/paste system
- 1970's – acid etching and microfills
- 1980's – light curing and hybrids
- 1990's – flowables and packables
- 2000's – nanofills

Rueggeberg J Prosthet Dent 2002

Indications

- Anterior restorations
- Posterior restorations
  - preventive resin
  - conservative class 1 or 2

Contraindications

- Large posterior restorations
- Bruxism
- Poor isolation

Advantages

- Esthetics
- Conservation of tooth structure
- Adhesion to tooth structure
- Low thermal conductivity

Disadvantages

- Technique sensitivity
- Polymerization shrinkage
  - marginal leakage
  - secondary caries
  - postoperative sensitivity
- Decreased wear resistance

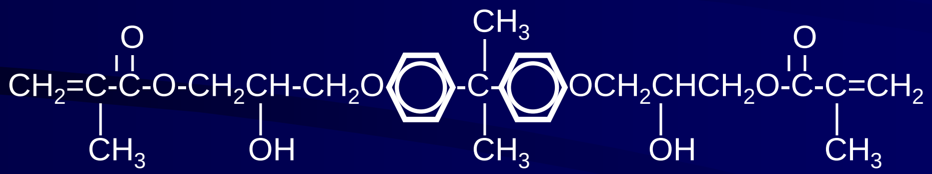
Composition

- Resin matrix
  - monomer
  - initiator
  - inhibitors
  - pigments
- Inorganic filler
  - glass
  - quartz
  - colloidal silica
- Coupling Agent

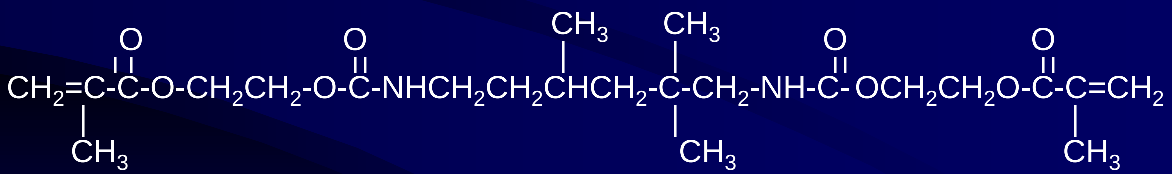
Phillip's Science of Dental Materials 2003

Monomers

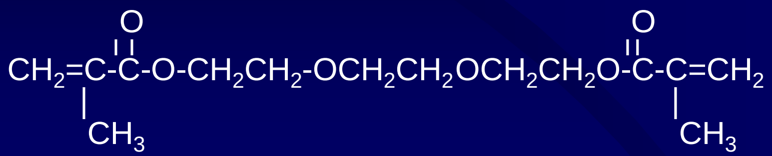
- Binds filler particles together
- Provides “workability”
- Typical monomers
  - Bisphenol A glycidyl methacrylate (Bis-GMA)



  - Urethane dimethacrylate (UEDMA)

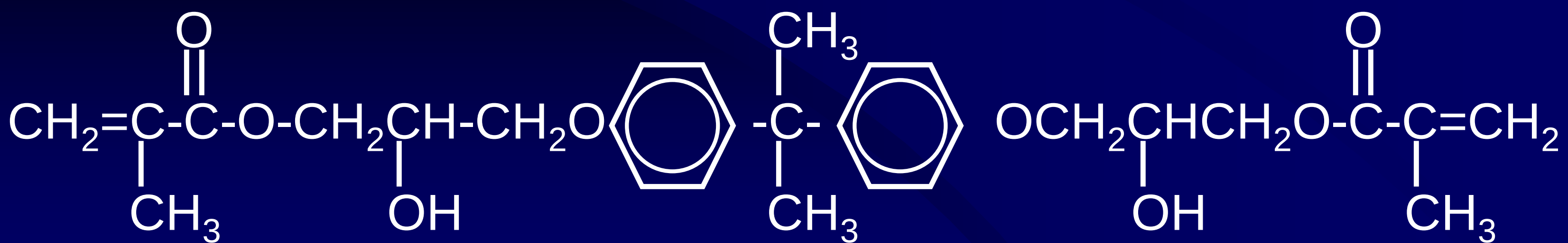


  - Triethylene glycol dimethacrylate (TEGMA)



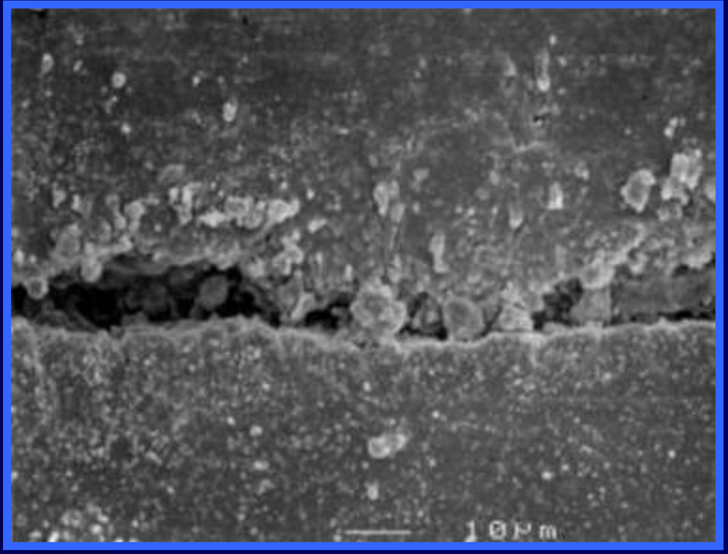
Monomers

- Bis-GMA
  - extremely viscous
    - large benzene rings
  - lowered by adding TEGDMA
    - freely movable
    - increases polymer conversion
    - increases crosslinking
    - increases shrinkage



Monomers

- Shrinkage
  - 2 – 7 %
  - marginal gap formation



Filler Particles

- Crystalline quartz
  - larger particles
  - not polishable
- Silica glass
  - barium
  - strontium
  - lithium
  - pyrolytic
    - sub-micron

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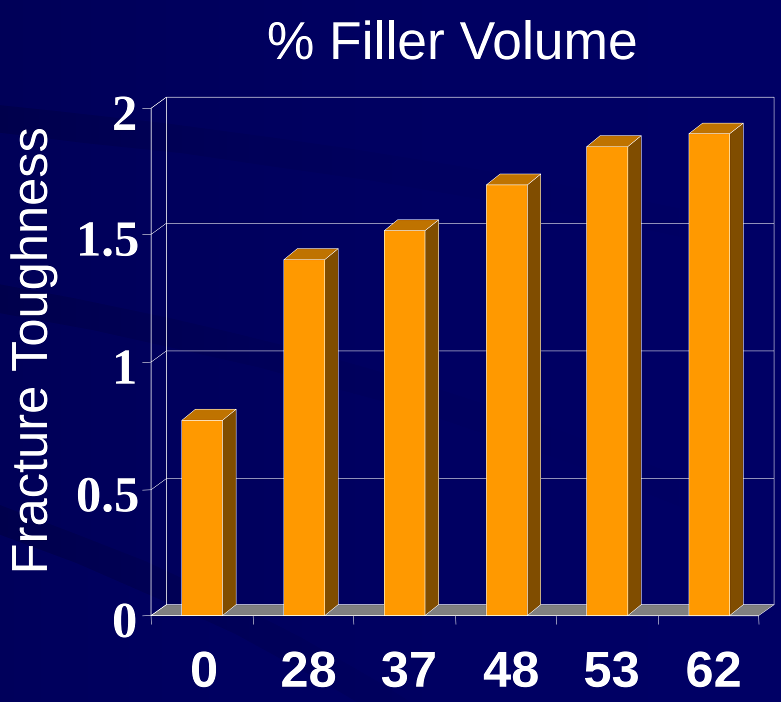
Filler Particles

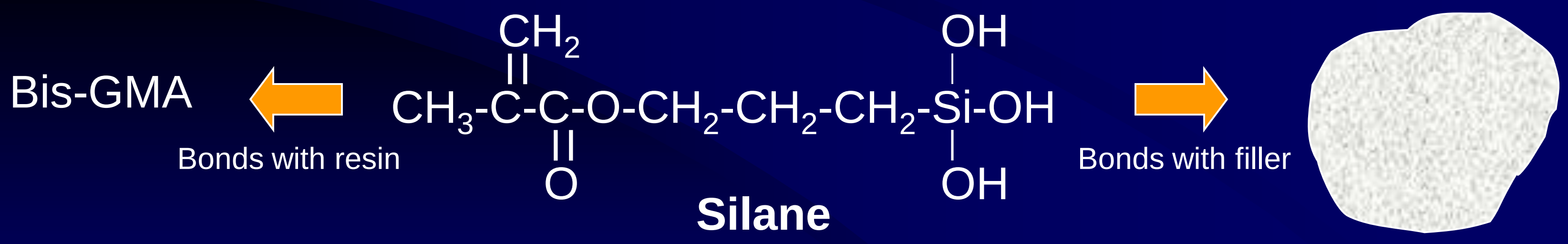
- Increase fillers, increase mechanical properties
  - strength
  - abrasion resistance
  - esthetics
  - handling
- 50 to 86 % by weight
- 35 to 71% by volume



Ferracane J Dent Res 1995

Coupling Agent

- Chemical bond
  - filler particle - resin matrix
    - transfers stresses
- Organosilane (bifunctional molecule)
  - siloxane end bonds to hydroxyl groups on filler
  - methacrylate end polymerizes with resin



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Inhibitors

- Prevents spontaneous polymer formation
  - heat
  - light
- Extends shelf life
- Butylated Hydroxytoluene

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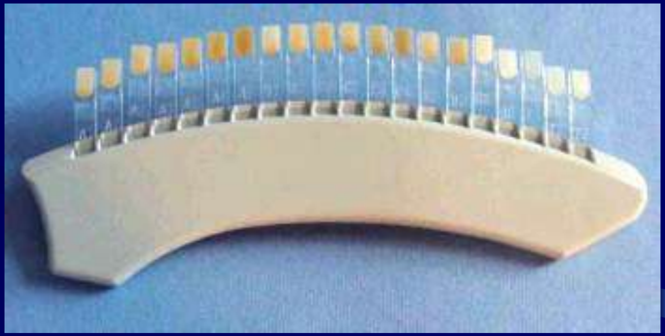
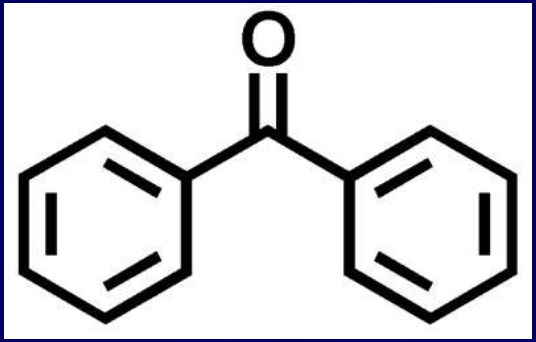
Pigments and UV Absorbers

- Pigments
  - metal oxides
    - provide shading and opacity
    - titanium and aluminum oxides
- UV absorbers
  - prevent discoloration
  - acts like a “sunscreen”
    - Benzophenone





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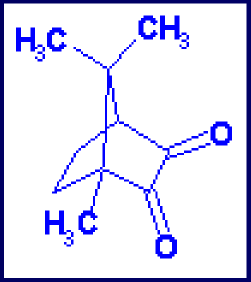
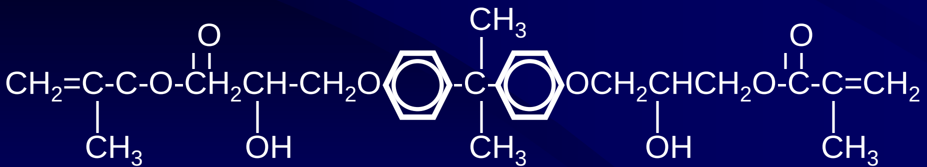
Visible-Light Activation

- Camphorquinone
  - most common photoinitiator
    - absorbs blue light
      - 468 nm range
- Initiator reacts with amine activator
- Forms free radicals
- Initiates addition polymerization



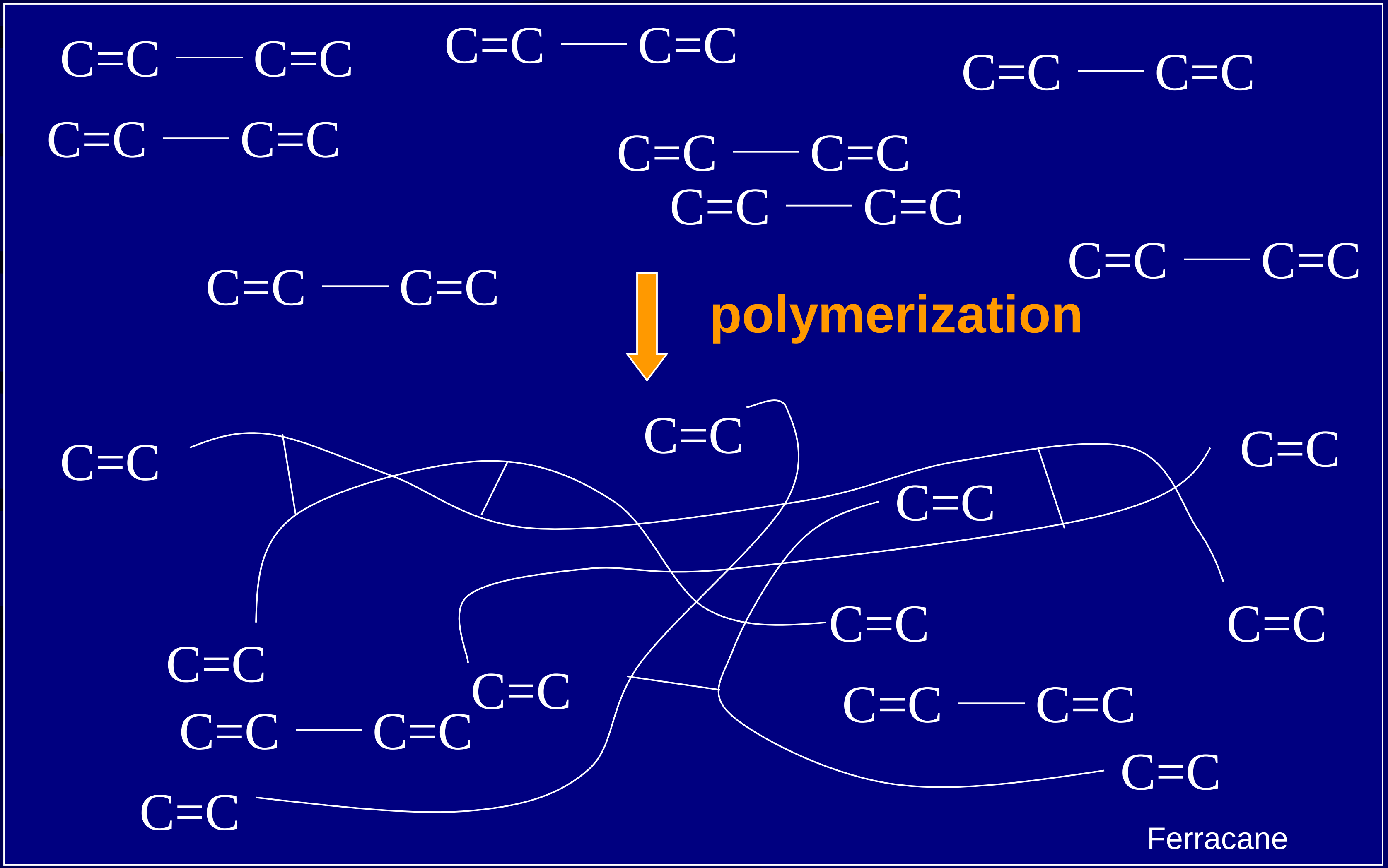


Bis-GMA

Polymerization

1. Initiation
   - production of reactive free radicals
     - typically with light for restorative materials
2. Propagation
   - hundreds of monomer units
   - polymer network
   - 50 – 60% degree of conversion
3. Termination

Craig Restorative Dental Materials 2002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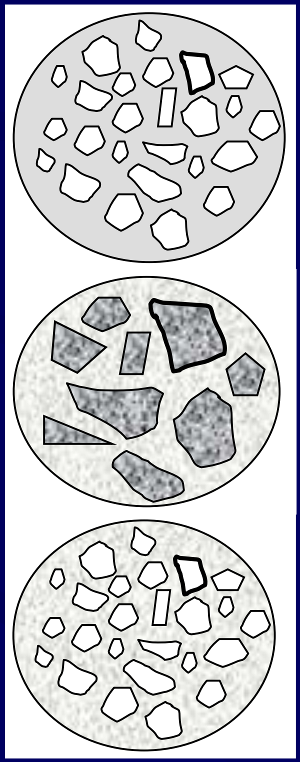
Ferracane

Classification System

- Historical
- Chronological
- Based on particle size
  - traditional
  - microfilled
  - small particle
  - hybrid



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Traditional (Macrofilled)

- Developed in the 1970s
- Filler: Crystalline quartz
  - produced by grinding or milling
  - large - 8 to 12 micron
- Difficult to polish
  - large particles prone to pluck
- Poor wear resistance
- Easy Fracture
- Examples: Adaptic, Concise
- Suitable for Class 3, 4 and 5

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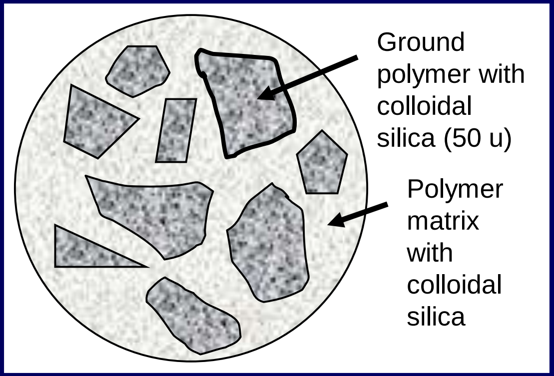
Microfills

- Better esthetics and polishability
- Tiny particles
  - 0.04 micron colloidal silica
  - increases viscosity
- To increase filler loading
  - filler added to resin
  - heat cured
  - ground to large particles
  - remixed with more resin and filler



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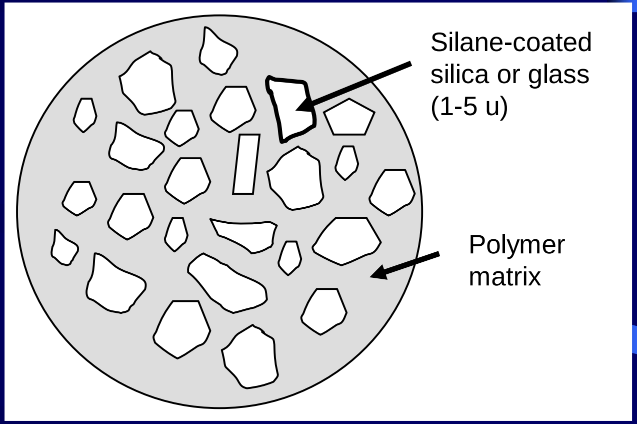
Microfills

- Lower filler content
  - inferior properties
    - increased fracture potential
    - lacks coupling agent
    - lacks radiopacity
- Linear clinical wear pattern
- Suitable for Class 3, 5
  - exceptions with reinforced microfills
    - Class 1 or 2

Small Particle

- 1 - 5 micron heavy-metal glasses
- Fracture resistant
- Polishable to semi-gloss
- Suitable for Class 1 to 5
- Example: Prisma-Fil



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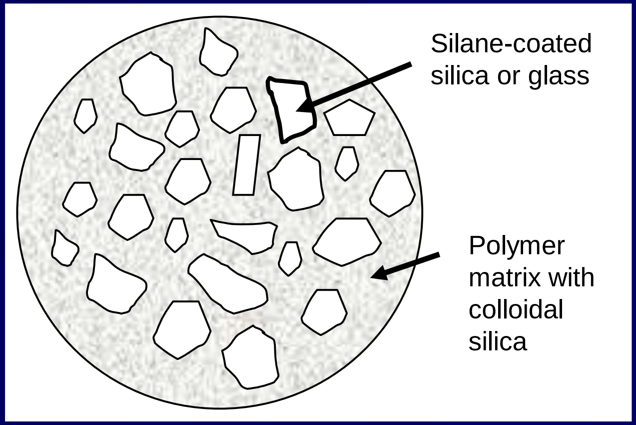
Hybrids

- Popular as “all-purpose”
  - microhybrids, microfilled hybrids
- 0.6 to 1 micron average particle size
  - distribution of particle sizes
    - maximizes filler loading
  - microfills added
    - improve handling
    - reduce stickiness



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Hybrids

- Strong
- Good esthetics
  - polishable
- Suitable
  - Class 1 to 5
- Multiple available


Table of Properties

Property	Traditional	Microfilled	Small Particle	Hybrid
Compressive strength (MPa)	250-300	250-300	350-400	300-350
Tensile strength (MPa)	50-65	30-50	75-90	70-90
Elastic Modulus (GPa)	8-15	3-6	15-20	7-12
Coefficient of Thermal Expansion (10^{-6}/ºC)	25-35	50-60	19-26	30-40
Knoop Hardness	55	5-30	50-60	50-60

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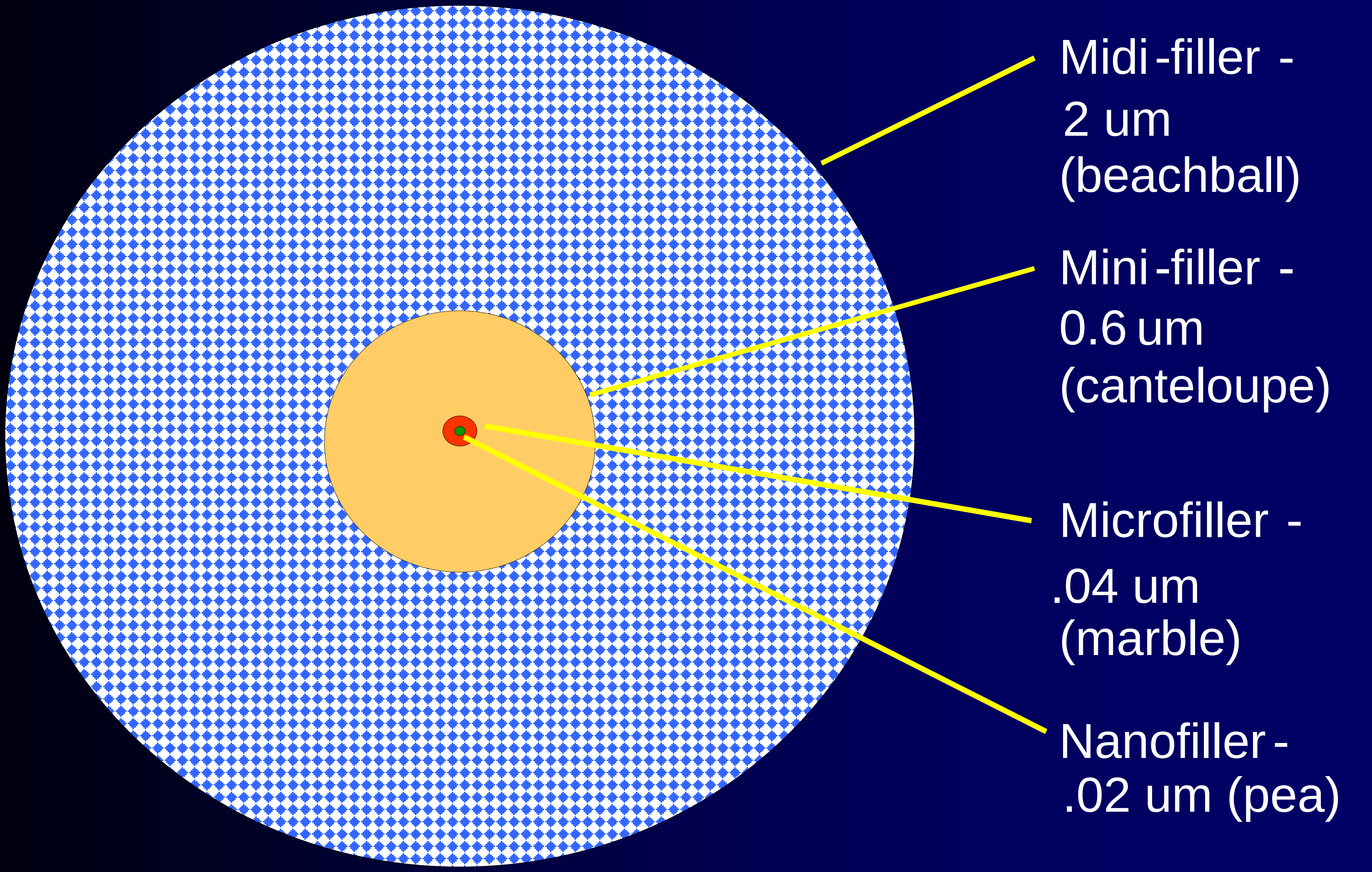
Newer Classification System

- Based on particle size
  - megafill
    - 0.5 - 2 millimeters
  - macrofill
    - 10 - 100 microns
  - midifill
    - 1 - 10 microns
  - minifill
    - 0.1 - 1 microns
  - microfill
    - 0.01 - 0.1 microns
  - nanofill
    - 0.005-0.01 microns
- Most new systems
  - minifillers
- Newest trend
  - nanofillers

Bayne JADA 1994



Relative Particle Sizes

(not to scale)

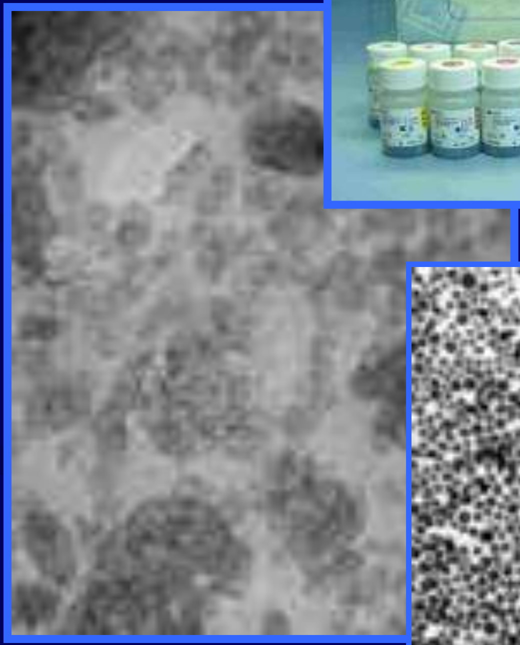
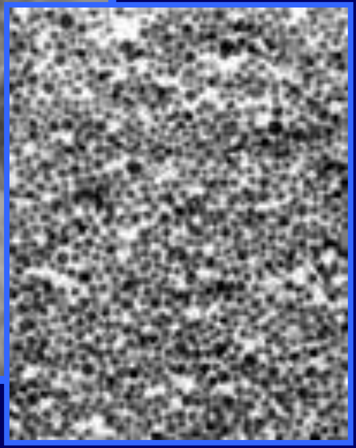
Nanofill vs. Nanohybrid

- Nanofills
  - nanometer-sized particles throughout matrix
- Nanohybrids
  - nanometer-sized particles combined with more conventional filler technology

Swift J Esthet Restor Dent 2005

Nanofilled Composite

- Filtek Supreme (3M ESPE)
- Filler particles
  - – filled: 78% wgt
  - – nanomers
    - 0.02 – 0.07 microns
  - – nanocluster
    - act as single unit
      - – 0.6 – 1.4 microns

Performance Factors

- Material factors
  - biocompatibility
  - polymerization shrinkage
  - wear resistance
  - polish mechanisms
  - placement types
  - mechanical & physical properties

Biocompatibility

- Tolerated by pulp
  - with good seal
- Rare allergic reactions
  - HEMA
- Cytotoxicity
  - short lived
    - not a chronic source
- Degree of cure important
  - decrease free monomer

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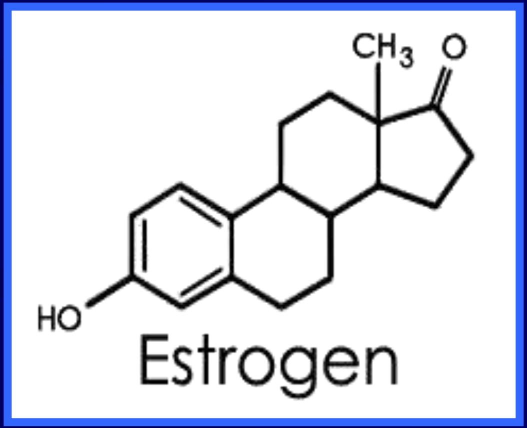
Systemic

- Estrogenic effects seen in cell cultures
  - impurities in Bis-GMA-based resins
    - Bis-phenol A in sealants
      - Journal Olea EHP 1996
  - however, insignificant short-term risk
    - literature review
      - Soderholm JADA 1999



Polymerization Shrinkage

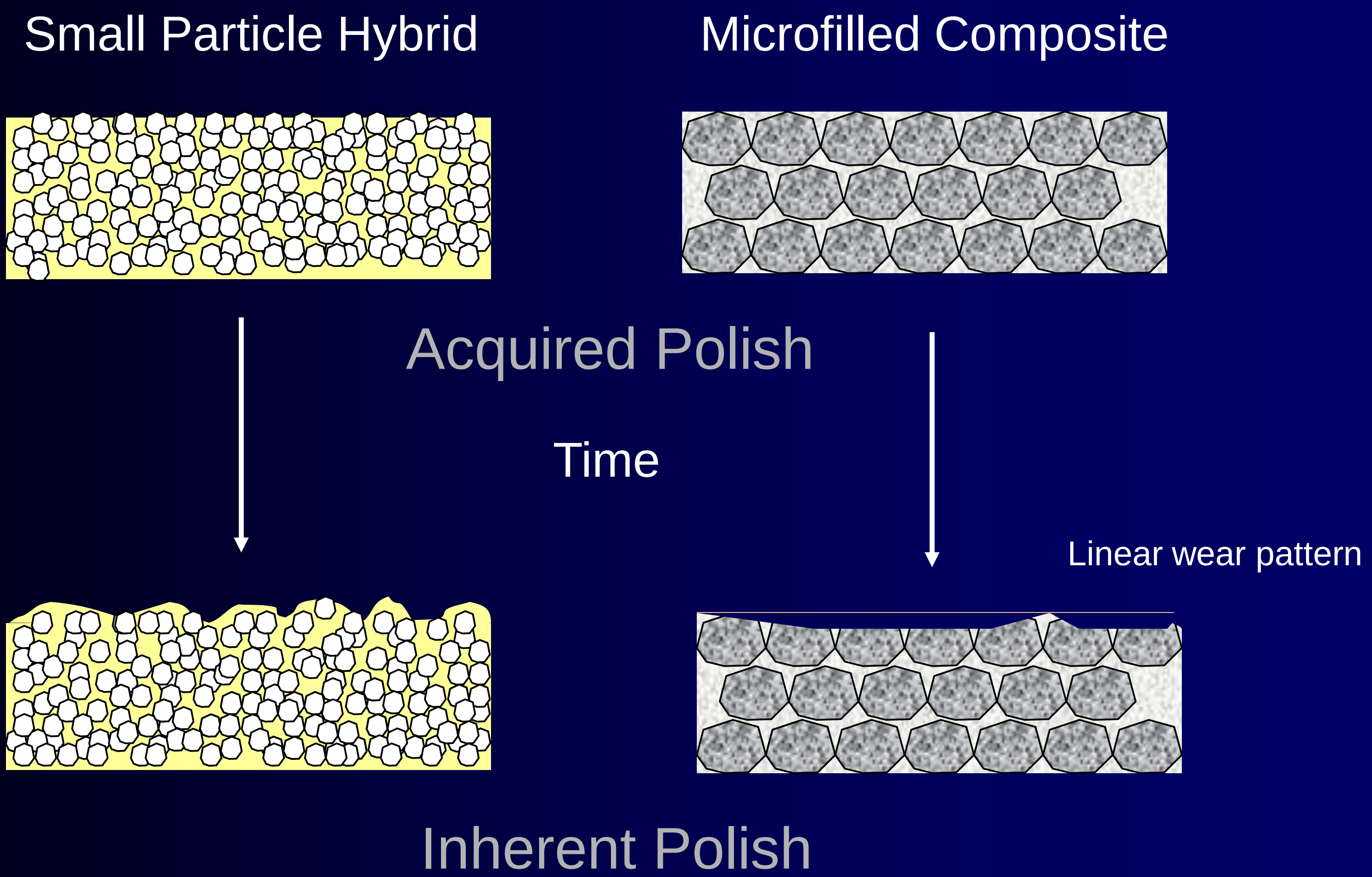
- Significant role in restoration failure
  - gap formation
    - secondary caries formation
    - marginal leakage
    - post-operative sensitivity
- Counteract
  - lower shrinkage composites
  - incremental placement

Polish Mechanisms

- Acquired polish
  - clinician induced
- Inherent polish
  - ultimate surface
- Microfills
  - high acquired, high inherent
    - similar resin matrix and fillers wear more evenly
- Hybrids
  - high acquired, acceptable inherent

Adept Report 1992

Polish Mechanisms



Adept Report 1992

Placement Types

Composite Brands

- Shaded
  - 4 Seasons (Ivoclar Vivadent)
  - Esthet-X (Dentsply)
  - Filtek Supreme (3M ESPE)
  - Point 4 (Kerr)
  - Venus (Heraeus Kulzer)
  - Renamel (Cosmedent)
  - Gradia Direct (GC)
- Anatomic
  - 4 Seasons (Ivoclar Vivadent)
  - Vitalescence (Ultradent)
  - Miris (Coltene/Whaledent)

Composite Selection

- Anterior/stress (Class 4)
  - hybrid
    - mini- or midi-fill
  - hybrid/microfill veneer combo

- Anterior/non-stress (Class 3 or 5)
  - hybrid
    - mini-fill
  - microfill

Composite Selection

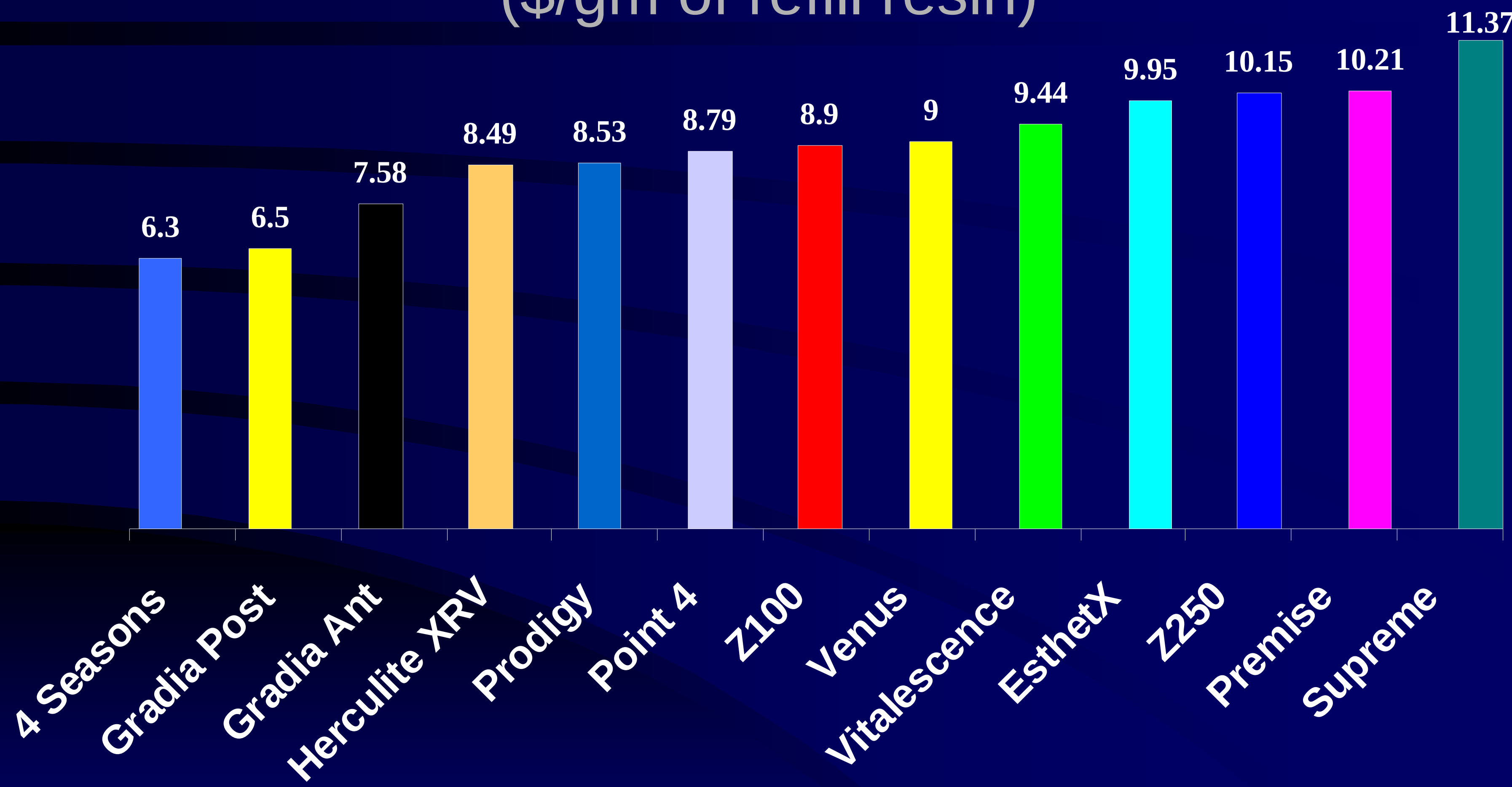
- Posterior
  - hybrid
    - mini- or midi-fill
  - reinforced microfill

Selecting a Brand

- Contents of kit
  - shades
  - bonding agent
  - unit-dose compules vs syringes
- Indications
  - anterior, posterior, both?
- Cost of kit
  - refills

Government Price

($/gm of refill resin)

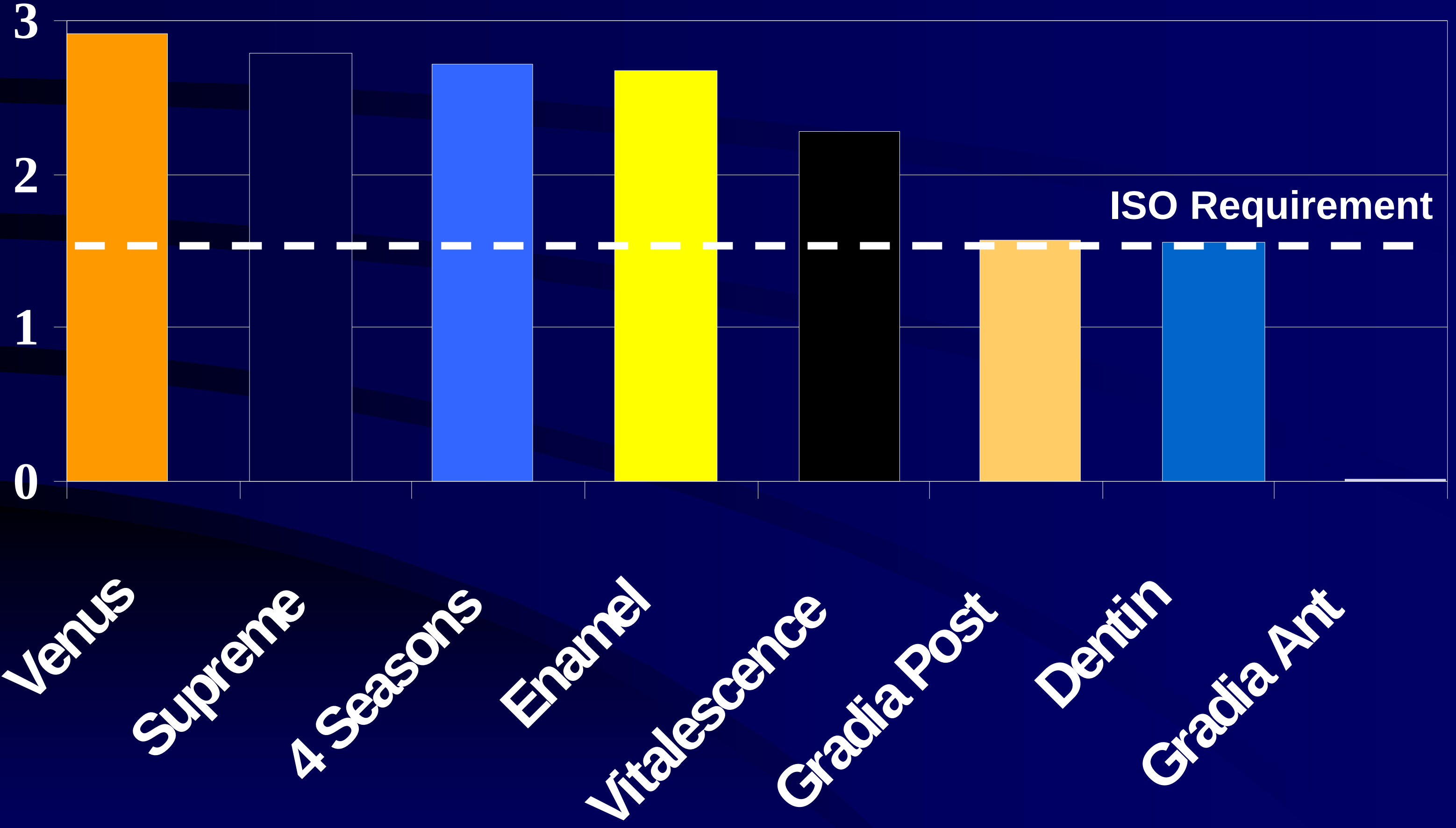


Prices current as of Jan 05

Selecting a Brand

- Results of lab and clinical studies
- Compositional characteristics
  - % filler content
  - average filler particle size

Radiopacity
(mm of aluminum)

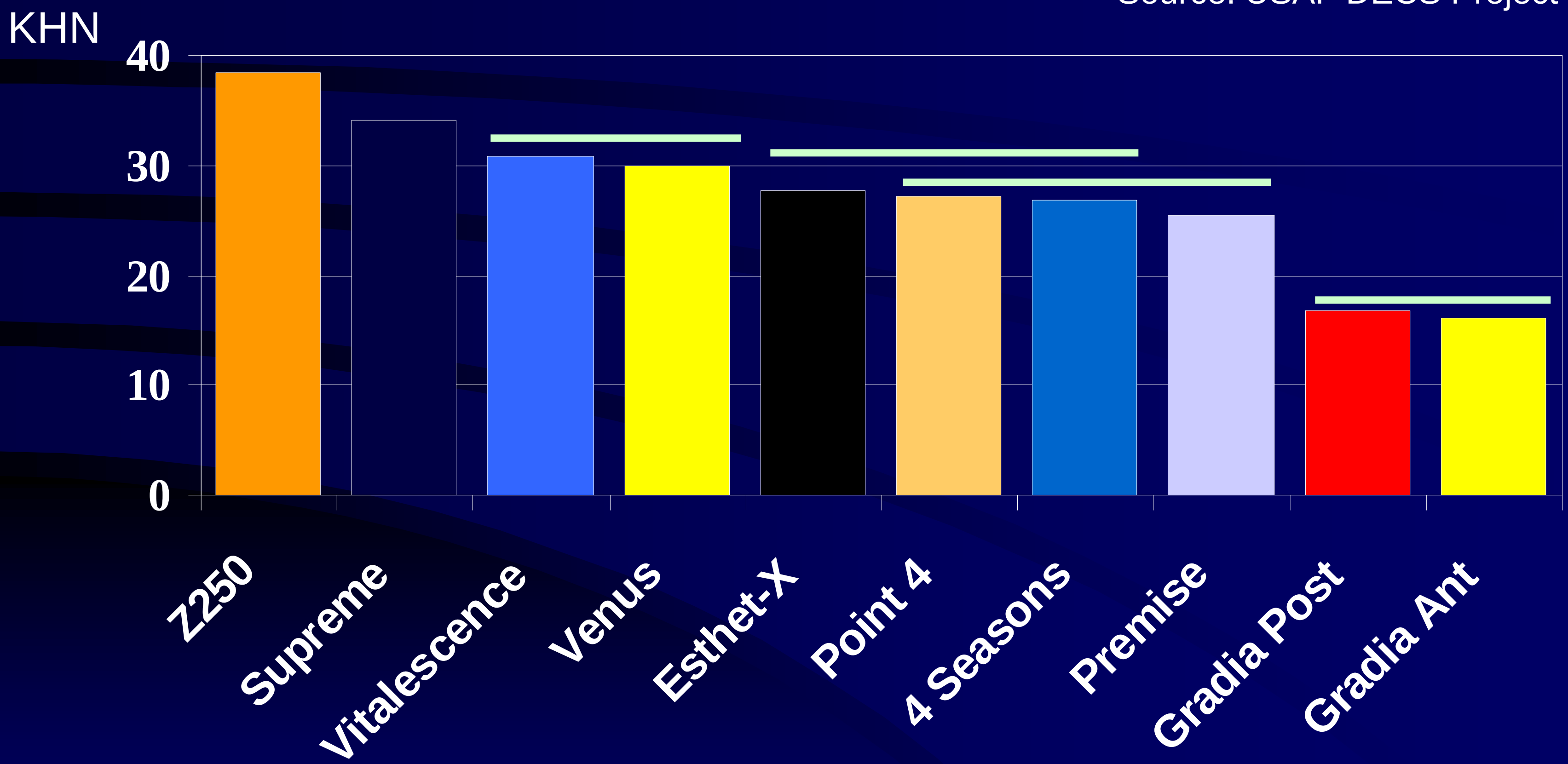


Source: USAF DECS Project 03-024

Surface Hardness

(24 hrs)

Source: USAF DECS Project 03-37

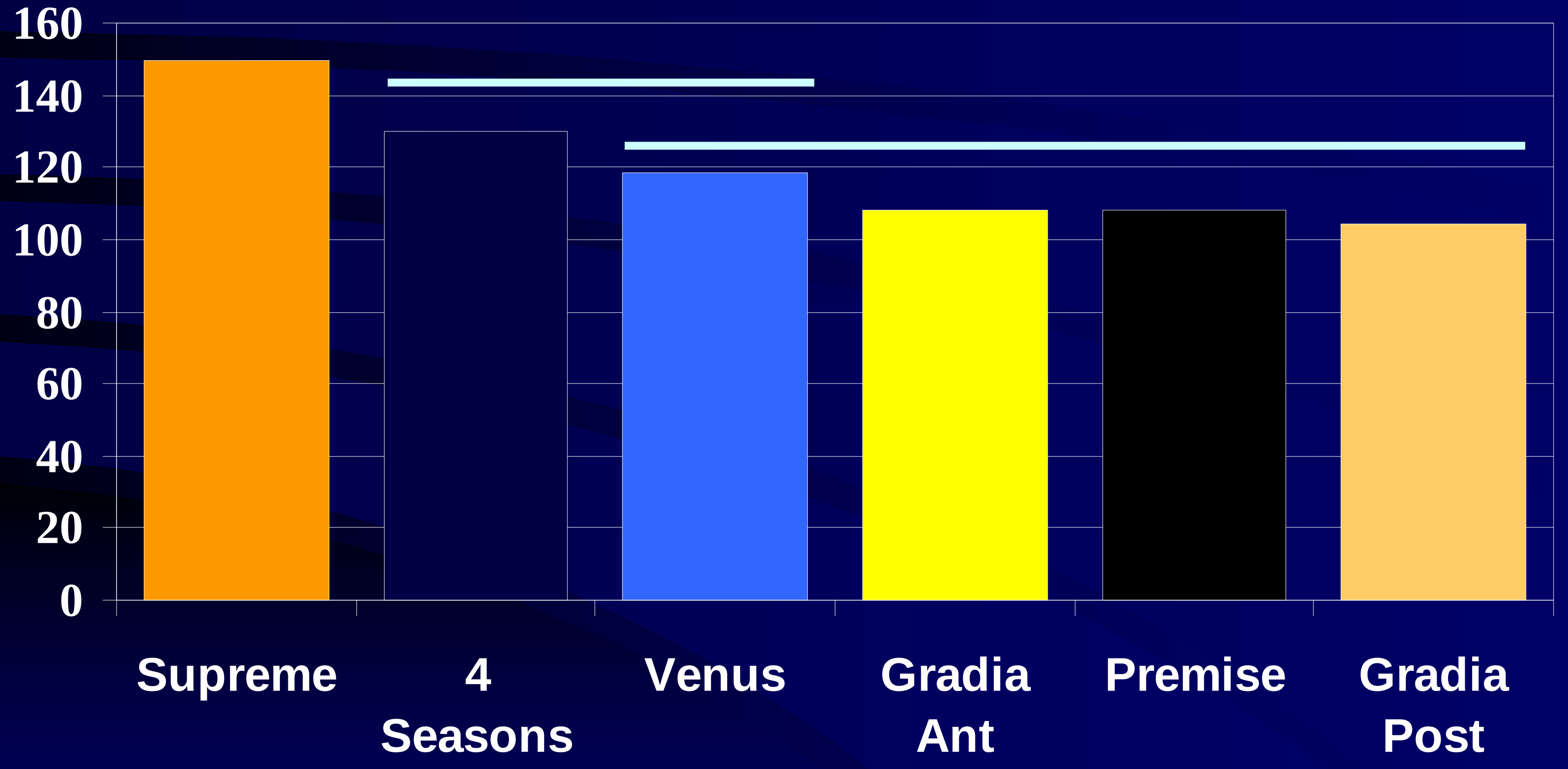


Horizontal lines connect nonsignificant differences (p<0.05); N=5

Flexural Strength

(24 hrs)

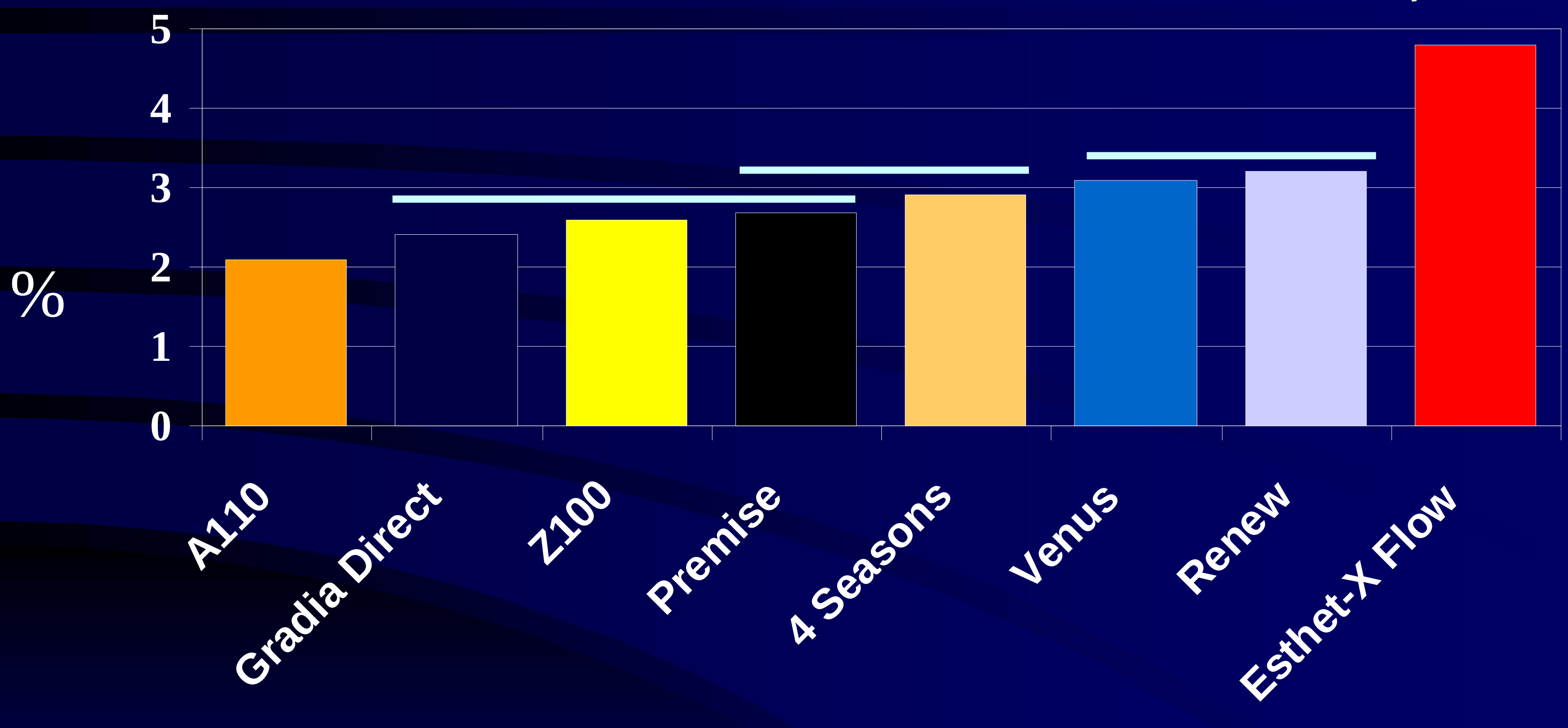
Source: USAF DECS Project 03-037



Horizontal lines connect nonsignificant differences ($p<0.05$); N=5

Volumetric Shrinkage

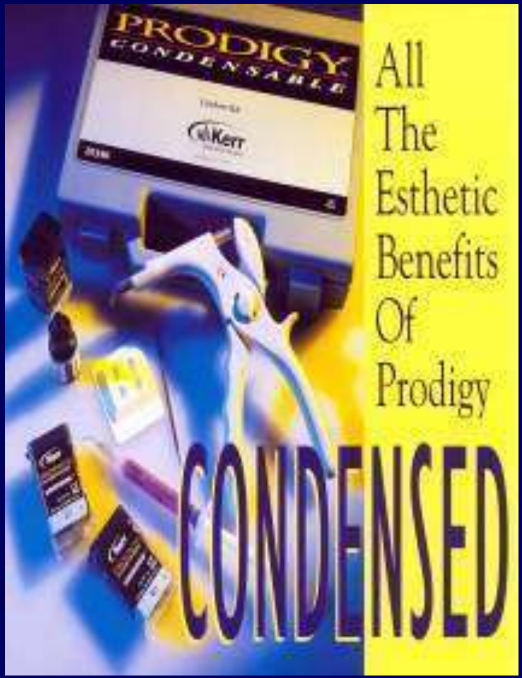
Source: USAF DECS Project 03-037



Horizontal lines connect nonsignificant differences ($p<0.05$); N=5

Composite Variants

- Packable
- Flowable



Packable Composites

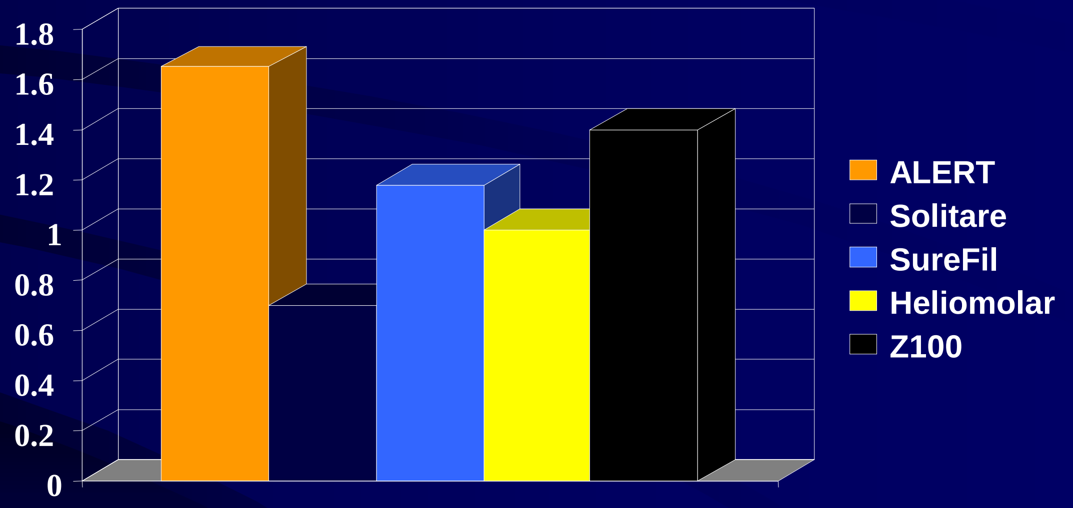
- Marketed for posterior use
  - increase in viscosity
    - better proximal contacts?
    - handle like amalgam?
- Subtle alteration of filler
  - shape
  - size
  - particle distribution
- Similar resin chemistry and filler volume

Click here for table of packable composites

Packable Composites

- Mechanical properties
  - similar to hybrids

Fracture Toughness



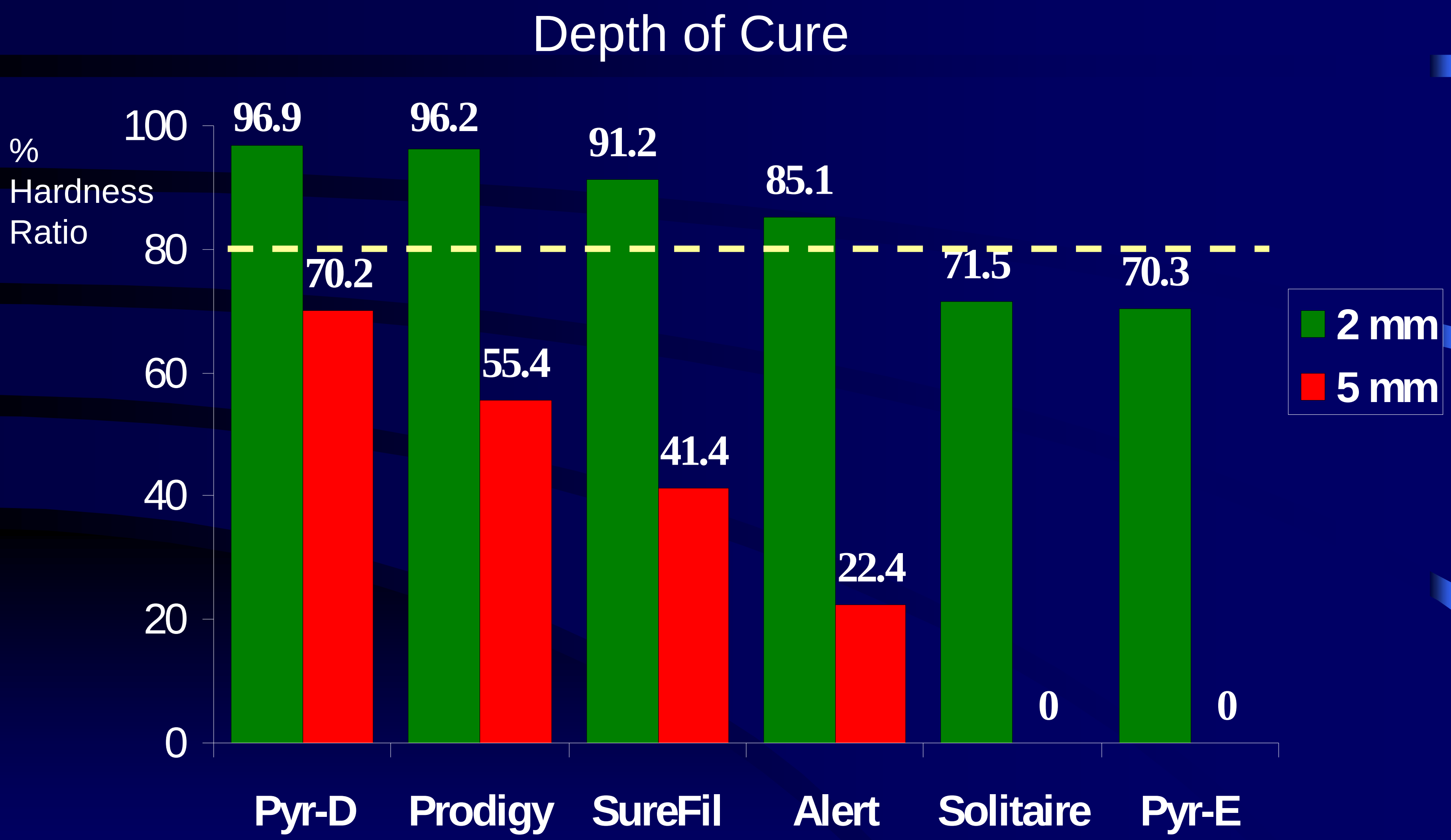
Choi J Esthet Dent 2000
Click here for abstract

Proximal Contact Studies

- Packables similar to hybrids
  - diameter and tightness
- Best contacts
  - sectional matrix system

Peumans Dent Mater 2001
-click here for abstract
Klein Am J Dent 2002

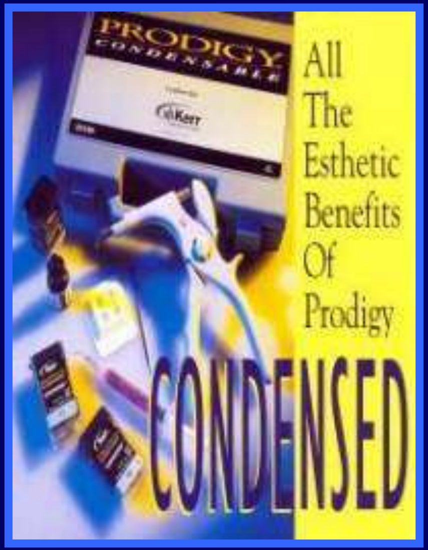
Packable Composite Resin



Choi J Esthet Dent 2000 Click here for abstract

Packable Vs. Hybrid Composites

- Mechanical properties similar
- Wear properties similar
- Curing depths similar
- Similar proximal contacts

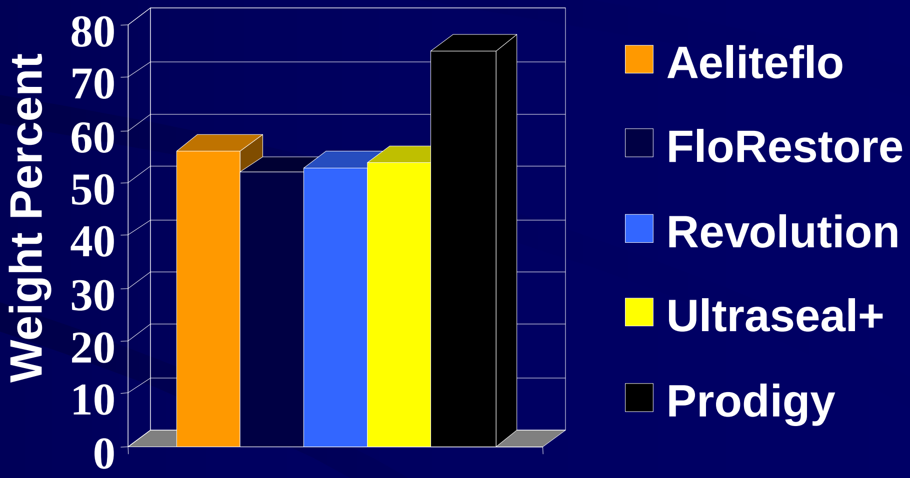


Choi J Esthet Dent 2000
Peumans Dent Mater 2001

Flowable Composites

- Marketed
  - class 1, 3, 5
  - liner
- Particle size similar to hybrid composites
- Reduced filler content
  - reduces viscosity

Percent Filler Loading

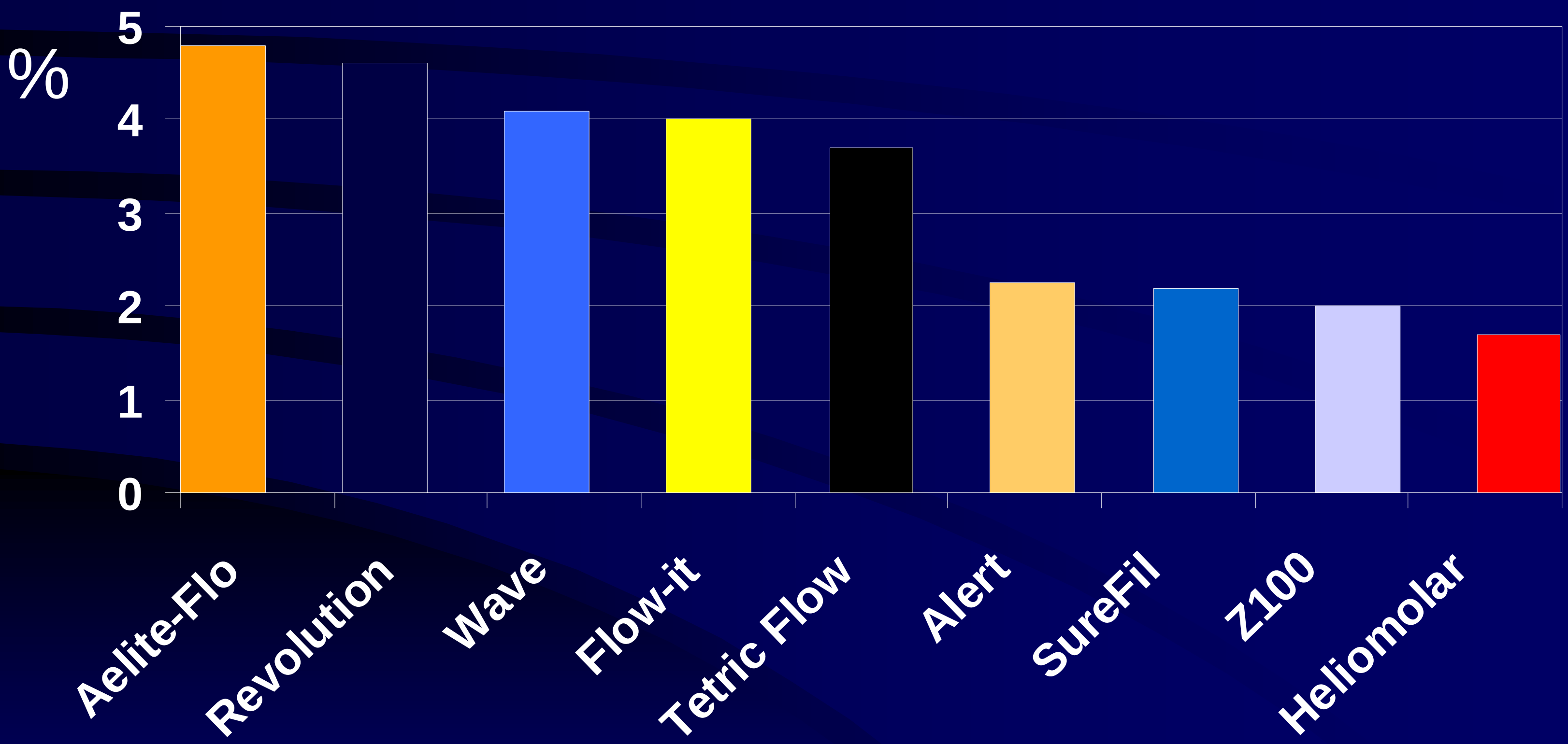


Bayne JADA 1998

Liners Under Direct Composites

- Increased flow
- Increased shrinkage
- Improved marginal integrity?
  - laboratory studies equivocal
    - most studies show no benefit
      - Braga JADA 2003
        - » click here for abstract
- Reduced post-operative sensitivity?
  - no clinical evidence of reduction
      - Perdigao Quint Int 2004
        - » click here for abstract

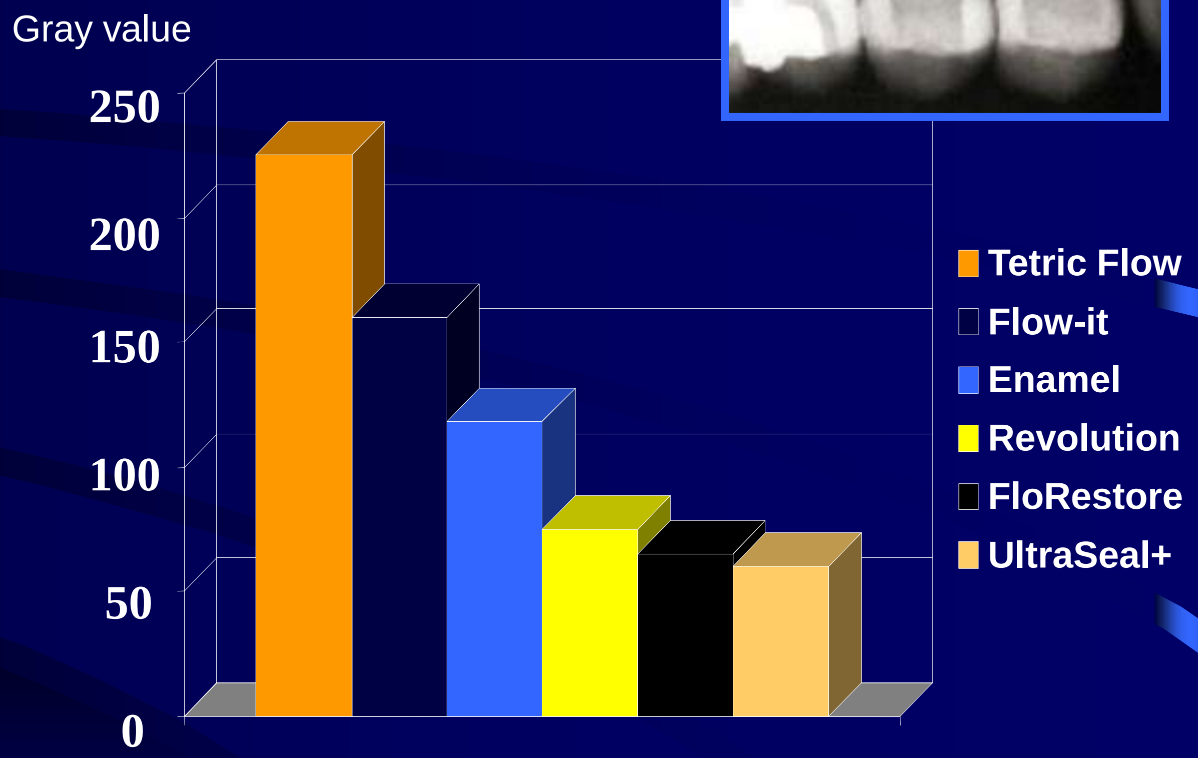
Polymerization Shrinkage



Tolidis JDR 1999

Radiopacity

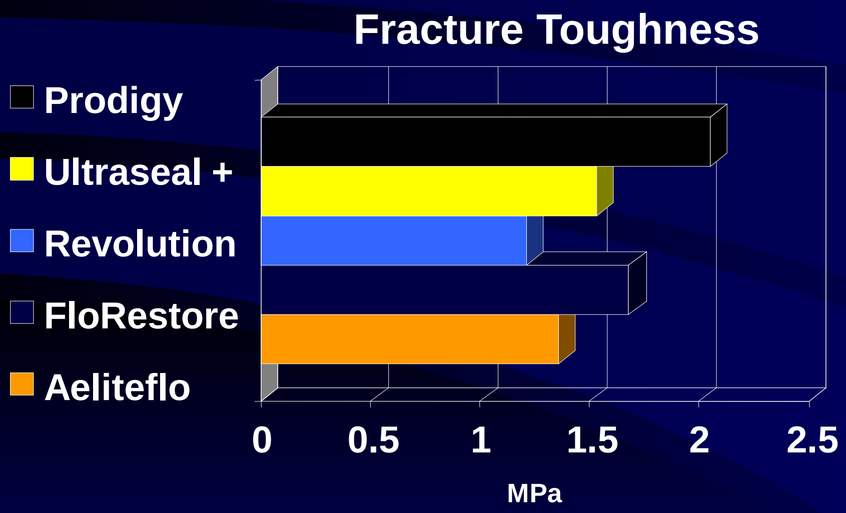
- Reduced radiopacity?
  - product specific
  - may be more difficult to distinguish on radiograph

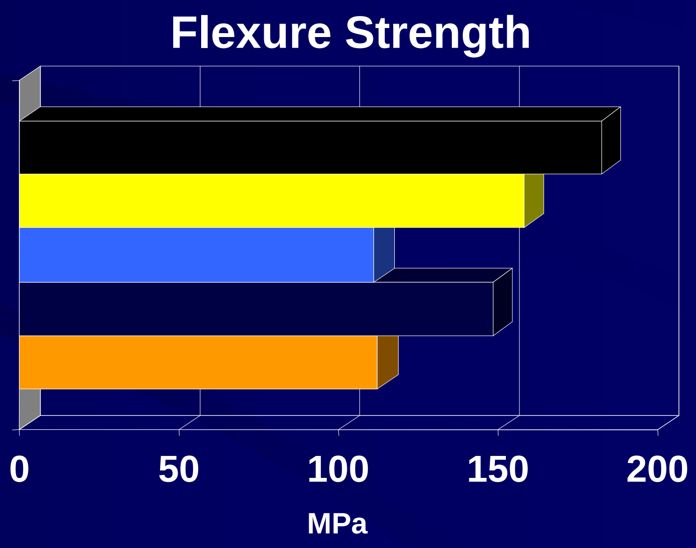


Murchison Quint Int 1999

Flowable Composite

- Mechanical properties
  - inferior to hybrids





Bayne JADA 1998

Flowable Composites

- Clinical applications
  - preventive resin restorations
  - small Class 5
  - provisional repair
  - composite repair
  - liners??

Regular Material Usage*

Civilian Practitioners

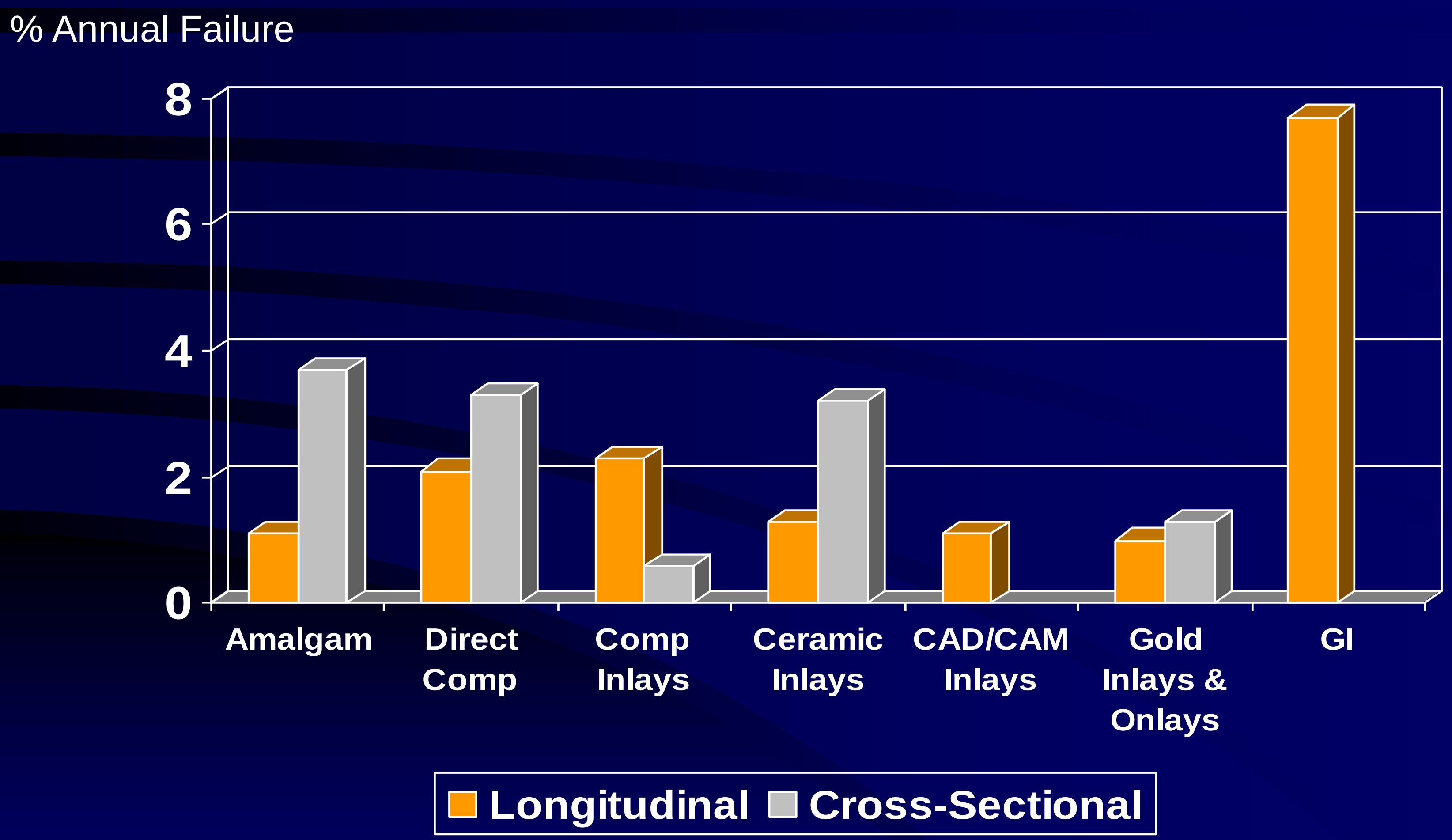
• Flowable Composite	81%
• Hybrid Composite	69%
• Amalgam	67%
• All-Purpose Composite	53%
• Microfill Composite	52%
• Resin-modified Glass ionomer	45%
• Packable Composite	33%
• Compomer	7%
• Other	1%

*Multiple responses

DPR 2005

Review of Clinical Studies

(Failure Rates in Posterior Permanent Teeth)



Hickel J Adhes Dent 2001