DENTAL CERAMICS

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(2019)

CONTENTS

DEFINITION

DENTAL CERAMICS are nonmetallic, inorganic structures, primarily containing compounds of oxygen with one or more metallic or semi-metallic elements.

HISTORY OF DENTAL CERAMICS

- Ceramic-like tools have been used by humans since the end of the Old Stone Age around 10,000 B.C. to support the lifestyles and needs of fisher-hunter-gatherer civilizations.

- The first porcelain tooth material was patented in 1789 by **de Chemant**, a French dentist in collaboration with **Duchateau,** a French pharmacist.

- In 1808, **Fonzi**, an Italian dentist, invented a “terrometallic” porcelain tooth held in place by a platinum pin or frame.

- **Planteau**, a French dentist, introduced porcelain teeth to the United States in 1817, and **Peale**, an artist, developed a baking process in Philadelphia for these teeth in 1822.

- **Charles Land** introduced one of the first ceramic crowns to dentistry in 1903.

- Two of the most important breakthroughs responsible for the long-standing superb esthetic performance and clinical survival probabilities of metal-ceramic restorations are described in the patents of **Weinstein** and **Weinstein (1962) and Weinstein et al. (1962)**.

- The first commercial porcelain was developed by **VITA Zahnfabrik** in about 1963.

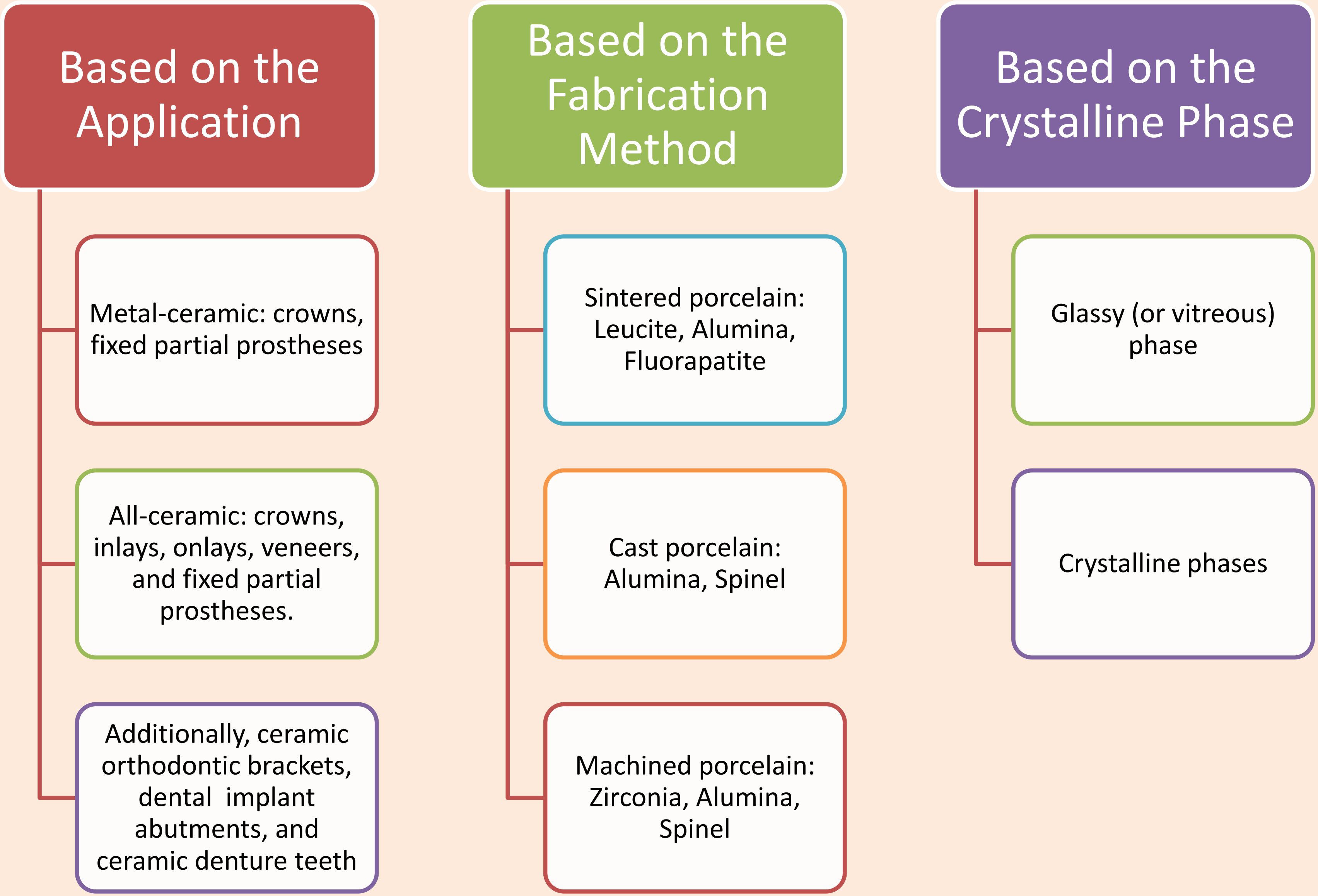
- **1965** – **Mc Lean &Hughes** used glass- alumina composite instead of feldspar porcelain resulting in stronger restorations.

- Improvement in all ceramic systems developed by controlled crystallization of a glass (Dicor) was demonstrated by **Adair and Grossman (1984)**.

- **1989** – The concept of All-Ceramic post &core was introduced using Dicor glass-ceramic initially, followed by In-cream, IPS Empress and Zirconia ceramics.

- New generation of ceramics, including Cercon, Lava, In Ceram Zirconia, IPS Empress2, and Procera All Ceram were used for ceramic prostheses

Classification: Craig



Based on the Application

- Metal-ceramic: crowns, fixed partial prostheses
- All-ceramic: crowns, inlays, onlays, veneers, and fixed partial prostheses.
- Additionally, ceramic orthodontic brackets, dental implant abutments, and ceramic denture teeth

Based on the Fabrication Method

- Sintered porcelain: Leucite, Alumina, Fluorapatite
- Cast porcelain: Alumina, Spinel
- Machined porcelain: Zirconia, Alumina, Spinel

Based on the Crystalline Phase

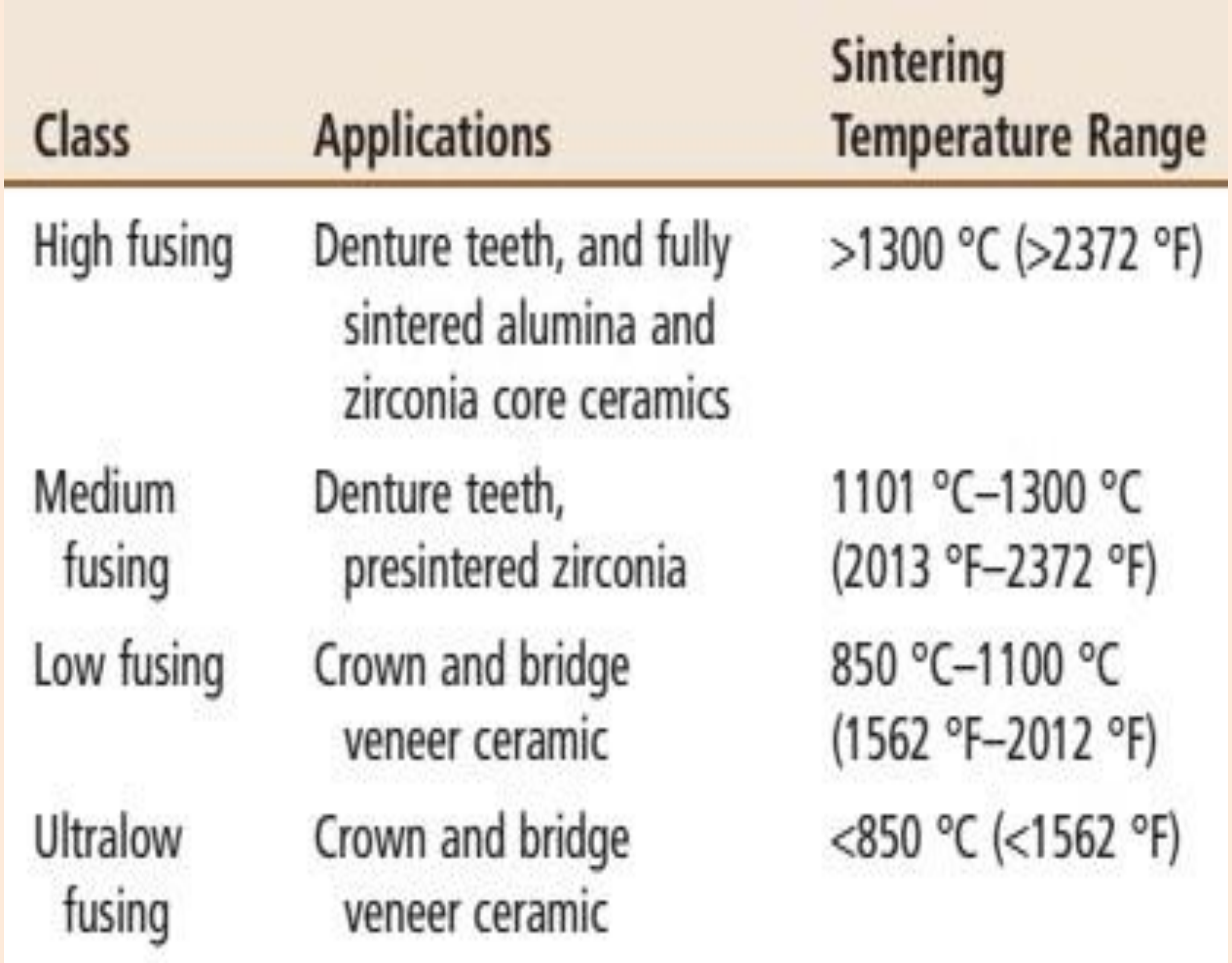
- Glassy (or vitreous) phase
- Crystalline phases

Classification: Anusavice

- **uses or indications**
  - Anterior and posterior crown, veneer, post and core,
  - **fixed dental prosthesis, ceramic stain**, **glaze**
- **composition**;
- **principal crystal phase or matrix phase**
- **Processing method**
  - casting,
  - sintering,
  - partial sintering
  - glass infiltration,
  - **slip casting** and sintering,
  - hot-isostatic pressing,
  - CAD-CAM milling, and copy milling

- **firing temperature**
  - ultralow fusing,
  - low fusing,
  - medium fusing,
  - High fusing
- **Microstructure**
  - amorphous glass,
  - crystalline,
  - crystalline particles in a glass matrix
- **Translucency**
  - opaque,
  - translucent,
  - transparent
- **Fracture resistance** : low, medium, high
- **Abrasiveness**

Classification of Dental Ceramics by Sintering Temperature



Class	Applications	Sintering Temperature Range
High fusing	Denture teeth, and fully sintered alumina and zirconia core ceramics	>1300 °C (>2372 °F)
Medium fusing	Denture teeth, presintered zirconia	1101 °C–1300 °C (2013 °F–2372 °F)
Low fusing	Crown and bridge veneer ceramic	850 °C–1100 °C (1562 °F–2012 °F)
Ultralow fusing	Crown and bridge veneer ceramic	<850 °C (<1562 °F)

BASIC STRUCTURE

- These are a mixture of crystalline minerals (feldspar, silica and alumina) in an amorphous (non-crystalline matrix of glass) vitreous phase.
- The glass-forming matrix of dental porcelains uses the basic silicone oxygen (Si-O) network.
- Their structures are characterized by chains of $(SiO4)^{4-}$ tetrahedra in which Si^{4+} cations are positioned at the center of each tetrahedron with O^{-} anions at each of the four corners.

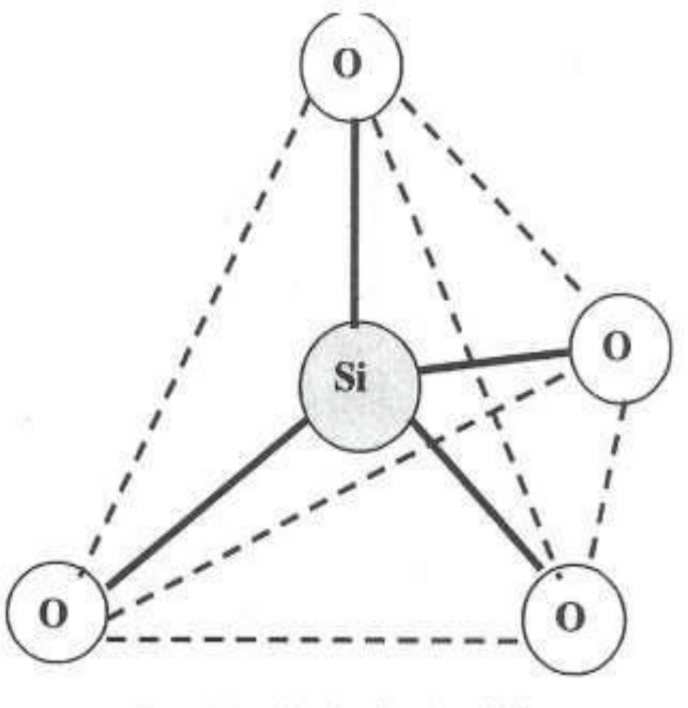
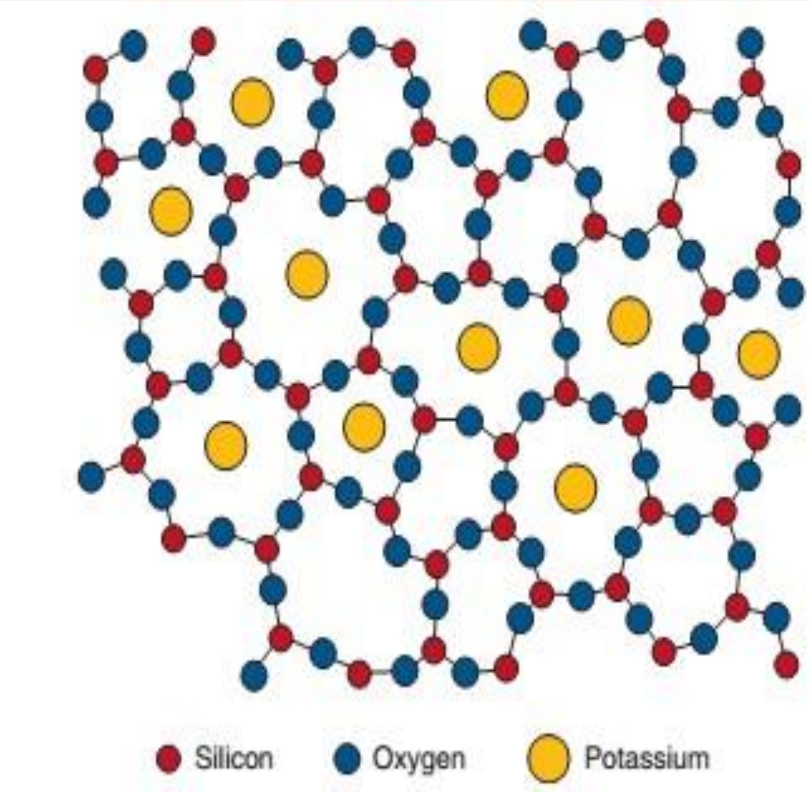


Figure 1. Tetrahedral configuration of Silica

- The primary structural unit in all silicate structures is the negatively charged silicon oxygen tetrahedron (SiO4) 4−

- The SiO4 tetrahedra are linked by sharing their corners.They are arranged as linked chains of tetrahedra, each of which contains two oxygen atoms for every silicon atom



Two dimensional amorphous structure of potassium silicate glass

- Alkali cations such as potassium or sodium tend to disrupt silicate chains and increase the thermal expansion of these glasses.

- Molecules with one oxygen atom (such as Na_2O, K_2O,or CaO)are useful in dental porcelains as fluxes.They may also act as opacifiers.

- Molecules that contain three oxygen atoms for every two other atoms(such as Al2O3) are used as stabilizers.They are also added as crack blockers and toughening crystals.

- Regular dental porcelain, being of a glassy nature is largely non crystalline and exhibits only a short range order in anatomic arrangement.

- The only true crystalline ceramic used in restorative dentistry is Alumina(A1 2O 3); which is one of the hardest and probably the strongest oxides known. Crystalline ceramics may have ionic or covalent bonds (Ionic crystals are compounds of metals with oxygen. e.g.: Alumina.

COMPOSITION

crystalline phase

glass matrix phase

- Feldspar
- Silica
- Kaolin
- Glass modifiers
- Color pigments
- Opacifiers

Feldspar :is responsible for forming the glass matrix .

- Feldspar is a naturally occurring mineral and composed of two alkali aluminum silicates such as potassium aluminum silicate ($K_2O-Al_2O_3-6SiO_2$); also called as potash feldspar or ortho clase and soda aluminum silicate ($Na_2O-Al_2O_3-6SiO_2$); also called as soda feldspar or albite.
- It is the lowest melting compound and melts first on firing.
- Most of the currently available porcelains contain potash feldspar as it imparts translucency to the fired restoration.

Role of feldspar:

Glass phase formation: During firing, the feldspar fuses and forms a glassy phase that softens and flows slightly allowing the porcelain powder particles to coalesce together.

- The glassy phase forms a translucent glassy matrix between the other components in the dense solid.

Leucite formation: Another important property of feldspar is its tendency to form the crystalline mineral leucite when melted, which is exploited to advantage in the manufacture of porcelain suitable for metal bonding

LEUCITE

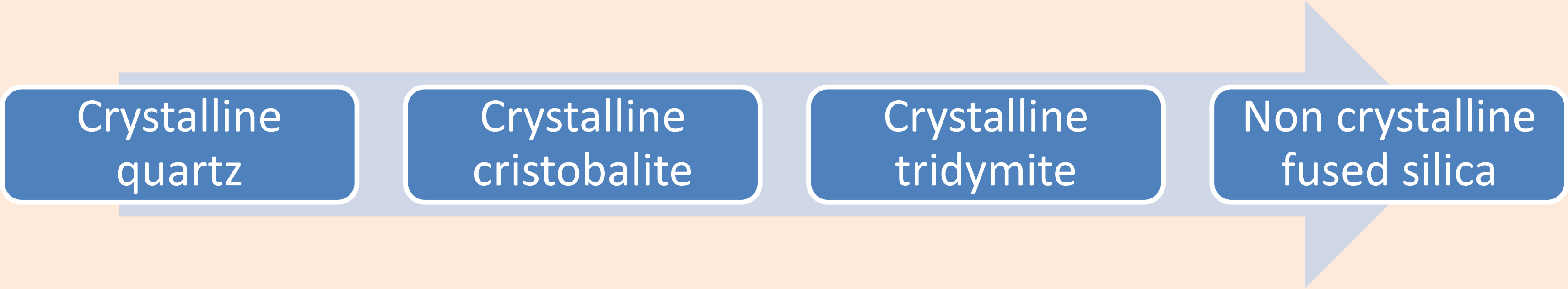
- Leucite is a **potassium-aluminium-silicate mineral.**

- It has high coefficient of thermal expansion.

- When feldspar is heated at temperatures between 1150C and 1530C,it undergoes incongruent melting to form crystals of leucite in a liquid phase.

- **INCONGRUENT MELTING** is the process by which one material melts to form a liquid plus a different crystalline material.

Silica:



Crystalline quartz

Crystalline cristobalite

Crystalline tridymite

Non crystalline fused silica

- Pure Quartz crystals (SiO_2)are used for manufacturing dental porcelain.
- Quartz (crystalline silica) is used in porcelain as a filler and strengthening agent.

COLOUR PIGMENTS

Metallic oxides are added as colour pigments

- Iron oxide - brown
- Copper oxide - green
- Nickel oxide - brown
- Titanium oxide - yellowish brown
- Manganese oxide - lavender
- Cobalt oxide - blue

OPACIFIERS

These include cerium oxide, zirconium oxide, titanium oxide and tin oxide.

PROPERTIES OF DENTAL CERAMICS

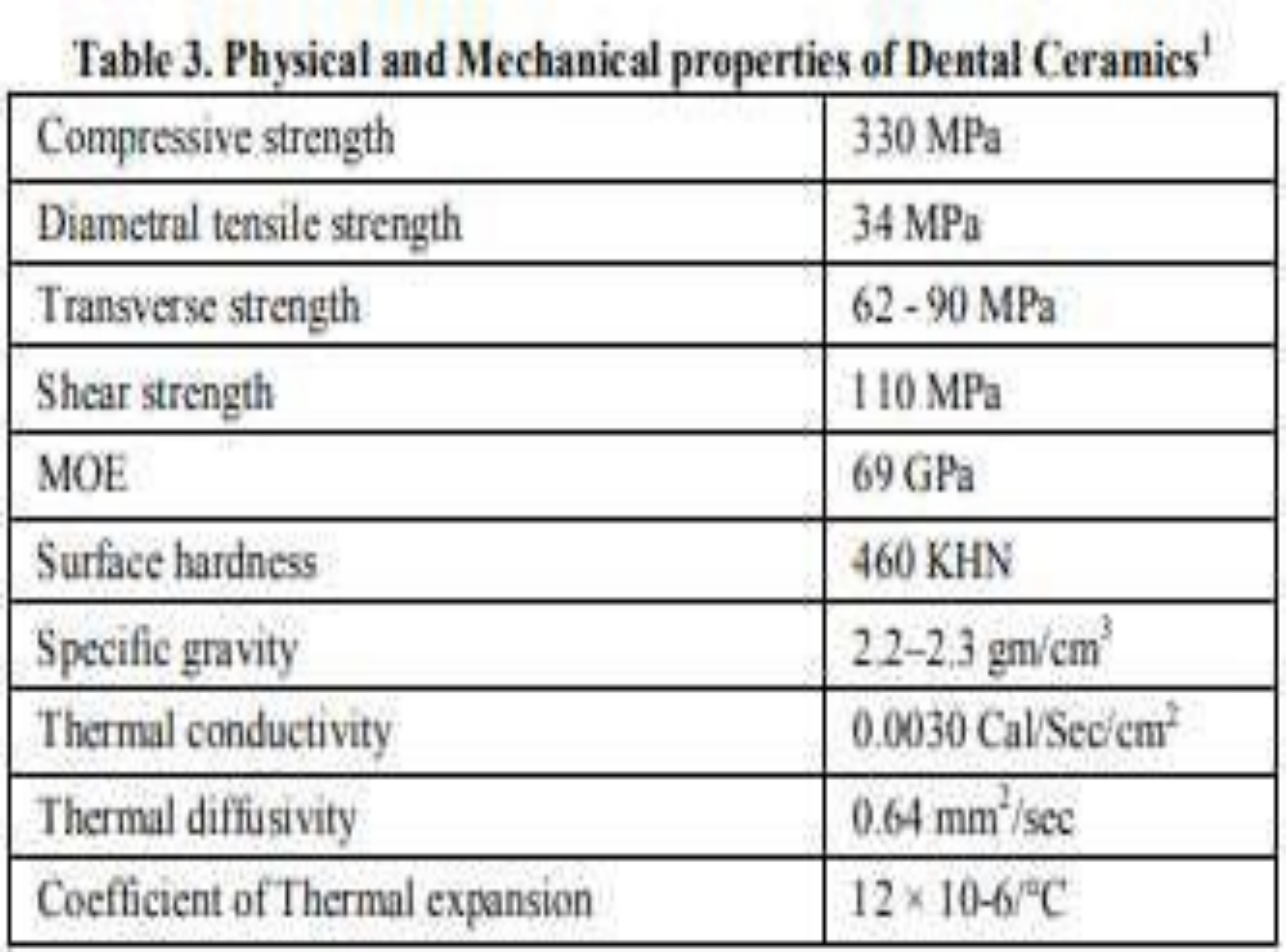


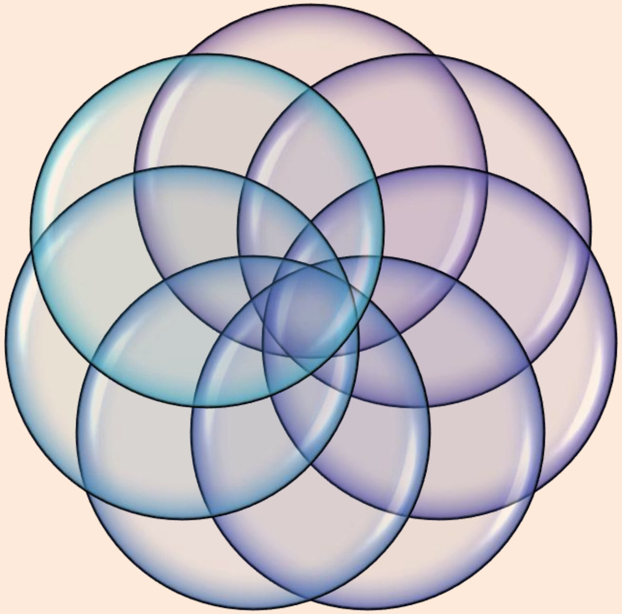
Table 3. Physical and Mechanical properties of Dental Ceramics[1]

Compressive strength	330 MPa
Diametral tensile strength	34 MPa
Transverse strength	62 - 90 MPa
Shear strength	110 MPa
MOE	69 GPa
Surface hardness	460 KHN
Specific gravity	2.2–2.3 gm/cm^3
Thermal conductivity	0.0030 Cal/Sec/cm^2
Thermal diffusivity	0.64 mm^2/sec
Coefficient of Thermal expansion	12 × 10-6/°C

resistant to
corrosion.

chemical
inertness.

stable



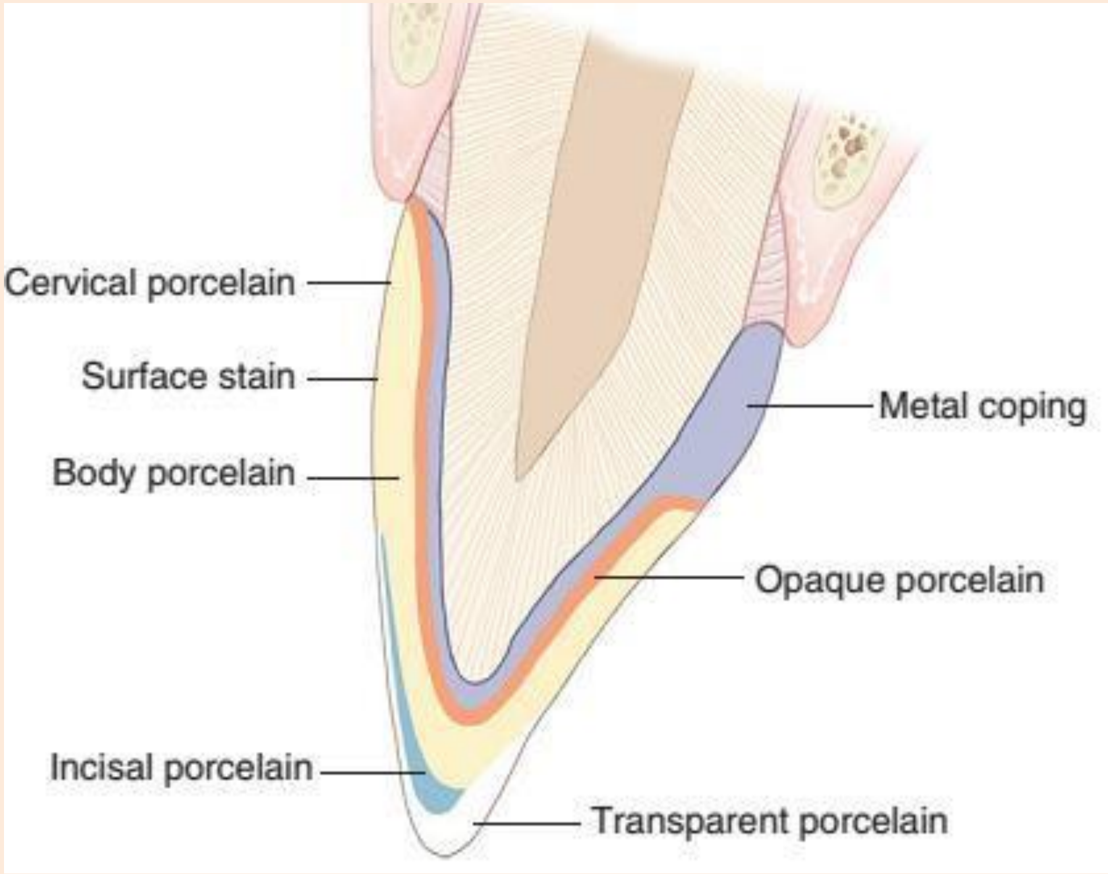
high hardness,
excellent wear
resistance

excellent strength
and fracture
toughness.

biocompatibile,
esthetic , refractory
nature

strong,
temperature-
resistant, and
resilient but brittle.

METAL CERAMIC SYSTEMS: COMPOSITION AND PROPERTIES


Cervical porcelain
Surface stain
Body porcelain
Incisal porcelain
Metal coping
Opaque porcelain
Transparent porcelain

Benefits of metal-ceramic prostheses

- The most outstanding advantage of metal-ceramic restorations is their resistance to fracture.

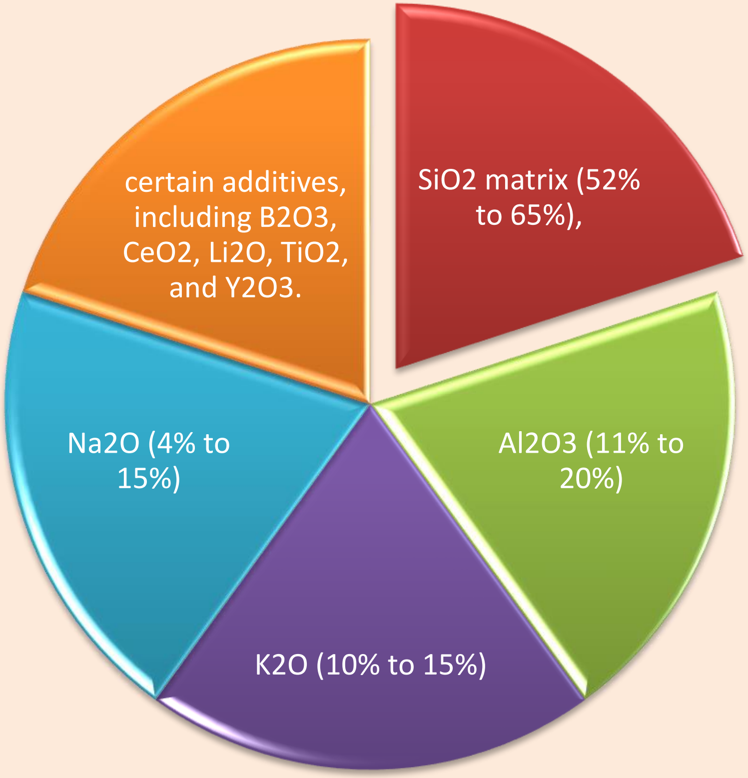
- With metal occlusal surfaces, the fracture rate in posterior sites could be reduced further.

- Advantage of metal-ceramic restorations over total ceramic restorations is that less tooth structure needs to be removed to provide the proper bulk for the crown. Metal alone is used on occlusal surfaces and lingual cusps, and porcelain butt-joint margins are used on facial and buccal surfaces.

- Such design also cause less wear of antagonist enamel surface.

CERAMIC COMPOSITION

1. A silica (SiO2) network and potash feldspar (K_2O•Al_2O_3•$6SiO_2$), soda feldspar (Na_2O•Al_2O•$6SiO_2$), or both.
2. Feldspathic porcelains contain, by weight, a variety of oxides



Potassium feldspar is mixed with various metal oxides

fired to high temperatures

forms leucite and a glass phase that will soften and flow slightly

The softening of this glass phase allows the porcelain powder particles to coalesce.

- Veneering ceramics ("porcelains") for metals have higher expansion and contraction coefficients than the ceramics used to veneer alumina or zirconia core ceramics. There are four types of veneering ceramics. Feldspathic porcelains include

- Ultralow- and low-fusing ceramics (feldspar-based porcelain, nepheline syenite–based porcelain, and apatite-based porcelain)
- Low-fusing specialty ceramics (shoulder porcelains and wash-coat ceramics)
- Ceramic stains
- Ceramic glazes (autoglaze and overglaze)

METAL COMPOSITION

- Single-unit crowns and bridges may be made from metal ceramic systems (combinations of metal substructure and veneering ceramic).
- Many alloys are available to be veneered with low-fusing and ultralow-fusing porcelains.
- The compositions of these high noble, noble, predominantly base metal alloys control the castability, bonding ability to porcelain, the esthetics of the metal- ceramic restoration, and the magnitudes of stresses that develop in the porcelains during cooling from the sintering temperature.

FABRICATION OF METAL CERAMIC PROSTHESIS

CAST METAL FOR METAL-CERAMIC PROSTHESIS

- To bond to alloys suitable for the copings, porcelains must have a sufficiently
  - Low sintering temperature
  - CTEs and CTCs that are closely matched to those of the alloys.

- The gold alloys developed for porcelain bonding have higher melting ranges than typical gold alloys for all-metal prostheses; the higher melting ranges are necessary to prevent sag, creep, or melting of the coping or framework during the sintering and/or glazing of porcelain.

- These gold alloys contain small amounts (about 1%) of base metals such as iron, indium, and tin.

- Both the metal and the ceramic must have coefficients of thermal expansion and contraction that are closely matched such that the metal must have a slightly higher value to avoid the development of undesirable residual tensile stresses in the porcelain.

- High tensile stresses in the veneering ceramic develop from a contraction coefficient mismatch between alloy and porcelain in which porcelain contracts more than the metal.

- For metal-porcelain systems that have an average contraction coefficient difference of ***0.5×10^{-6}/k or less,*** fracture is unlikely to occur.These are known as ***thermally compatible systems***

CAST METAL COPINGS AND FRAMEWORKS (TECHNICAL ASPECTS)

- Copings and frameworks for metal-ceramic prostheses are produced by:

a) Casting of molten metal

b) CAD-CAM machining

c) Electrolytic deposition techniques

d) Swaged metal processes.

- The most common method is the melting and casting of specialized metals for the casting process, the relatively high melting temperatures of most alloys can break down gypsum-bonded investments at the casting temperatures, so the more refractory phosphate-bonded investment must be used.

- Oil from fingers and other sources such as air lines represents a possible contaminant.

- The surface may be cleansed adequately by finishing with clean ceramic-bonded stones or sintered diamonds, which are used exclusively for finishing.

- Final sandblasting with high-purity alumina abrasive before oxidation ensures that the porcelain will be bonded to a clean and mechanically retentive surface.

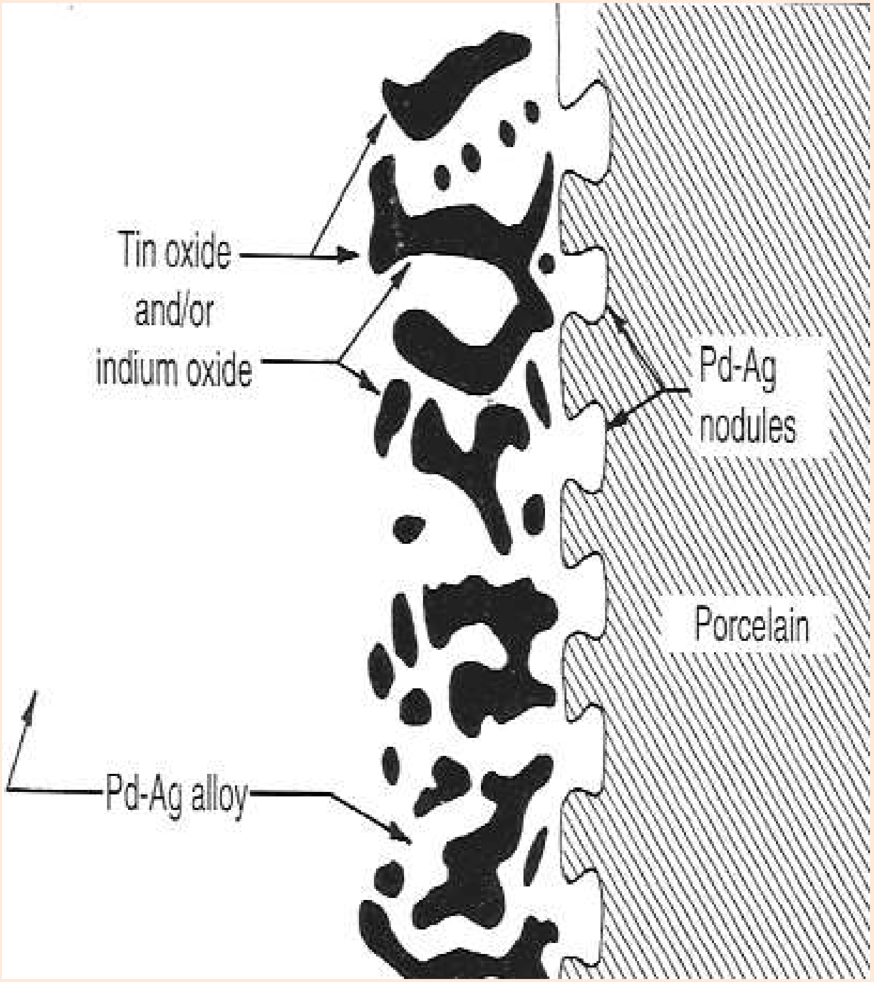
- Opaque porcelain is condensed on the oxidized surface at a thickness of approximately 0.3 mm and is then fired to its sintering temperature. Translucent porcelain is then applied, and the tooth form is created.

Oxidizing

- The base metals form a surface oxide layer during the oxidation treatment, and this surface oxide is responsible for development of a bond with porcelain. This process is sometimes called degassing.

- Controlled oxide layer should be created .

- An alloy such as olympia, a gold-palladium, silver-free alloy, is heated to a temperature of 1038C to burn off any remaining impurities to form a thin oxide layer



CREEP OR SAG

•Base metal alloys are less susceptible to sag deformation than gold-based alloys.

•High-temperature creep or sag of some high noble and noble alloys occurs when the temperature approaches 980C.

•Once the alloy temperature decreases by 100C or more, no further creep deformation occurs.

•For high noble alloys, the span of fixed partial dentures should not exceed three units, since the mass of prosthesis may increase the bending stress to the point where permanent deformation occures at porcelain sintering temperature

Porcelain condensation:

- Porcelain for ceramic and metal-ceramic prostheses as well as for other applications is supplied as a fine powder designed to be mixed with water or binder and condensed into the desired form.

- The porcelain is usually built to shape using a liquid binder to hold the particles together. This process of packing the particles and removing the liquid is known as *condensation*.

- Proper and thorough condensation is also crucial in obtaining dense packing of the powder particles.

- This provides two benefits:

a) Lower firing shrinkage
b) Less porosity in the fired porcelain.

- <u>VIBRATION</u>
- mild vibrations are used to densely pack the wet powder upon the underlying matrix. The excess water comes to the surface and is blotted with a tissue paper.

- <u>SPATULATION:</u>
- A small spatula is used, to apply and smoothen the wet porcelain. This action brings excess water to the surface where it is removed.

- <u>BRUSH TECHNIQUE:</u>
- The dry powder is placed by a brush to the side opposite from an increment of wet porcelain. As the water is drawn toward the dry powder, the wet particles are pulled together.

BINDERS

Distilled water: Is the most popular binder used in dentin and enamel porcelain.

Propylene glycol: Used in alumina core build up.

Alcohol or formaldehyde based liquid for opaque / core build up.


Shade 3 M2 TRANSPA DENTINE
VITAVM15
50g
END ENAMEL
VITAVM15
50g
OP1 OPAQUE
VITAVM15
50g


VITA
VITA OPAQUE FLUID
250ml
VITA
VITA OPAQUE FLUID
VITA VMK Master
VITA TITANKERAMIK
VMK 95
250 ml

Building porcelain:

1. The powder is mixed on a glass slab.

2. The mix should not be overstored to avoid the incorporation of large air bubbles.

3. High room temperature and dry atmosphere is to be avoided as the powder can dry out rapidly due to which air spaces are created in the powder bed.

Firing dental porcelain:

After the condensation and building of a crown it is fired to high density and correct form. At this stage the green porcelain is introduced into the hot zone of the furnace and the firing starts, the glass particles soften at their contact areas and fuse together. This is often referred to as **sintering**

SINTERING PROCEDURE

The condensed porcelain mass is placed in front of or below the muffle of a preheated furnace at approximately 650 °C for low-fusing porcelain.

This preheating procedure permits the remaining water to evaporate.

After preheating for approximately 5 minutes, the porcelain is placed into the furnace and the firing cycle is initiated.

As sintering of the particles begins, the porcelain particles bond at their points of contact and the structure shrinks and densifies.

As the temperature is raised, the sintered glass gradually flows to fill the air spaces.

Air becomes trapped in the form of voids because the fused mass is too viscous to allow all of the air to escape.

An aid in the reduction of porosity in dental porcelain is VACCUM FIRING

When porcelain is placed in the furnance, porcelain powder particles are packed together with air channels around them.

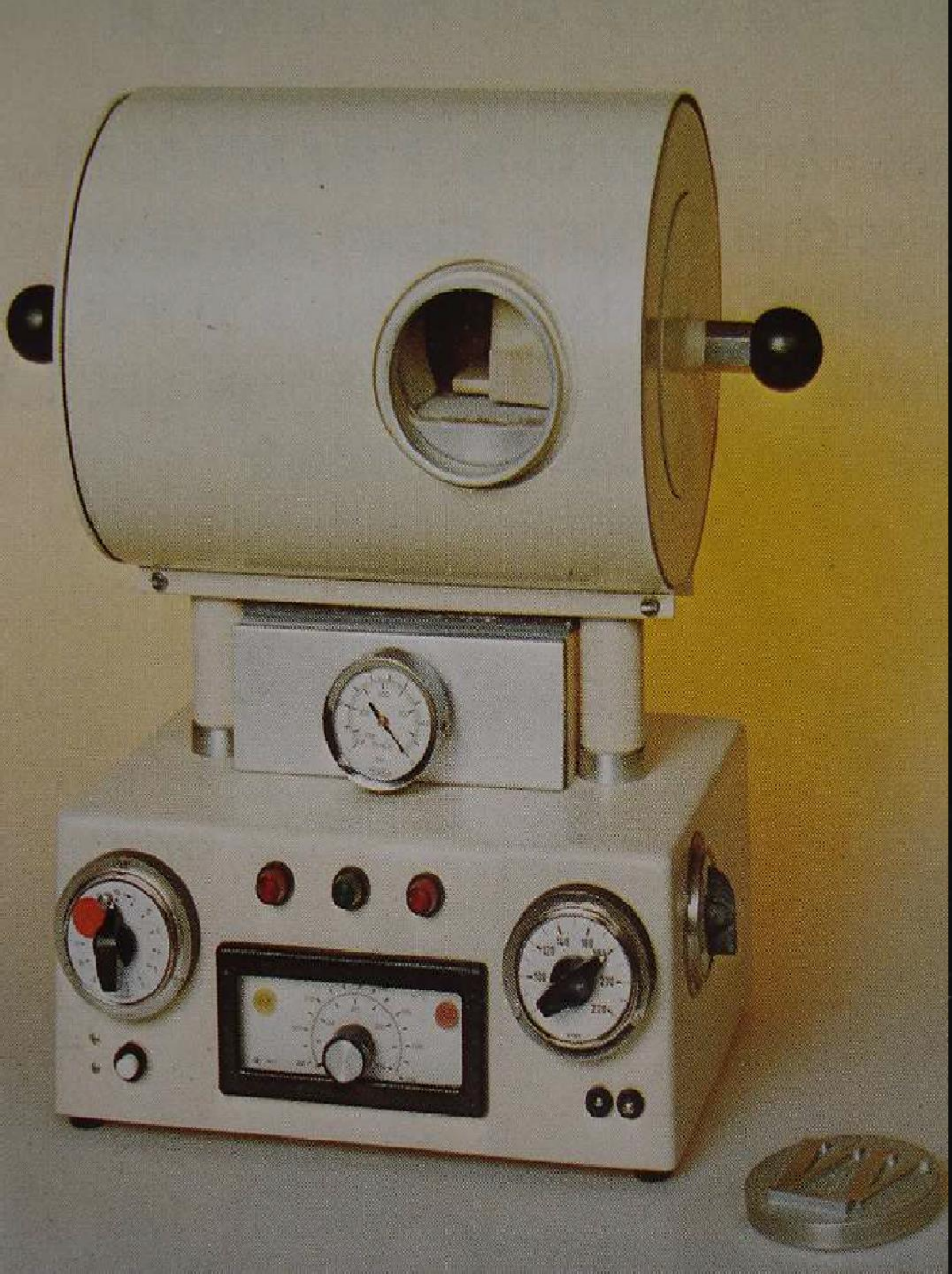
As the air pressure inside the furnace is reduced to about one tenth of atmospheric pressure by the vacuum pump, the air around the particles is also reduced to this pressure.

As the temperature rises, the particles sinter together, and closed pores are formed within the porcelain mass.

At a temperature about 55 °C below the sintering temperature, the vacuum is released and the pressure inside the furnace increases by a factor of 10, from 0.1 to 1 atm.

Because the pressure is increased by a factor of 10, the pores are compressed to one tenth of their original size, and the total volume of porosity is accordingly reduced.

- **Advantages of vacuum-fired porcelain**
  - There is a general increase in the strength of the porcelain.
  - The porcelain will have greater translucence.
  - Porcelain for vacuum firing can have a finer and graded particle size, thus making it less difficult to carve a built-up mass.
  - Shade is markedly affected by vacuum firing. The lessened number of air spaces decreases the internal reflective surfaces.



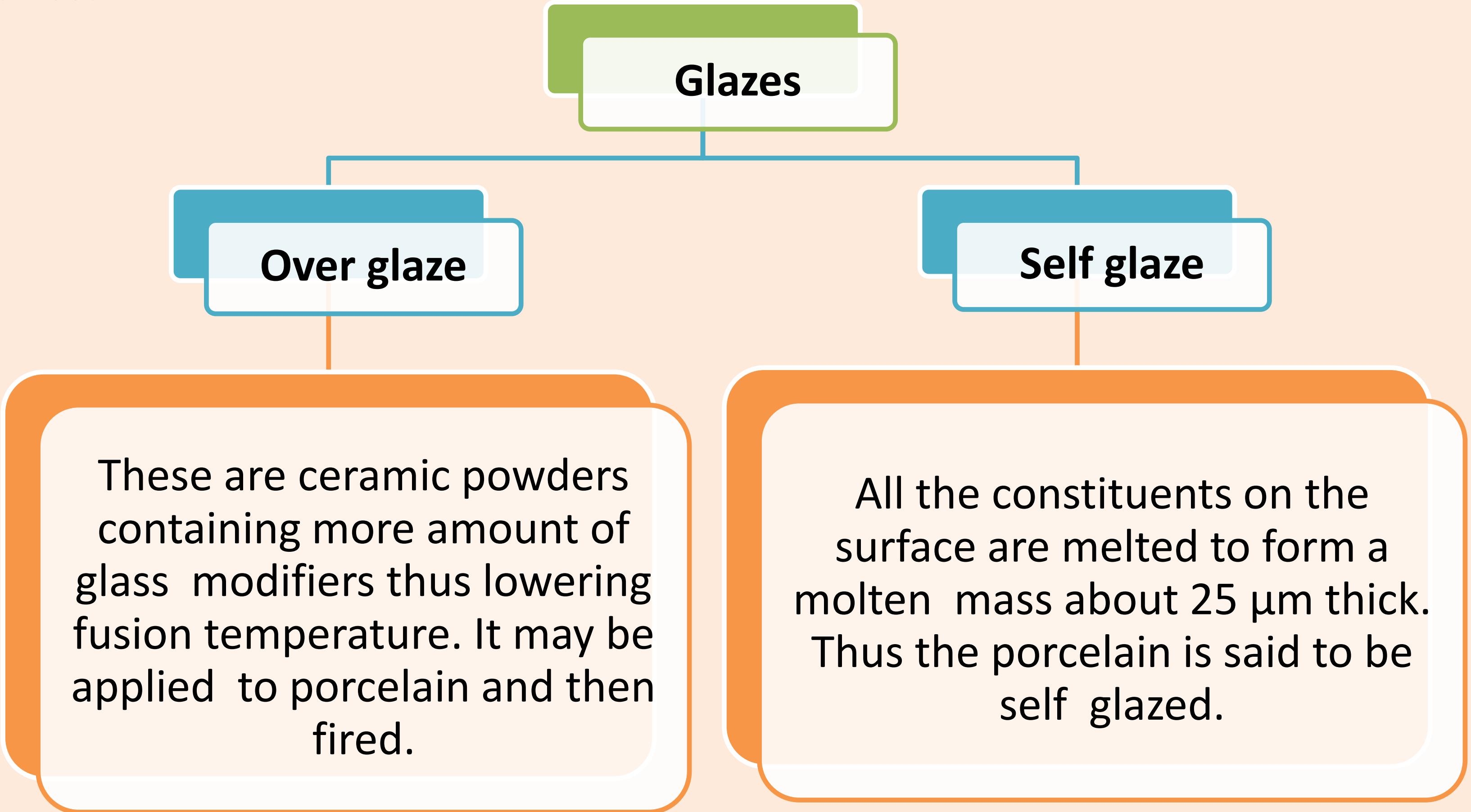

DRY
DRY
EUROMAT

Classification of the Stages in Maturity

Stages in firing	Changes in porcelain
Low Bisque:	• The surface of the porcelain is very porous and easily absorb a water soluble die. • At this stage the grains of porcelain start to soften. • Shrinkage is minimal and the fired body is extremely weak and friable. • Lack translucency and glaze.
Medium Bisque:	• The surface is slightly porous but the flow of the glass grains has increased. • A definite shrinkage has taken place. • Lacks translucency and high glaze.
High Bisque:	• The surface of the porcelain is completely sealed and presents a much smoother surface with a slight shine. • Shrinkage is complete. • Appears glazed.

GLAZES AND STAINS

- The esthetics of porcelains for metal-ceramic and ceramic prosthesis, veneers, and denture teeth may be enhanced through the application of stains and glazes to provide a more lifelike appearance and colour match to adjacent teeth or restorations.
- The fusing temperature of glazes are reduced by addition of glass modifiers, typically alkali oxide, which reduces the chemical durability of glazes.



Glazes

Over glaze

These are ceramic powders containing more amount of glass modifiers thus lowering fusion temperature. It may be applied to porcelain and then fired.

Self glaze

All the constituents on the surface are melted to form a molten mass about 25 µm thick. Thus the porcelain is said to be self glazed.

- Autoglazed feldspathic porcelain is stronger than unglazed porcelain. The glaze is effective in sealing surface flaws and reducing stress concentrations.

- If the glaze is removed by grinding, the transverse strength is reduced and if this surface is left in rough condition it can cause increased wear of enamel.

FIGURE 18-7 Autoglazed veneer ceramic.

METAL-CERAMIC CROWNS AND BRIDGES BASED ON SWAGED METAL FOIL LAMINATES

- The most widely used product of this type has been Captek (Precious Chemicals Co., Inc., Altamonte Springs, FL), which is an acronym for "capillary assisted technology."

- The product is designed to fabricate the metal coping of a metal- ceramic crown without the use of a melting and casting process.

- It is a laminated gold alloy foil sold as a metal strip.

Strip P
Au-Pt-Pd

Strip G
Au-Ag

- For bridges, the pontics are made typically from a palladium- based alloy that is gold-coated. The technology is based on the principle of capillary action to produce a gold-based composite metal.

- Captek P and G metals can yield thin metal copings for crowns or frameworks for metal-ceramic bridges. The maximal span length recommended for Captek-porcelain bridges is 18 mm, which allows space for up to two pontics.

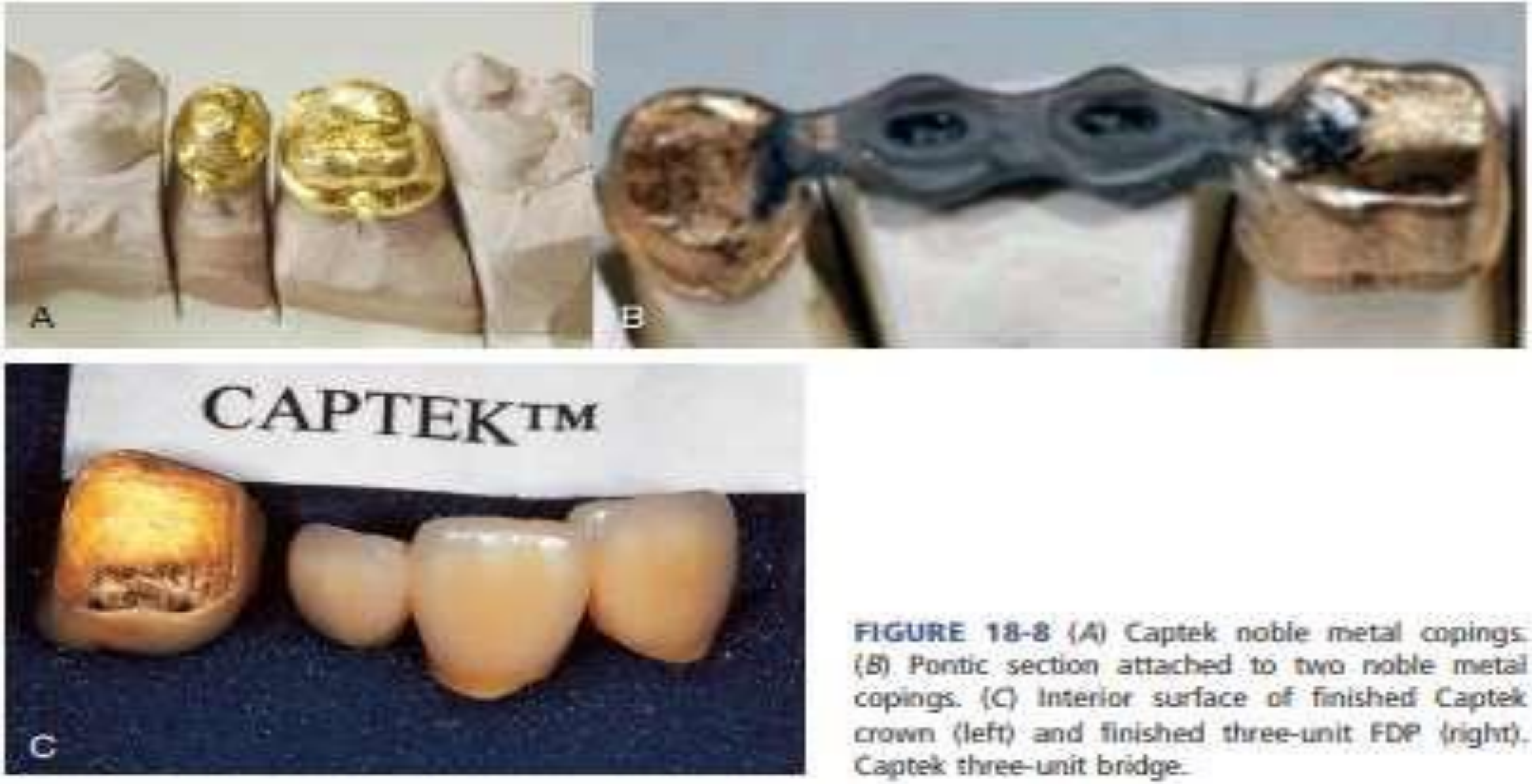


FIGURE 18-8 (*A*) Captek noble metal copings. (*B*) Pontic section attached to two noble metal copings. (*C*) Interior surface of finished Captek crown (left) and finished three-unit FDP (right). Captek three-unit bridge.

FABRICATION BY CAPTEK

Captek™ alloys are composed of two major components:

1. The first component, when heated, forms a microscopic three-dimensional network of capillaries.

2. The second, when melted, flows to fill these capillaries. This microscopic process works by the forces of capillary attraction to produce a solid-metal composite alloy .

Master refractory die is prepared that replicates the prepared tooth.

The die is heat-treated, and the margins are marked with a red pencil. Captek adhesive is applied to the die to enhance adhesion to the Captek metal and to enhance capillary action.

After heat treatment, Captek P metal, a malleable Au-Pt-Pd alloy, is adapted to the surface.

This metal layer provides a three-dimensional capillary network that will subsequently be filled with Captek G metal (97.5% Au, 2.5% Ag by weight) to form an alloy with a high gold content.

After this composite material is burnished on the die and the margins are trimmed, it is sintered in a porcelain furnace.

The metal copings and Pd-Ag pontics (if needed) are then coated with a slurry of Au, Pt, and Pd powder (Capbond) and liquid, resulting in a thin coating of gold to enhance areas of Captek P that have been ground during adjustment and to provide a gold color similar to that of areas that have not been ground.

The metal surfaces are veneered with two thin coats of an opaque porcelain and additional layers of translucent porcelain

- The completed copings have a thickness of approximately 0.25 mm. Thus, this method provides thinner metal copings than those (0.50 mm) typically produced by the cast-metal process.

- The atomic bonding of veneering ceramics to Captek copings and frameworks is controlled by a special bonder layer, while bonding of ceramics to cast metal is controlled by oxidizable elements within the alloy surface.

- The accuracy of marginal adaptation for captek crowns is highly dependent on the skill of the dental technician in trimming the burnished metal copings.

- Another potential concern for the Captek system is the difficulty of bonding the dissimilar metals in the coping and the pontic surfaces.

- Clinical data for Captek crowns and bridges are very limited. Thus, caution must be exercised in using this system for crowns and bridges in high-stress areas.

BONDING PORCELAIN TO METAL

Three factors control the durability of metal-ceramic bonding

- Mechanical interlocking or interatomic bonding at the interface between porcelain and metal oxide.
- Interatomic bonding across the oxide-porcelain interface.
- The type and magnitude of residual stress in the veneering ceramic

Mechanical interlocking or interatomic bonding at the interface between porcelain and metal oxide

- Airborne particle abrasion is used to produce a clean surface with controlled roughness.
- The increased area of the rough metal surface also permits the formation of greater density of chemical bonds.
- Low contact angle between metal and porcelain indicates good wetting and quality of bond that forms.

Interatomic bonding across the oxide-porcelain interface

- The formation of an oxide layer is the key to adequate metal-ceramic bond.
- Elements like tin, indium, iridium are added to form the oxide layer and to improve the bond.
- Some noble alloys containing silver have been shown to lead to porcelain discolouration or **GREENING** due to ionic diffusion of silver in porcelain.

The type and magnitude of residual stress in the veneering ceramic

- High thermal residual stresses between metal and porcelain can lead to failure.
- Porcelain should have thermal contraction coefficient slightly lower than metal. This condition places the porcelain under slight residual compression, which makes it less sensitive to the tensile stresses induced by mechanical loading

FAILURE OF METAL-CERAMIC BONDING

- **Cohesive failure**: Porcelain-porcelain, metal- metal, oxide-oxide.
- **Adhesive failure**: Porcelain-oxide, metal-oxide, metal-porcelain.
- **Mixed failure**: Any combination of the previous failures.

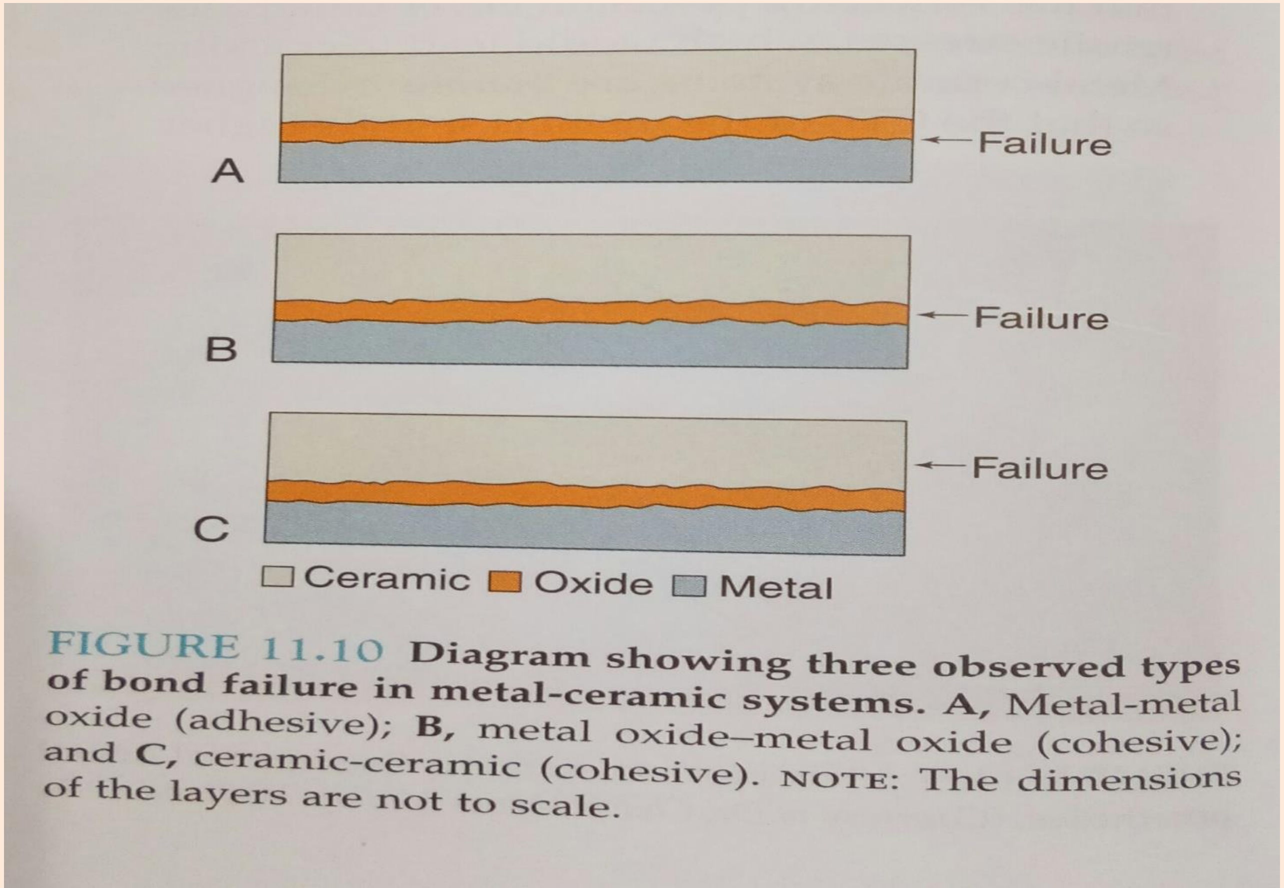


FIGURE 11.10 **Diagram showing three observed types of bond failure in metal-ceramic systems. A,** Metal-metal oxide (adhesive); **B,** metal oxide–metal oxide (cohesive); and **C,** ceramic-ceramic (cohesive). NOTE: The dimensions of the layers are not to scale.

FAILURE AND REPAIR OF METAL-CERAMIC RESTORATIONS

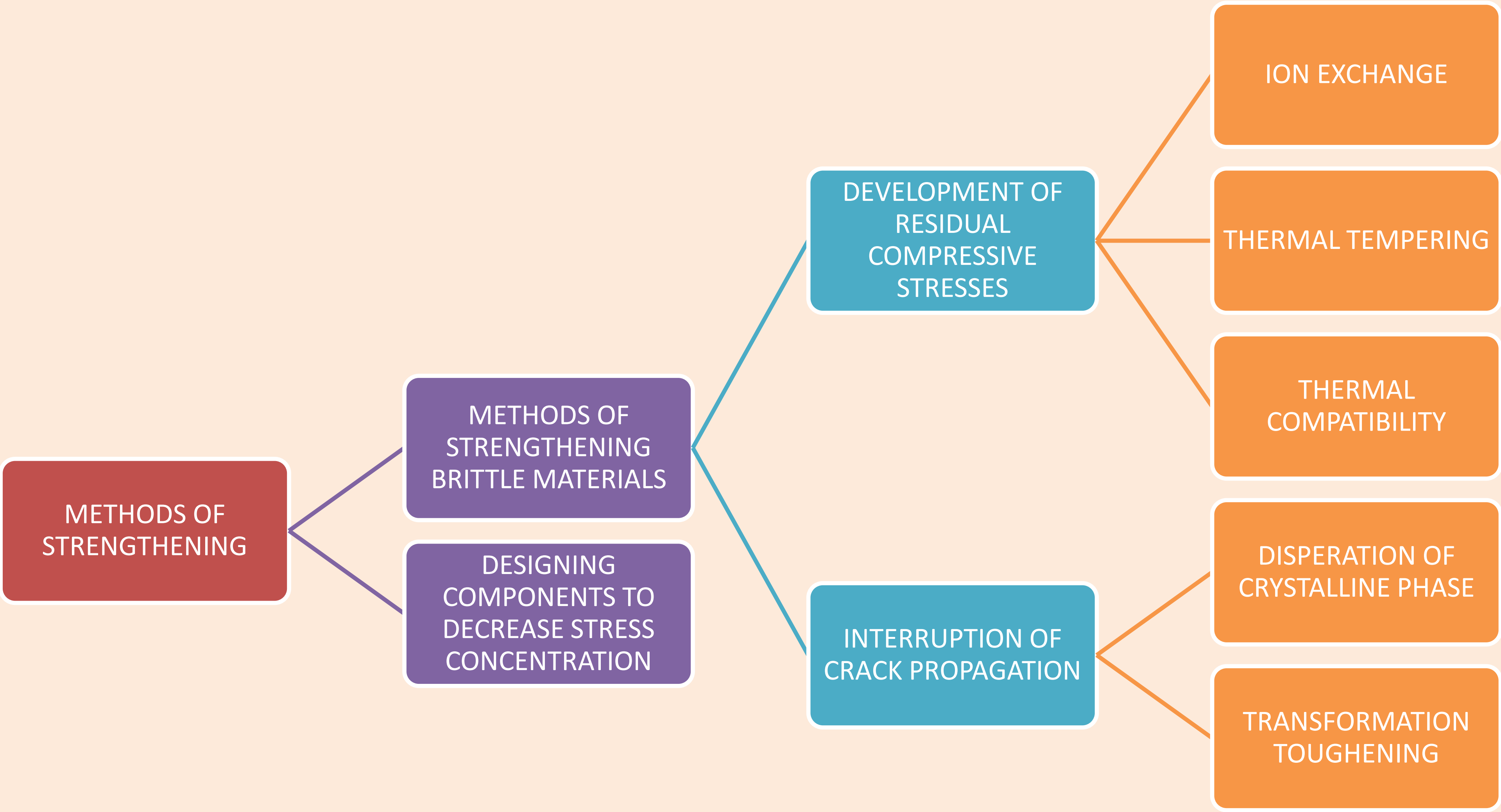
- When metal-ceramic prosthesis fails, it is often due to adhesive failure between porcelain and metal or cohesive failure within the ceramic near the metal-ceramic interface.
- Ideally, the prosthesis should be retrieved, metal surface should be cleaned, and a new oxide layer should be formed on the exposed area prior to porcelain application and firing.
- However, this requires removal of prosthesis which is both unpleasant to patient and time consuming.

So, a variety of other techniques have been developed

1. When porcelain fragments are available and no functional loading is exerted on the fracture site, silane coupling agent can be used to achieve good adhesion between the composite and porcelain.however, this kind of repair is considered only temporary.
2. Systems are available for coating the metal surface with silica particles through the air borne abrasion. The particles are embedded in the metal surface on impact, then a silane coupling agent can be applied.
3. Base metal alloys can be coated with tin followed by application of acid primer.

These methods may delay the eventual need for remaking the prosthesis.

METHODS OF STRENGTHENING CERAMICS



METHODS OF STRENGTHENING

- METHODS OF STRENGTHENING BRITTLE MATERIALS
  - DEVELOPMENT OF RESIDUAL COMPRESSIVE STRESSES
    - ION EXCHANGE
    - THERMAL TEMPERING
    - THERMAL COMPATIBILITY
  - INTERRUPTION OF CRACK PROPAGATION
    - DISPERATION OF CRYSTALLINE PHASE
    - TRANSFORMATION TOUGHENING
- DESIGNING COMPONENTS TO DECREASE STRESS CONCENTRATION

DEVELOPMENT OF RESIDUAL COMPRESSIVE STRESSES

- During cooling if porcelain veneer contracts more than the metal coping or framework, axial and hoop tensile stresses may develop which may cause cracking of ceramic.

- If compressive stress is developed in the area of ceramic structure, a greater level of offsetting tensile stress would need to be developed during oral function of the prosthesis to reach the tensile stress needed to cause fracture.

ION EXCHANGE

- This technique is also called as **chemical tempering**

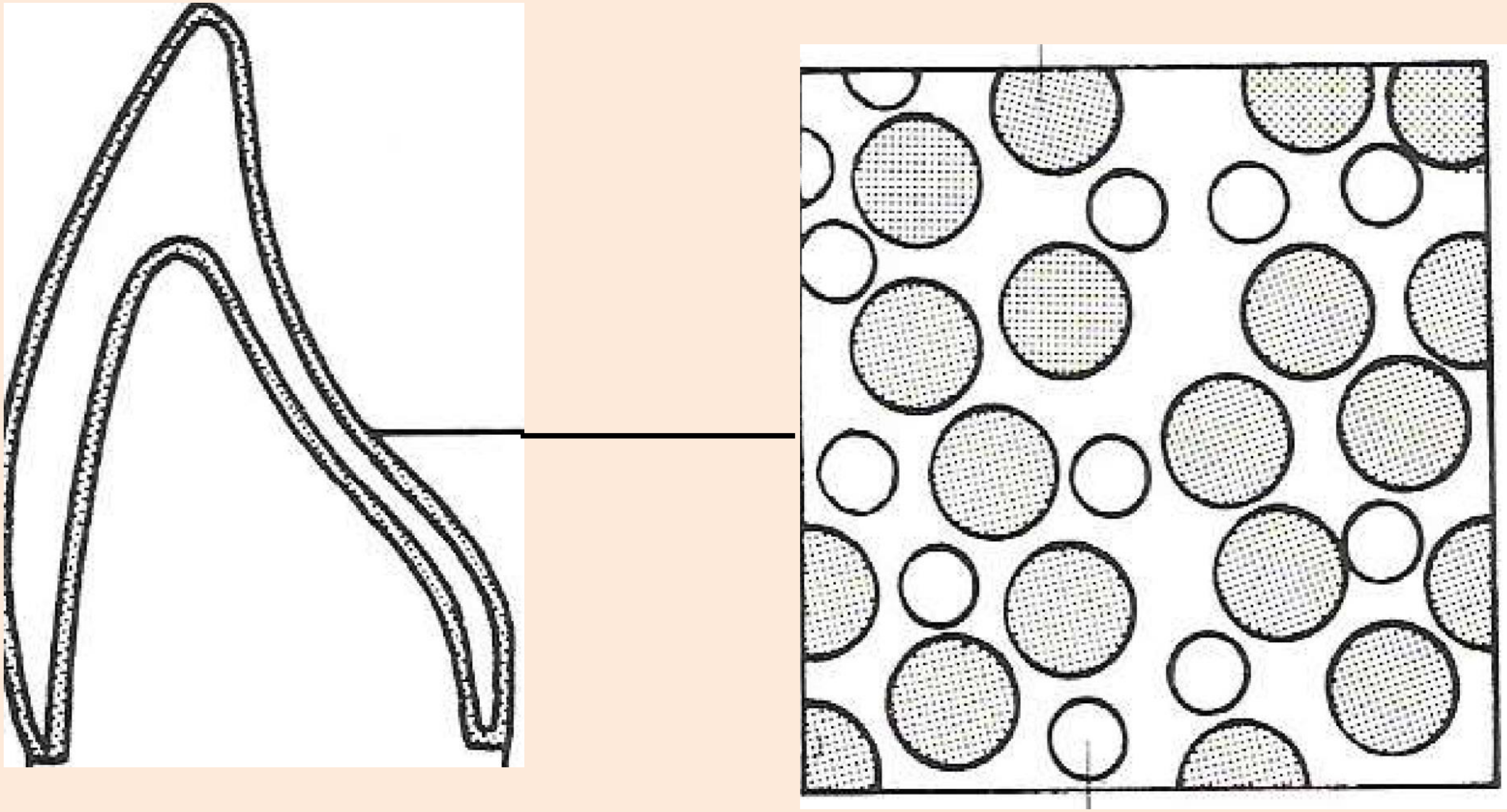
- In this procedure a sodium containing glass is placed in a bath of molten potassium nitrate, potassium ions in the bath exchange places with some of the sodium ions in the surface of the glass particle.

- The potassium ion is about 35% larger than the sodium ion. The diffusion of the potassium ion into place formerly occupied by sodium ion creates large residual compressive stresses in the surface of the glass. These residual stresses produce a strengthening effect.

- The depth of compression zone is less than 100um

Ion-exchanged crown

Porcelain after ion-exchange in potassium nitrate



Surface Porcelain strengthened by crowding of Atoms

● K^+ ○ Na^+

Thermal tempering:

- This is the most common method of strengthening glass.

- This creates residual surface compressive stresses by rapidly cooling (quenching) the surface of the object while it is hot and in the softened state.

- This rapid cooling produces a skin of rigid glass surrounding a soft molten core. As the molten core solidifies, it tends to shrink, but the outer skin remains rigid.

- The pull of the solidifying molten core as it shrinks, creates residual tensile stresses in the core and residual compressive stresses within the outer surface.

- For dental applications it is more effective to quench the glass phase ceramics in silicone oil or other special liquids than using air as it may not uniformly cool the surface.

Thermal compatibility

- The metal and porcelain should be selected with slight mismatch in their thermal contraction coefficient.

- Usually the difference of $0.5 \times 10^{-6}/°C$ in thermal expansion between metals and porcelain .

- It causes the metal to contract slightly more than does the ceramic during cooling after firing the porcelain which results in development of residual compression in the ceramic surface.

MINIMIZING THE EFFECT OF STRESS CONCENTRATIONS

- The surface flaws act as sharp slits under intraoral loading, tensile stresses concentrate at the tips of these flaws and can result in formation of crack.

- Stress raisers are discontinuities in ceramic structures in brittle materials that cause stress concentration.

- Abrupt changes in shape/ thickness in the ceramic contour can act as stress raisers and make the restoration more prone to failure.

- Sharp line angles in preparation and small particle of porcelain along internal margin of crown also causes tensile stresses.

- If the occlusion is not adjusted properly on a porcelain surface, contact points rather than contact areas will greatly increase the localized stresses in the porcelain surface as well as within the internal surface of the crown.

- These contact stresses can lead to the formation of the **Hertzian cone cracks**, which may lead to chipping of the occlusal surface.

Dispersion of crystalline phase

- The crystalline phase with greater thermal expansion coefficient than the matrix produces tangential compressive stress (and radial tension) near the crystal matrix interface. Such tangential stresses divert the crack around the particle.

- When a tough, crystalline material such as a alumina in particulate form is added to a glass, the glass is toughened and strengthened because the crack cannot penetrate the alumina particles as easily as it can the glass and this technique is applied in the development of aluminous porcelains for PJCs.

ALL-CERAMIC SYSTEMS

ALUMINOUS PORCELAIN

- McLean and Hughes(1965) developed an alumina-reinforced porcelain core material for the fabrication of ceramics crowns.

- They provide slightly better esthetics for anterior teeth.

- However, the strength of the core porcelain used for alumina-reinforced crowns was inadequate to warrant its use for posterior teeth.

•One method of producing aluminous porcelain crowns was to form a tin oxide coating on platinum foil. The objective of this technique was to reduce the weakening effect of surface irregularities on the inner surface of porcelain crowns by bonding a thin platinum foil to the inner surface that would be cemented to the prepared tooth.

•Atomic bonding of aluminous porcelain was promoted by electroplating the platinum foil with a thin layer of tin and oxidizing it in a furnance to provide a continuous film of tin oxide.

•It reduces subsurface porosity and the formation of microcracks in the porcelain, thereby increasing the fracture resistance of the restoration.

•The clinical performance of these crowns was excellent for anterior teeth.

GLASS-CERAMICS

- A glass-ceramic is a material that is formed into the desired shape as a glass and then subjected to a heat treatment to induce partial devitrification-that is, loss of glassy structure by crystallization of the glass.

- Crystalline particles,needles, or plates formed during the ceramming process interrupted the propagation of cracks in the material when an intra-oral force is applied, thereby promoting increased strength and toughness.

- The use of glass-ceramics in dentistry was first proposed by MacCulloch in 1968.

The first commercially available castable ceramic material for dental use, DICOR, was developed by Corning Glass Works and marketed by Dentsply International.

Dicor was a castable glass formed into an inlay,facial veneer, or full crown

Formed by lost wax casting process.

After the glass casting core or coping was recovered from the casting investment the glass was sandblasted to remove the residual casting investment and the sprues are cut away.

The glass was then covered by a protective “embedment” material and subjected to a heat treatment.

- This heat treatment caused microscopic platelike crystals of tetrasilicic fluormica to grow within the glass matrix-CERAMMING

Once the glass was cerammed, it was fit on the prepared dies, ground as necessary, and coated with veneering porcelain and a stain and glaze layer to match the shade and appearance of adjacent teeth.

- Dicor glass ceramics was capable of producing remarkably good esthetics, perhaps because of “CHAMELEON EFFECT” in which part of the color of the restoration was picked up from the adjacent teeth as well as from the tinted cements used for luting the restorations.

- This type of ceramic is characterized by the controlled crystallization of a glass through the presence of one or more nucleating agents.

Composition

- Dicor contains 55% by volume of tetrasilicic fluormica ($KMg_2.5Si_4O_{10}F_2$),
  derived from the quaternary ceramic system,K_2O-MgF_2-MgO-SiO_2.

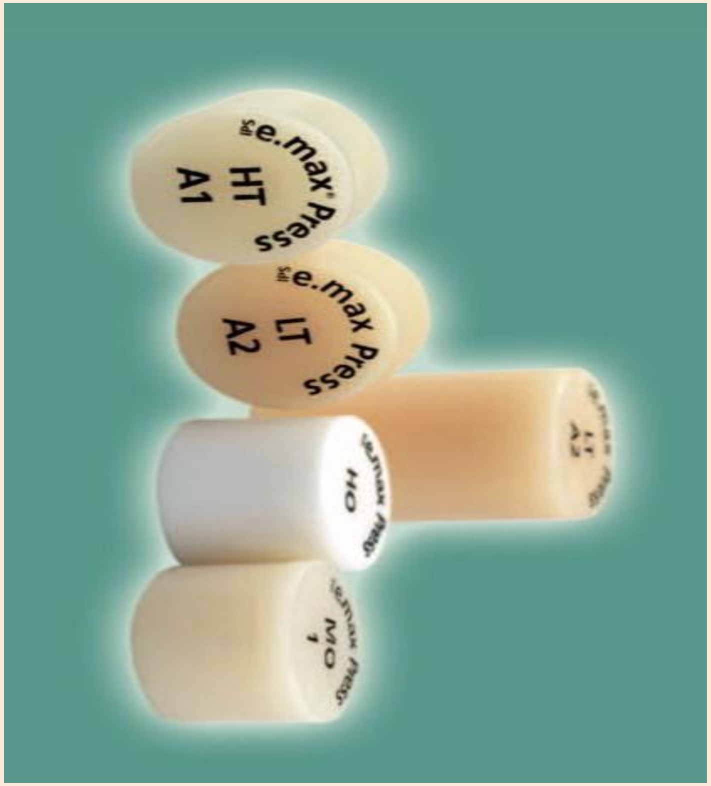
- Dicor was the first castable glass used for dental prosthetic applications.

Drawbacks

- It has low flexural strength(110 to 172MPa)
  low fracture toughness(1.6 to 2.1MPa.$m^{1/2}$)
- Dicor and Dicor MGC glass ceramics are no longer used in dentistry.

HOT-ISOSTATICALLY PRESSED (HIP) GLASS-CERAMICS

Leucite-based glass ceramic



Indications

- for anterior veneer and crowns and premolars inlays, onlays and crowns

The most well-known leucite-based products are

- IPS Empress(Ivoclar Vivadent)
- Cerpress SL Pressable Ceramic System(Leach and Dillon)
- Finesse All-Ceramic System(DENTSPLY Ceramco)

- Contain approximately 35% by volume of leucite($K_2O.Al_2O_3.4SiO_2$) crystals.
- The glass-matrix layering ceramic for these core materials also contains leucite.

Drawback

- Low flexural strength(upto 112MPa)
- Low fracture toughness(0.9 to 1.3 Mpa.$m^{1/2}$)
- Not recommended for molar crowns or bridges.

Lithia-based products

IPS Empress 2(Ivoclar Vivadent)

Optec OPC 3G (Pentron laboratory technologies)

- contain approximately 65% to 70% by volume of lithia disilicate ($Li_2O.2SiO_2$) as the principal crystal phase.

- The lithia disilicate materials used as glass-ceramics have a narrow sintering range, which makes processing of ceramic prosthesis very technique sensitive.

- This glass-ceramic is composed, by volume, of approximately 70% lithium disilicate and 30% glass.
- It is fairly translucent but somewhat more opaque than the leucite-based glass-ceramic(Empress), but it is a stronger core ceramic than leucite-based glass-ceramic.

- Mean flexural strength is approximately 350 Mpa.
- Fracture toughness is 3.3 Mpa.m$^{1/2}$

Indications

- most anterior and posterior crowns and for anterior three unit bridges.

Drawback

- Although the core ceramic fracture resistance is moderately high, veneered prosthesis have been reported to be susceptible to chipping, which may require replacement or recontouring of the affected prosthesis.

GLASS-INFILTERED CORE CERAMICS

To minimize sintering shrinkage and to ensure adequate fit of ceramic prosthesis, three glass-infiltered core ceramic systems have been developed.

- One based on partially sintered alumina
- One based on a magnesia-alumina spinel(MgAl2O4)
- One with a zirconia-alumina core.

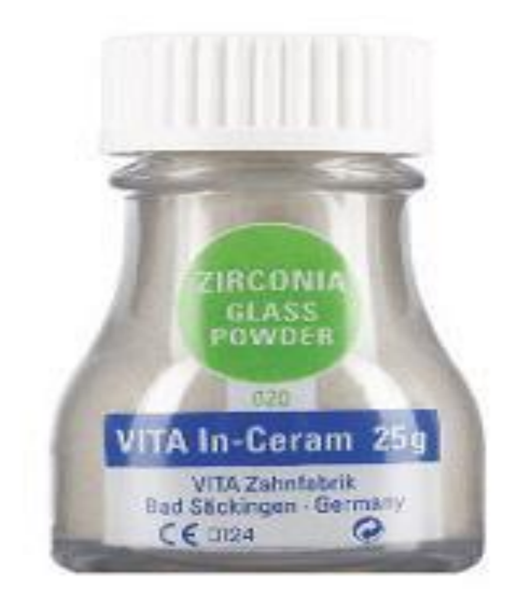
VITA In-Ceram Alumina

Contains approximately 85% of alumina by volume.

- The partially sintered framework is formed by slip-casting process, which produces dense packing of particles against a porous die
- After firing at 1120C for 10 hours or more, a partially sintered structure is formed.This porous core ceramic framework is then infused with molten lanthanum glass.

In-Ceram Zirconia

- In-ceram Zirconia contains 62% alumina, 20% zirconia, and 18% infiltrated glass.
- In its glass infused form, it is indicated primarily for crown copings and three unit anterior and posterior frameworks.



- After glass infiltration, In-Ceram Spinell ceramic is more translucent than In-Ceram Alumina or In-Ceram Zirconia but its mean strength is significantly lower.

- Mean flexural strength

In-Ceram Spinell-350MPa
In-Ceram Alumina-600MPa
In-ceram Zirconia-620MPa

- Because there is no shrinkage associated with this process, marginal adaptation is expected to be comparable to hot-pressed method but it is superior to the copy-milled technique.

ALUMINA CORE CERAMIC

PROCERA ALLCERAM(Nobel Biocare) is an alumina core ceramic that is indicated for anterior and posterior crowns.

- A die is first produced from an impression and digitized using a mechanical profiling device and a computer that converts the coordinates of the die surface into a digitized database.
- An oversized die is then produced onto which pure alumina is dry pressed
- The oversize green alumina body is then sintered and the resulting shrinkage yields the desired size and shape, onto which a feldspathic porcelain veneer is applied and sintered.

- The Procera All Ceram core is more translucent than In-Ceram Zirconia and it has comparable strength(620 to700MPa)

- Since alumina cannot be acid etched to produce micromechanical retention, sandblasting the surface with silica-coated alumina particles by a rocatec system is required to ensure resin bonding.

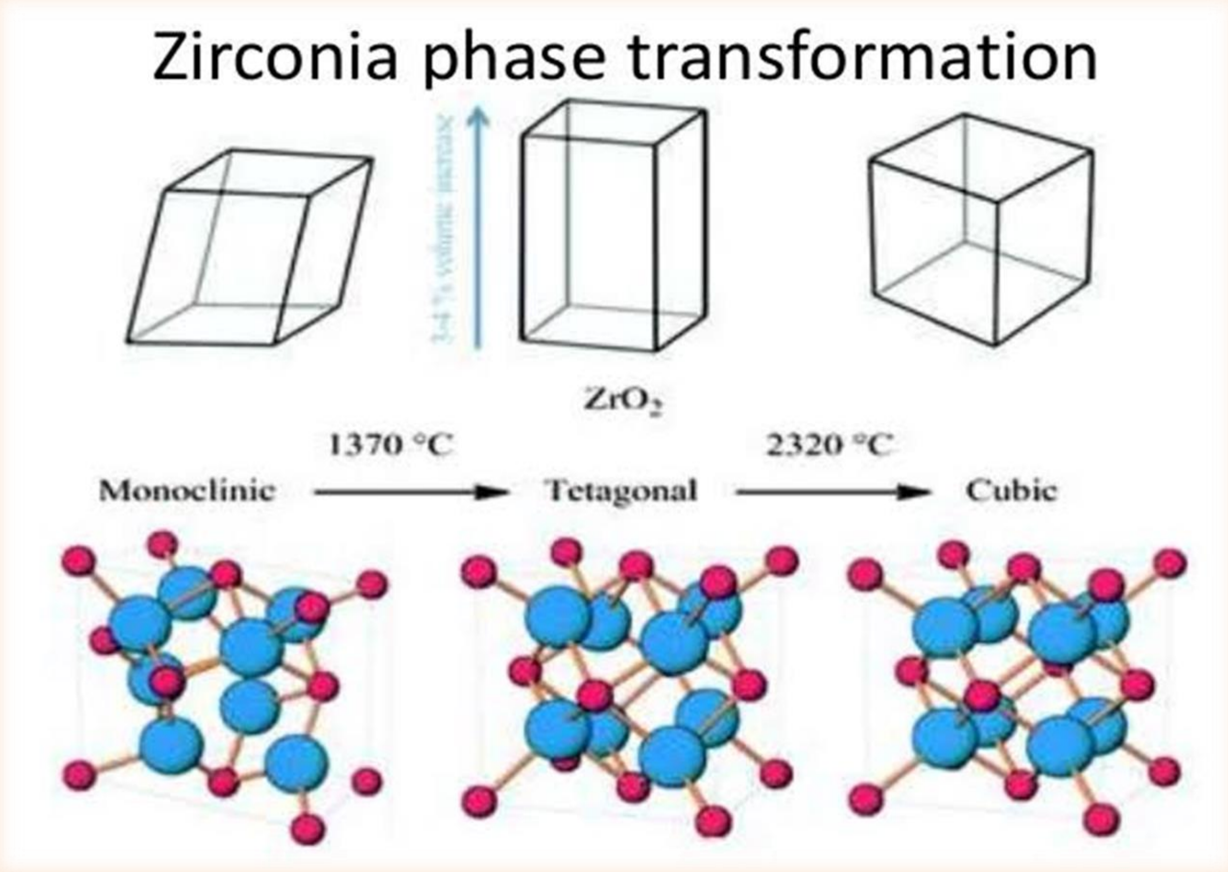
YTTRIA-STABILIZED ZIRCONIA

Under atmospheric pressure, pure zirconia can exhibit three different crystal structures.

At temperatures greater than 2367C, zirconia has a cubic structure

Between 1167C and 2367C, zirconia is tetragonal

Below 1167C, zirconia is monoclinic



- The tetragonal to monoclinic phase transition results in a 3% to 5% volume increase, which produces cracks in the bulk zirconia samples and a reduction in strength and toughness.

- If one modifies the composition by doping with Mg, Ca, Sc, Y, or Nd, the high-temperature tetragonal phase can be stabilized at room temperature.

- Tetragonal to monoclinic phase transformation stresses are avoided, microcracks are prevented.

- Another possibility for stabilizing the high-temperature tetragonal phase at room temperature is to reduce the crystal size to less than 10nm.

Zirconia

- Zirconia is a non-metal with an extremely low thermal conductivity-about 20% as high as that of alumina(Al2O3).

- It is chemically inert and highly corrosion resistant.

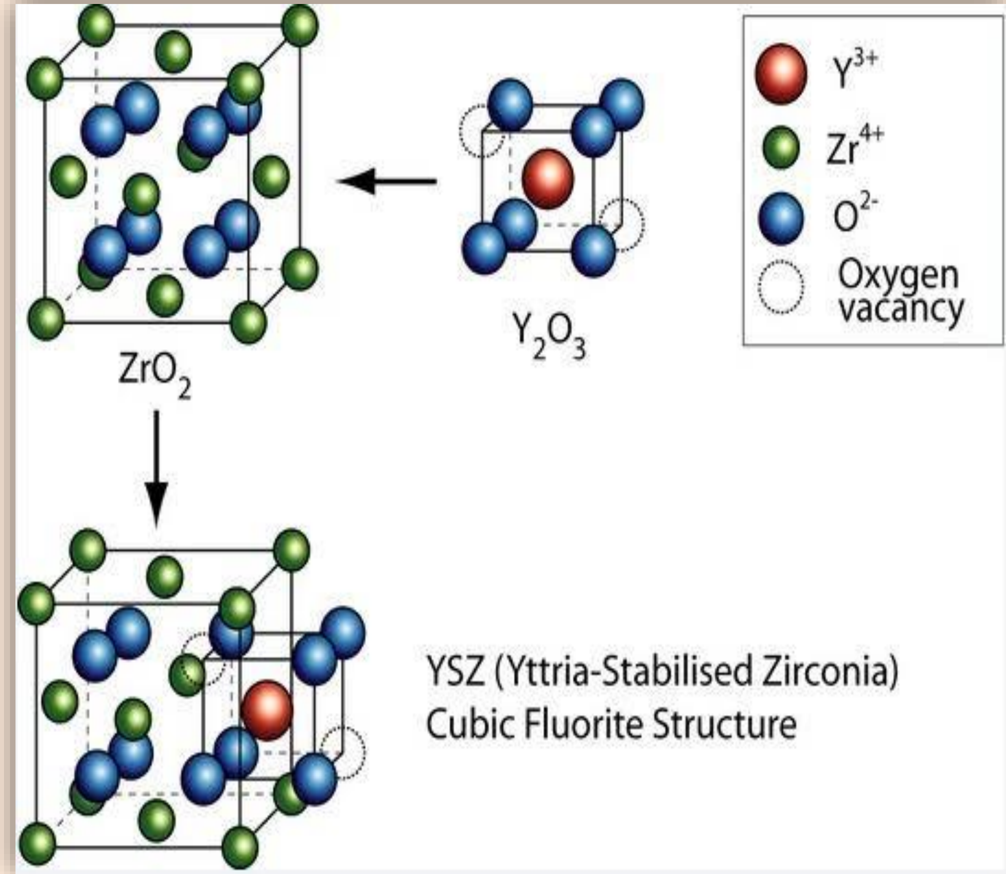
- Pure ZrO2 has a monoclinic crystal structure at room temperature and transforms to tetragonal and cubic zirconia at elevated temperatures.

- To solve this problem, stabilizing oxides such as magnesium oxide(MgO), yttrium oxide(Y2O3), calcium oxide(CaO), and cerium oxide(Ce2O3) are added to zirconia.

- The stability of single-phase tetragonal zirconia is enhanced by highly stable trivalent stabilizers such as yttria, which induce vacancies, or tetravalent stabilizers such as ceria, which are oversized or undersized with respect to zirconium.

- The most common stabilizer for dental applications is yttria(Y2O3). The addition of 3 to 5 mol% of Y2O3 results in a stabilized core ceramic referred to as yttria-stabilized zirconia or yttria- stabilized tetragonal zirconia polycrystals (Y-TZP).

- The structural stabilization of zirconia by yttria results in a significant proportion of metastable tetragonal phase.



- This metastable tetragonal phase strengthens and toughens the structure by a localised transformation to the monoclinic phase when tensile stresses develop at crack tips.

- The resulting volume expansion adjacent to crack tips produces a high local compressive stress around the crack tips, which increases the localized fracture toughness and inhibits the potential for crack propagation.

- This phenomenon of transformation toughening increases the flexural and tensile fracture resistance of stabilized zirconia prosthesis and presumably the survival of zirconia based restorations.

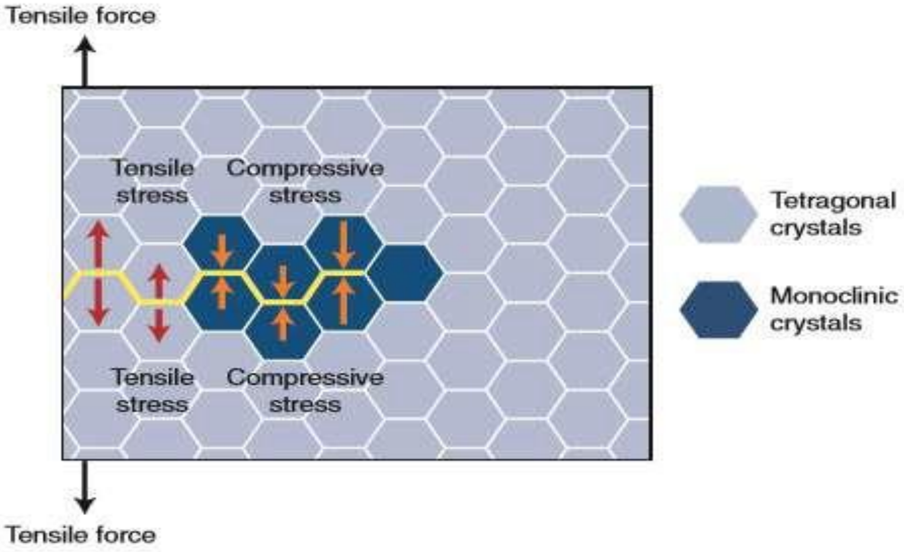


FIGURE 18-35 Schematic illustration of transformation toughening of a Y-TZP ceramic.

Many Y-TZP products are available in dentistry for CAD-CAM processing.These Y-TZP products fall into three groups

•Products that are milled in the green (compacted) state
•Products that are milled in a partially sintered state
•Products that are milled in a fully sintered state

Because of strengthening and toughening mechanism, yttria stabilized zirconia is sometimes refered to as ceramic steel.

•A regeneration heat treatment of machined or superficially ground Y-TZP at 900C for 1 hr or for less time at 900C to 1000C converts the monoclinic phase within the surface back to the tetragonal phase.

•Thus if veneer firing occurs after a grinding procedure, the thermal treatment can induce the reverse transformation of monoclinic to the tetragonal phase in the ground areas of the zirconia structure.

CAD-CAM

- CAD-CAM technology designs a ceramic restoration from a captured optical impression of a prepared die.

- The CAD system projects this image of the preparation and the surrounding structures onto a computer monitor , allowing an operator to design the parameters of the restoration(i.e., occlusal, gingival margins).

- The CAM portion of the system allows the computer to direct the micromilling device to machine the ceramic restoration to the exact dimensions designed by the operator.

- This method involves the manipulation of a three-dimensional (3D) design on the computer. A virtual die and framework are created digitally, therefore eliminating the need for wax up.

- A computer controlled milling machine with automated production is used to fabricate an oversized framework, which is then fully sintered.

- The CAD/CAM system includes three components:
  - Scanning
  - Designing
  - Milling

The types of scanning methods are

- Optical camera
- Contact digitization(mechanical scanner)
- White or coloured light or laser projection

- CEREEC 3D,Sirona System uses an intra-oral optical camera to produce a digital image of the prepared tooth and the adjacent teeth.

- Procera system reads the surface of stone master die of the prepared tooth using a sphere or scanning stylus that is in the contact with the stone surface.

- LAVA Chairside Oral Scanner uses a triangulated, white light optical system to digitize the master model. Not only are the tooth preparations digitized, but also full anatomic contours can be developed from an internal library or scanned in manually.

CAD Software

- The CAD software program mimics the same steps that a technician will follow to fabricate the prosthesis i.e. Margin selection, block out of any undercuts, placement of a die spacer for a cement layer, path of insertion in case of multiple abutments.

- By using the standard template library(STL) open file format, data can be sent to any CAM system that accepts STL.

CAD Hardware

The actual fabrication can be accomplished by either subtractive or additive method.

Subtractive technique

- It involves cutting the coping or framework from a solid block.

- Restorations milled out of sintered monoblock from hard machining will be more accurate in shape with precise dimensions.
- Requires more time
- Machine tools are exposed to heavy wear.
- More risk of introducing microscopic cracks.

- Soft machining requires less time, there is less wear of machining tools, however the accuracy of shape and contour is more crucial because shrinkage must be compensated for and controlled.

Additive technique

- It involves building a coping or partial denture framework by adding materials onto the die.
- An oversized metal die should be created to allow for shrinkage during sintering process.
- As the powder is applied to the oversized metal die, it is compacted under isostatic pressure.
- At this green stage a CAM milling procedure is used to finalize the outside contours of coping or framework.

Evolution of CEREC system

- Chairside Economical Restoration of Esthetic Ceramics

or

- computer-assisted CERamic REConstruction

- Mörmann and Brandestini of zurich university developed in 1980

- Dr. Alain Ferru, a young French software engineer developed the basic layout of the design software in 1983

CeReC 1

- CEREC was first introduced in 1986
- It consisted of a mobile unit containing :
  - 1.A small camera
  - 2.A computer with screen and
  - 3.3-axis-of rotation milling machine
- The Old milling machine water-pressure driven.
- Clinical shortcoming
  - Occlusal anatomy had to be created by the clinician
  - Inaccuracy of fit or large interfacial gaps
  - Clinical fracture
  - Relatively poor esthetics

CeReC 2

- Mobile unit containing small camera, computer with screen and 3-axis-of-rotation milling machine with electric motor

- better and smoother cutting of ceramic - better fitting restorations

- Upgrading of software - allows machining of occlusal surface

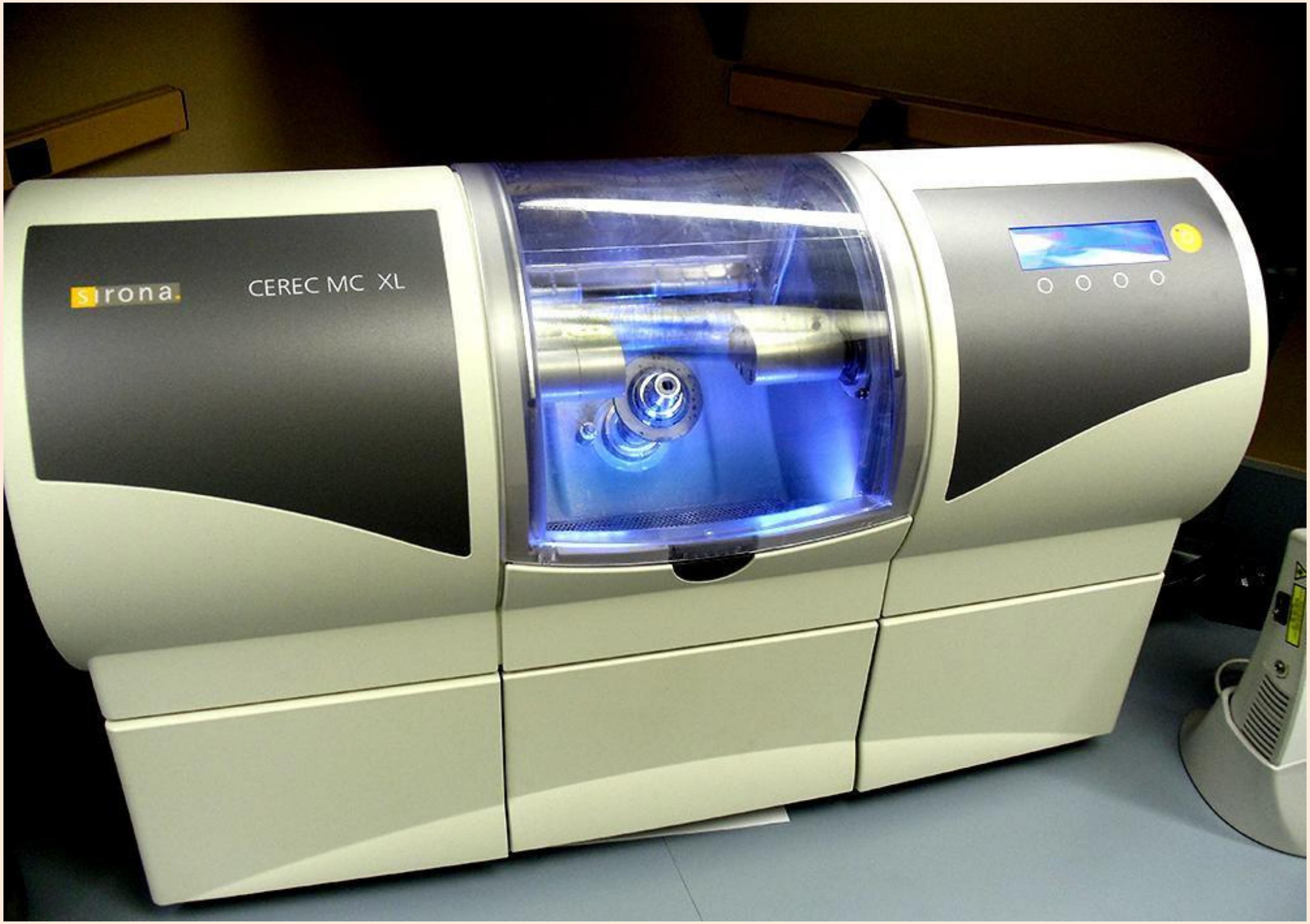
CeReC 3

- In 2003,three-dimensional virtual display of the preparation, of the antagonist and of the functional registration became available

- The 2005 and 2006 versions include the automatic adjustment of a selected digital full-crown anatomy to the individual preparation, to the proximal contacts and to the occlusion

- In 2006, a “step bur” replaced the cylinder

CEREC AC, Sirona Dental System



CONCLUSION

- Dental ceramic technology is one of the fastest growing areas of dental material research and development. The past decades have seen the development of several new groups of ceramics.

- Each system has its own merits, but may also have shortcomings.

- Combination of materials and techniques are beginning to emerge which aim to exploit the best features of each.

- The diversity and sophistication of the CAD-CAM systems may prove to be influential in the future.

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THANK YOU