REVIEW OF CERAMICS AND PORCELAINS:

A. Review of Definitions and Terminology:

1. Ceramic = Any compound involving metallic and non-metallic elements.
   a. Enamel = Ceramic coating over a substrate.
   b. Porcelain = Ceramic based on potassium aluminosilicate.
      (1) Dental Porcelain = narrow compositional range of porcelains

B. Review of Ceramic Structure:

1. Arrangement:
   a. Mixture of crystalline and non-crystalline phases

2. Bonding:
   a. Ionic and/or Covalent

3. Composition:
   a. Silicate Types:
      (1) Clays (hydrated aluminosilicates)
      (2) Feldspars (anhydrous aluminosilicates)
      (3) Quartz (silica)
   b. Non-silicate Types:

4. Defects:
   a. Pores
   b. Cracks

C. Review of Ceramic Properties:

1. Physical Properties:
   a. Intermediate Density (1.0-3.8 gms/cc)
   b. High Melting Point (= Refractory)
   c. Low Coefficient of Linear Thermal Expansion (1-15 ppm/°C)
   d. Excellent Optical Properties (Good translucency)

2. Chemical Properties:
   a. Low Chemical Reactivity
   b. Low Absorption and Solubility

3. Mechanical Properties:
   a. High Modulus
   b. Much stronger in Compression than Tension (approximately 10x)
   c. Brittle (Low plastic deformation, <0.1%, low fracture toughness)

4. Biological Properties:
   a. Relatively Inert
D. Review of Range of Ceramic Microstructures:

1. Composite Theory Analysis of Ceramic Phases:
   a. Continuous Phases: Non-crystalline Phases
   b. Dispersed Phases: Crystalline Phases and Pores
   c. Interfaces: Internal and External

2. Mechanisms of Microstructural Formation:
   a. Melting: Liquefaction of all particles
   b. Vitrification: Liquefaction of some particle parts.
   c. Sintering: Solid state diffusion between particles.
DENTAL PORCELAINS:

A. Classification Systems for Dental Porcelains:

1. Classification Based on Fusion Temperatures:
   a. **High Fusing**: 1288 - 1371 °C (2350 - 2500 °F)
      Used for ---> Denture Teeth, Aluminous Cores
   b. **Med Fusing**: 1093 - 1260 °C (2000 - 2300 °F)
      Used for ---> PJC, Porcelain Inlays
   c. **Low Fusing**: 871 - 1066 °C (1600 - 1950 °F)
      Used for ---> P/M Restorations ***

2. Classification Based on Application Design:
   a. Porcelain Core : Porcelain veneered onto ceramic cores
   b. Porcelain Inlay : Porcelain restoration
   c. Cast Porcelain : Cast porcelain crown
   d. Porcelain/Metal : Porcelain veneered to metal

3. Classification Based on Usage of Low Fusing Porcelains:
   a. **Opaque Porcelains** = Low Fusing Glass + Opacifiers
   b. **Body Porcelains** = Low Fusing Glass + Colorants
      (1) Incisal or Enamel = (" + very little colorant)
      (2) Gingival or Dentin = (" + yellowish oxides )
      (3) Modifiers = (" + white/gray oxides)
   c. Stains or Glazes = Low Fusing Glass + Colorants

B. Chemical Analyses of Low Fusing Porcelains:

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<th></th>
<th>BIODENT Opaque B62</th>
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MANIPULATION TECHNIQUES FOR DENTAL PORCELAIN:

A. Definitions and Terminology Related to Manipulation:

1. **Condensation** = Padding and/or packing of porcelain powders into position prior to firing.
2. **Biscuit** = Cohesive powder compact at particle-to-particle contacts after initial fusion.
3. **Frit** = An unfused or partially fused powder mass.
4. **Firing** = Heating of porcelain powder or biscuits to eliminate the porosity and form a completely solid mass.
5. **Soaking** = Holding at a fixed firing temperature.

B. Stages of Creating P/M Restorations:

1. Metal alloy casting.
2. Metal alloy cleaning and surface roughening.
3. Metal alloy surface pre-treatments, pre-oxidation, pre-conditioning, application of bonding agents, and/or opaquing.
4. Porcelain application.
5. Porcelain firing stages:
   - (a) Low bisque firing = Little shrinkage/ Little fusion
   - (b) Med bisque firing = A lot of Shrinkage/ Some porosity
   - (c) High bisque firing = Shrinkage complete/ Min porosity
6. Glazing

C. Analysis of Porcelain Densification Variables: P,V,T,t effects

1. Minimize the number of firings overall to increase strength.
2. Heat well below the melting range of the metal substructures.
3. Use firing cycles with longer times at lower temperatures to increase final strength.
4. Heat slowly to accommodate for poor thermal conductivity which tends to create premature surface densification and entrap porosity.
5. Use vacuum firing because air fired porcelains are too weak to be polished or adjusted occlusally by grinding.
6. Use porcelain powders with smaller particles because the resulting finer porosity will have less effect on esthetics and strength.
7. Overall shrinkage is not influenced much by composition or compaction methods.
8. Tensile strength is influenced by composition, firing cycles, and surface integrity of final porcelain.

D. Porcelain Properties After P/M Bonding:

1. Compressive strength much greater than tensile strength (approximately 10x).
   - CS = 48,000 psi (porcelain), ĈS = 60,000 psi (amalgam), ĈS = 60,000 psi (enamel)
2. Coefficient of Linear Thermal Expansion = 14-15 ppm/ °C
3. Very sensitive to crack propagation from pore or cracks (low fracture toughness)
PORCELAIN STRENGTHENING MECHANISMS FOR PFM RESTORATIONS:

A. **Alumina Reinforcement:** Prevents Crack Propagation

1. Major strengthening effect if properly introduced
2. Particles of alumina act as barriers to crack propagation
3. Cracks which originate at interior or exterior surfaces are deflected or stopped prior to catastrophic failure.

B. **Porcelain-to-Metal Bonding:** Prevent Porcelain Flexure

1. Types of Metal Substrates:
   a. Precious Metal Alloys:
      (1) Gold Based: Au-Pt-Pd
      (2) Silver Based: Ag-Pd
   b. Non-Precious Metal Alloys:
      (1) Nickel Based: Ni-Cr
      (2) Cobalt Based: Co-Cr
2. Requirements for Metal Substrates:
   a. CTE matched to the porcelain.
   b. High modulus and proportional limit (No flexure).
   c. Corrosion resistance.
   d. Mechanism for chemical bonding to porcelain.

C. **Porcelain Pre-Stressing:**

1. Pre-Stressing Design:
   a. Force the porcelain coefficient of thermal expansion to be slightly more than that for the metal to create compression at room temperature.
   b. Coefficient of thermal expansion must be very close to but not exactly the same as that for the metal.
      (1) Minor mismatches can create catastrophic radial stresses.
      (2) 3 ppm/°C error over a temperature range of 925 °C would create a local shear stress of 40,000 psi
      (3) Shear bond strengths of most systems are approximately 20,000 psi.
MULTIPLE CHOICE STUDY QUESTIONS:

1. Which one of the following reasons is the proper explanation for brittle fractures common in ceramic materials?
   a. Low electrical conductivity
   b. Intermediate density
   c. High modulus
   d. High melting point
   e. Low fracture toughness

2. Which ONE of the following oxides is NOT a major component in most porcelain compositions?
   a. Calcium oxide
   b. Alumina
   c. Silica
   d. Potassium Oxide

3. Which ONE of the following categories of materials is NOT found in dental porcelain compositions?
   a. Kaolin
   b. Feldspar
   c. Quartz
   d. Silicon Carbide
   e. Metallic Oxides

4. Which ONE of the following types of porcelains is NOT involved in the production of Cerestore aluminous porcelain crowns?
   a. High fusing porcelains
   b. Med fusing porcelains
   c. Low fusing porcelains

5. Which ONE of the following components is NOT found in opaquing porcelain formulations?
   a. \( \text{CaSO}_4 \)
   b. \( \text{SiO}_2 \)
   c. \( \text{TiO}_2 \)
   d. \( \text{ZrO}_2 \)
   e. \( \text{K}_2\text{O} \)

6. Which ONE of the following components is the key oxide in a porcelain opaquing composition?
   a. \( \text{SiO}_2 \)
   b. \( \text{K}_2\text{O} \)
   c. \( \text{SnO}_2 \)
   d. \( \text{RbO}_2 \)
   e. \( \text{CaO} \)

7. Porcelain bonded to metal restorations are based on which ONE of the following categories of porcelains?
   a. High fusing porcelains
   b. Med fusing porcelains
   c. Low fusing porcelains
8. Which ONE of the following types of porcelains may be affected intraorally by saliva and/or acids?
   a. Incisal porcelains
   b. Opaque porcelains
   c. Gingival porcelains
   d. Glazes
   e. Med fusing porcelains

9. What types of colorant oxides are normally part of dentin porcelains?
   a. Blue colored oxides
   b. Yellow colored oxides
   c. Gray colored oxides
   d. White colored oxides
   e. Tan colored oxides

10. Densification which involves partial melting is called:
    a. Vitrification.
    c. Liquefaction.
    d. Recrystallization.
    e. Compaction.

11. Which ONE of the following choices accurately summarizes the volumetric changes which occur during porcelain firing?
    a. Firing Shrinkage and Cooling Shrinkage
    b. Firing Expansion and Reaction Shrinkage
    c. Firing Expansion and Compaction Shrinkage
    d. Condensation Shrinkage and Firing Shrinkage
    e. Condensation Shrinkage and Cooling Shrinkage

12. During firing most porcelains shrink about:
    a. 10 volume percent
    b. 20 volume percent
    c. 30 volume percent
    d. 40 volume percent
    e. 50 volume percent

13. Which ONE of the following factors does NOT influence the initial level of powder particle compaction prior to firing?
    a. Powder particle size and distribution
    b. Method of condensation
    c. Powder composition

14. Which ONE of the following is the LEAST important effect on the residual porosity in a fired porcelain?
    a. Method of condensation
    b. Partial pressure of the firing furnace
    c. Rate of heating of the porcelain
    d. Maximum temperature of firing
    e. Firing time

15. Which ONE of the following factors will NOT reduce internal porosity in porcelains?
    a. Longer firing times
    b. Vacuum firing
    c. Careful compaction prior to firing
    d. High firing temperatures
    e. Faster heat-up during firing cycles
16. A porcelain bonded to metal restoration should be designed so that the porcelain is in:
   a. Slight compression
   b. Slight tension
   c. Slight shear
   d. Slight flexion
   e. Slight torsion

17. The coefficient of thermal expansion of dental porcelains which are to be bonded to metal substrates should be:
   a. Significantly lower than the metal value
   b. Slightly lower than the metal value
   c. Equal to the metal value
   d. Slightly more than the metal value
   e. Significantly greater than the metal value

18. Which ONE of the following is included in dental porcelains to impart color?
   a. Porosity
   b. Metallic oxides
   c. Oxidized metal chips
   d. Organic stains
   e. Crystalline ceramics

19. Dental porcelains display the greatest resistance to mechanical deformation under which ONE of the following types of loading?
   a. Compression
   b. Tension
   c. Shear
   d. Torsion
   e. Flexion

20. The coefficient of thermal expansion of processed porcelain in porcelain-to-metal restorations is approximately:
   a. 10 ppm/°C
   b. 14 ppm/°C
   c. 18 ppm/°C
   d. 25 ppm/°C
   e. 35 ppm/°C

21. Aluminous porcelain is based on:
   a. Increased levels of alumina dissolved in the porcelain glass composition.
   b. Aluminized surfaces of the porcelain powders.
   c. Particles of alumina dispersed within the porcelain glass matrix.
   d. Crystallized porcelain created by adding aluminum nucleating agents.
   e. Alumina glazed porcelain.

22. Which ONE of the following acids is capable of readily dissolving ceramic materials?
   a. Hydrofluoric acid
   b. Citric acid
   c. Phosphoric acid
   d. Polyacrylic acid
   e. Tannic acid
DISCUSSION STUDY QUESTIONS:

1. For CAD/CAM restorations, would you choose high fusing, medium fusing, low fusing, or none of the above types of porcelain? Explain why?

2. Explain the major differences in esthetics between dental porcelain and aluminous porcelains.

3. How much difference in oxide types is a body versus an opaque porcelain?

4. Explain why low fusing dental porcelain has a lower compressive strength than dental amalgam, dental composite, dentin, and enamel?

5. Explain the principal difference in design for cavity preparation of alumina reinforced porcelains versus PFM porcelains for crowns.