INTRODUCTION

A. Overview:
   1. History: Traditionally, only metallic materials used for inlays, onlays, crowns, or bridges.
   2. Esthetics: Esthetic concerns have facilitated the use of ceramics.
   3. Considerations for material selection:
      a. type and size
      b. location
      c. patient characteristics
      d. patient desires
      e. clinician’s opinion
   4. General Advantages:
      a. biocompatibility
      b. chemically inert
      c. wear resistant
      d. esthetic
   5. General Disadvantages:
      a. low strength (toughness)
      b. poor durability (longevity)
      c. technique sensitive (not user friendly)
      d. dimensional accuracy
      e. costs (fabrication related)
      f. can be etched by fluoride treatments
      g. clinical history

B. Dental applications of (high-strength) ceramics:
   1. Inlays, onlays, veneers
   2. Anterior all-ceramic crowns, bridges, (post-and-cores)
   3. Posterior all-ceramic crowns; posterior bridges?

C. Biomechanics and design considerations for high strength ceramics:
   1. Elimination of pores (fabrication) & surface flaws (fabrication and handling)
   2. Restriction of crack propagation: second phase that is reinforcing (e.g., crystals)
   3. Prevention of local stresses: butt joint margin design
   4. Increased ceramic thickness (or thickness recommended by manufacturer)
   5. Control of fatigue effects (Proper bonding to tooth structure!)

D. Fabrication Technologies:
   1. Vitrification (Liquid Phase Sintering)
   2. Casting Glass / Ceramming
   3. Solid State Sintering / Infiltration (or impregnation) – “powder processing”
   4. CAD/CAM Milling
   5. Copy Milling
E. New Definitions and Terminology:
1. Glass-ceramic = system of ceramic crystals precipitated in a glassy matrix
2. Ceramming = process of precipitating crystalline phase in glassy matrix
3. Castable glass = non-crystalline ceramic designed to be cast by lost wax technique
4. Injectable glass = non-crystalline ceramic designed to be injection molded (also referred to as pressable ceramic)
5. Glass infiltrated ceramic = partially sintered ceramic particles that are infused with glassy matrix

F. Esthetics for ceramics:
1. Enameling with feldspathic porcelain
2. Glazing
3. Internal shade control??

G. Precautions for all-ceramic crowns (to minimize the risks of poor esthetics, clinical failures, remakes, etc.):
1. Analyze potential stress-state of crown (using evidence of bruxism, clenching, or malocclusion as contraindications)
2. Make sure that the dental lab has sufficient experience preparing the specific type of all-ceramic restoration desired
3. Dentist should consider previous esthetic success with PFM restorations
4. Determine requirement for high degree of translucency
5. Patients must be informed (of benefits, risks, and alternatives)
6. Clinician must follow recommended protocols from manufacturers
7. Skill of the clinician in cavity preparations of this kind

CURRENT DENTAL CERAMICS

A. Feldspathic porcelain (low leucite content):
1. condensed and sintered
2. veneers; anterior crowns; low-stress inlays and onlays; crowns (PFMs); metal ceramic fixed partial dentures (FPDs)

B. Leucite-reinforced porcelain:
1. powder processed and sintered; pressure molded
2. anterior crowns; low-stress posterior crowns
3. examples:
   (1) Optec HSP - powder processed (Pentron – no longer available)
   (2) IPS Empress (injectable porcelain system) – pressable (Ivoclar)
   (3) OPC (Optimal Pressable Ceramic) – pressable (Pentron)
   (4) Finesse All-Ceramic – pressable (Ceramco)

C. Alumina-reinforced porcelain:
1. powder processed and sintered
2. anterior crowns; low-stress posterior crowns
3. examples:
   (1) Vita VMK Hi-Ceram (Vita Zahnfabrik)
   (2) Vitadur-N (Vita Zahnfabrik)
   (3) Vitadur Alpha (Vita Zahnfabrik)
D. **High density alumina (Al₂O₃) core:**
   1. powder processed, machined in “green-body” state, and sintered
   2. anterior & posterior crowns; anterior FPDs; low-stress posterior FPDs
   3. examples:
      (1) *Procera AllCeram* (Noble Biocare)

E. **High density zirconia (ZrO₂) core:**
   1. powder processed, machined in “green-body” state, and sintered
   2. posterior crowns; anterior and posterior FPDs
   3. examples:
      (1) *Lava* (3M-ESPE)
      (2) *Cercon* (Dentsply-Ceramco)
      (3) *Denzir* (Dentronic)

F. **Glass-infiltrated core:**
   1. slip-cast, sintered, and infiltrated with glass
   2. anterior & posterior crowns; anterior FPDs; posterior FPDs (*In-Ceram Zirconia* only)
   3. example: *In-Ceram* (“infused ceramic”)
      (1) *In-Ceram Alumina* [Al₂O₃] (Vita Zahnfabrik)
      (2) *In-Ceram Spinell* [MgAl₂O₄] - enhanced translucency, mechanical properties inferior to *In-Ceram Alumina* - anterior use only (Vita Zahnfabrik)
      (3) *In-Ceram Zirconia* (ZrO₂) – enhanced mechanical properties (Vita Zahnfabrik)

G. **Glass-ceramic core ceramic:**
   1. cast and cerammed; pressure molded
   2. anterior & posterior crowns; anterior FPDs (*Empress 2*)
   3. example:
      (1) *Dicor* “Dentsply International / Corning Glass” - mica based, no longer available
      (2) *IPS Empress 2* – lithia disilicate core / (Ivoclar)

H. **Ceramics for CAD-CAM (*CEREC; CEREC 2*) and copy milling (*Celay*):**
   1. milled or ground
   2. anterior & posterior crowns; 3-unit anterior FPDs (*In-Ceram Alumina*)
   3. examples:
      (1) *Dicor MGC* “machinable glass-ceramic” - mica based, no longer available
      (2) *Vita Mark II* - machinable feldspathic porcelain (Vita Zahnfabrik)
      (3) *In-Ceram Alumina* and *In-Ceram Spinell* – crowns & bridges (Vita Zahnfabrik)
      (4) *ProCAD* - modified “machinable” version of IPS Empress (Ivoclar)
Manufacturers:

Dentsply-Ceramco Inc.
Six Terri Lane
Burlington, NJ 08016
800-487-0100
http://www.ceramco.com

Ivoclar North America, Inc.
175 Pineview Dr.
Amherst, NY 14228
800-533-6825
http://www.ivoclarna.com

Pentron Laboratory Technologies, LLC
PO Box 724
Wallingford, CT 06492
800 551 0283
http://www.pentron.com

Noble Biocare USA Inc.
22895 Eastpark Drive,
Yorba Linda, CA 92887
800 993 8100
http://www.nobelbiocare.com

Vident (US distributor of Vita Zahnfabrik products)
3150 East Birch Street
Brea, California 92621
800-828-3839
http://www.vident.com

3M-ESPE
3M Center Building
St. Paul, MN 55144-1000
800-364-3577
http://www.3m.com/espe
Study Questions (correct answers are underlined)

1. Which of the following is not an advantage of the use of dental ceramics when compared to most metals and metal alloys:
   a. biocompatible
   b. wear resistant
   c. esthetic
   **d. mechanically durable**
   e. chemically inert

2. Ceramics are susceptible to etching by which of the following:
   a. HCl
   b. HF
   c. HNO₃
   **d. NH₄HF₂**
   e. H₂SO₄

3. Which of the following is a property exhibited by most ceramics:
   a. high thermal conductivity
   b. high thermal expansion
   c. high toughness
   d. high tensile strength
   **e. high compressive strength**

4. Dicor and Dicor MGC contain which crystalline reinforcing phase:
   a. α-alumina
   **b. tetrasilicic fluormica**
   c. β-quartz
   d. β-eucryptite
   e. potassium fluorrichterite

5. Feldspathic porcelain can be formed from which group of oxides:
   a. SiO₂, Al₂O₃, ZnO
   b. Na₂O, K₂O, SiO₂
   c. Al₂O₃, Na₂O, SiO₂
   d. MgO, Al₂O₃, SiO₂
   **e. Al₂O₃, K₂O, SiO₂**

6. Which of the following dental ceramic materials does not contain leucite:
   a. Optec HSP
   b. Feldspatic porcelain
   **c. In-Ceram**
   d. IPS Empress
   e. Vita Mark II porcelain
7. The costs of dental ceramic restorations can be high because:
   a. special handling requirements are needed due to toxicity concerns
   b. dentists are even greedier than lawyers
   c. placement is much more difficult than for metal or resin-based restorations
   d. **special fabrication equipment is often needed**
   e. the price of SiO₂ continues to increase at an exponential rate

8. Which of the following pairs is incorrect:
   a. Procera - alumina
   b. **Dicor MGC – machinable feldspathic porcelain**
   c. Dicor MGC – machinable glass-ceramic
   d. IPS Empress – leucite
   e. InCeram – alumina

9. Which of the following statements is incorrect for dental ceramics:
   a. currently available high-strength dental ceramics require stains and shading/veneering porcelains for esthetic enhancement
   b. **pores and other surface flaws are most detrimental when located on the occlusal (outer) surface of ceramic restorations**
   c. fluoride treatments can damage the surface finish of dental ceramic materials
   d. vitrification is the most commonly used fabrication technique for dental porcelains
   e. pores and other surface flaws are most detrimental when located on the internal surface of ceramic restorations

10. Which of the following statements is correct for dental ceramics:
    a. **because of their brittle nature, dental ceramics are less fatigue resistant than most metals and metal alloys**
    b. castable dental ceramics are more easily cast than metals and metal alloys
    c. the high cost of dental ceramics is related to the high costs of the raw materials that are required for their production
    d. early use of dental all-ceramic systems resulted in very low clinical failure rates
    e. dental ceramics have fracture toughness values approximately ½ that of most dental metal alloys

11. Zirconia is the toughest available ceramic material for dental restorative applications. It’s toughness is derived primarily from which of the following:
    a. the fine grain (crystal) size that is possible through powder fabrication
    b. the presence of 3+ distinct crystal phases in the final microstructure
    c. **the ability of tetragonal phase zirconia to transform under stress to monoclinic phase, which produces internal compressive residual stresses**
    d. the presence of ductile zirconium particulates in the final structure
    e. the tough cubic structure that is the stable phase at room temperature