All-Ceramic Restorations

Dr. Ala'a Al-Haddad

BDS, MFDS, MSc, PhD

Assistant professor, Conservative Dentistry (University of Jordan)

Fixed & Removable Prosthodontics (University of Manchester, UK)

Outline:

- Background
- Dental ceramics
- Characteristics
- Applications
- Composition
- Classifications
- Fabrication techniques
- Types and structures
- Strengthening
- New advancements
- Cementation

Ceramics:

- is derived from the Greek word “keramos”, which means ‘a material produced by burning or firing’.

- Inorganic compounds with non-metallic properties typically composed of metallic and nonmetallic elements, and made by firing at a high temperature to achieve desirable properties.

- Inorganic, non-metallic materials, which are typically crystalline in nature,
- compounds formed between metallic and nonmetallic elements such as :
  - aluminum & oxygen (alumina - Al_2O_3),
  - calcium & oxygen (calcia - CaO),
  - silicon & nitrogen (nitride- Si_3N_4) .

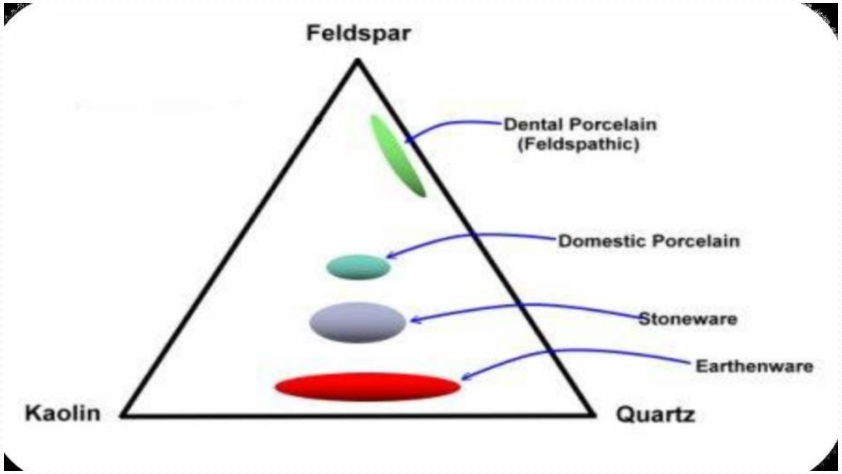
Dental ceramics:

- nonmetallic, inorganic structures primarily containing compounds of oxygen with one or more metallic or semi-metallic elements like aluminum, calcium, lithium, magnesium, phosphorus, potassium, silicon, sodium, zirconium & titanium.
- Main components are Silica (SiO_2) and feldspar with small addition of crystalline (Al_2O_3,MgO,ZrO_2) and/or oxides.


Ceramics versus porcelain:

- Porcelain:
  - refers to a family of ceramic materials composed essentially of Kaolin, Quartz, and Feldspar, also fired at high temperature.
  - widely used ~3000 years.

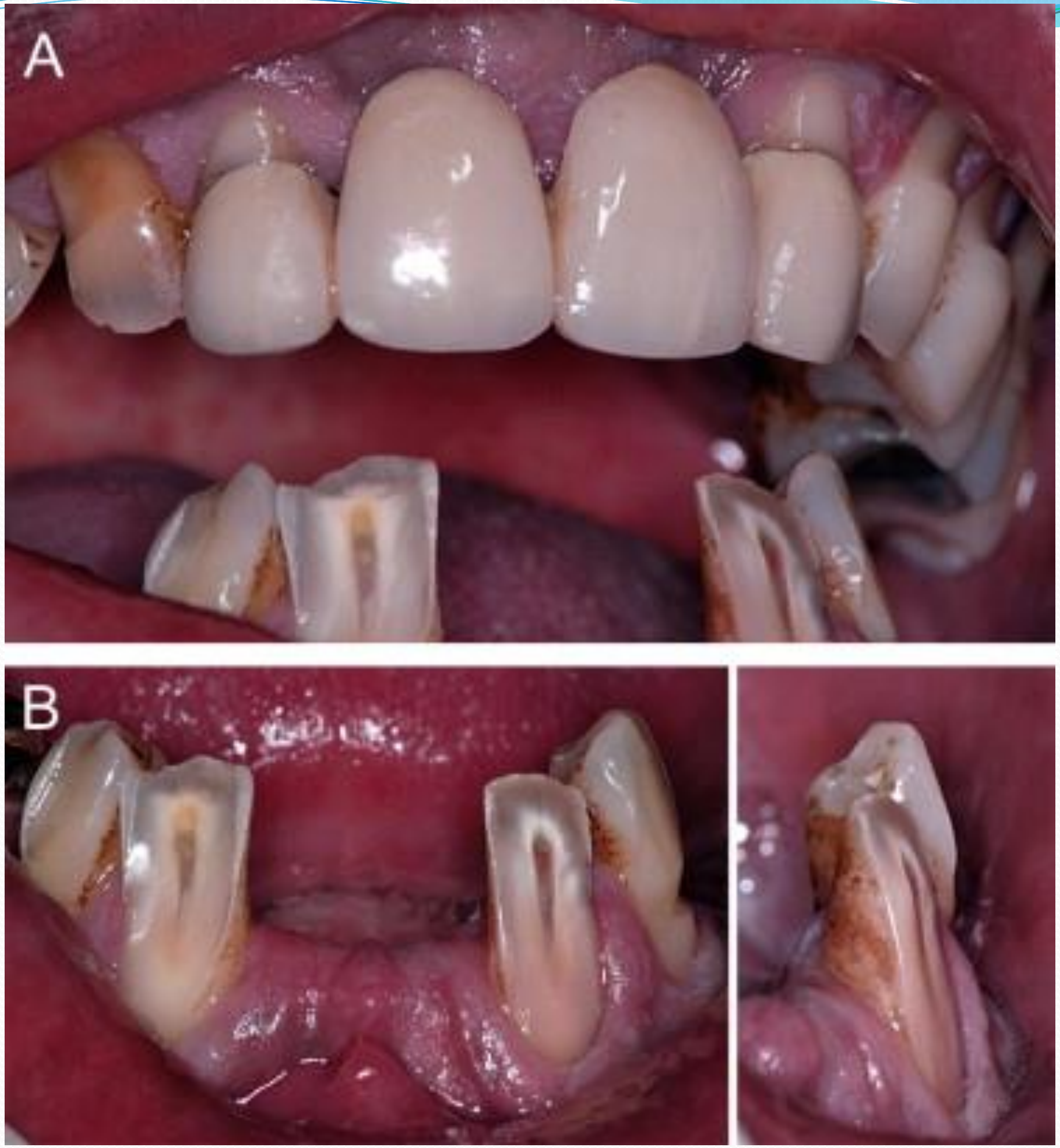
- Dental Porcelains:
  - The kaolin is almost omitted from the structure and therefore is called ‘**Feldspathic porcelain**’.



Characteristics of dental Ceramics:

- Excellent biocompatibility;
  - chemically inert in oral cavity
- excellent aesthetics,
  - difficult to be stained
- Strong but brittle:
  - High compressive strength
  - Low tensile and shear strength
- Low thermal diffusivity
- co-efficient of thermal expansion is almost close to the natural tooth.
- High surface hardness, Wear resistant

- Brittleness, low fracture toughness.
- Expensive
- Sensitive manipulation technique
  - Difficult to Fabricate, require skilful technician
  - Require large connector
- Abrasive to Natural Teeth
- Firing shrinkage
  - Should be built to bigger size.
- Questionable Durability
  - High Clinical Failure rates ?


A
B

Applications:

- Dental Ceramics are used for making:
  - Crowns and bridges,
  - Veneers over metal substructures.
  - Inlays and Onlays
  - Artificial denture teeth
  - Posts
  - Implant fixtures and abutments
  - Orthodontic brackets
  - Ceramic Burs, abrasive agents




Composition:

- Feldspar: (60-80%)
  - are naturally occurring minerals
  - the lowest melting compound and melts first on firing.
  - composed of two alkali aluminum silicates:
    - potash feldspar: potassium aluminum silicate (K_2O-Al_2O_3-$6SiO_2$);
      - Most commonly used; as it imparts translucency to the fired restoration.
    - soda feldspar: soda aluminum silicate (Na_2O-Al_2O_3-$6SiO_2$);
      - Lowers fusing temperature.

- Quartz: (15 – 25%)
  - pure crystals of SiO_2
  - has high fusion temperature
  - provides the framework as it remains same at the firing temperature of the porcelain.
  - acts as filler in the porcelain restoration.

- Kaolin: (4%)
  - A variety of Clay
  - Acts as Flux or binder
  - Gives opacity
  - Increases mouldablity of unfired poreclain
- Opacifiers:
  - Zr, Ti, Sn, Ce Oxides
- Pigments:
  - provide the characteristic shade
- Glass modifiers:
  - lower the softening temperature and increase the fluidity

Composition of dental ceramics:

Ingredient	Functions
Feldspar (naturally occurring minerals composed of potash [K_2O], soda [Na_2O], alumina and silica).	It is the lowest fusing component, which melts first and flows during firing, initiating these components into a solid mass.
Silica (Quartz)	• Strengthens the fired porcelain restoration. • Remains unchanged at the temperature normally used in firing porcelain and thus contribute stability to the mass during heating by providing framework for the other ingredients.
Kaolin (Al_2O_3.2 SiO_2. 2H_2O - Hydrated aluminosilicates)	• Used as a binder. • Increases moldability of the unfired porcelain. • Imparts opacity to the finished porcelain product.
Glass modifiers, e.g. K, Na, or Ca oxides or basic oxides	They interrupt the integrity of silica network and acts as flux.
Color pigments or frits, e.g. Fe/Ni oxide, Cu oxide, MgO, TiO_2, and Co oxide.	To provide appropriate shade to the restoration.
Zr/Ce/Sn oxides, and Uranium oxide (opacifiers)	To develop the appropriate opacity.

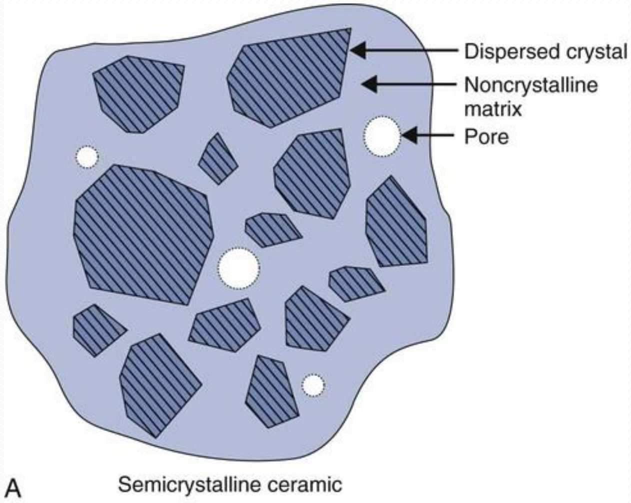
P. Jithendra Babu et al. Dental Ceramics: Part I – An Overview of Composition, Structure and Properties. American Journal of Materials Engineering and Technology, 2015, Vol. 3, No. 1, 13-18. doi:10.12691/materials-3-1-3

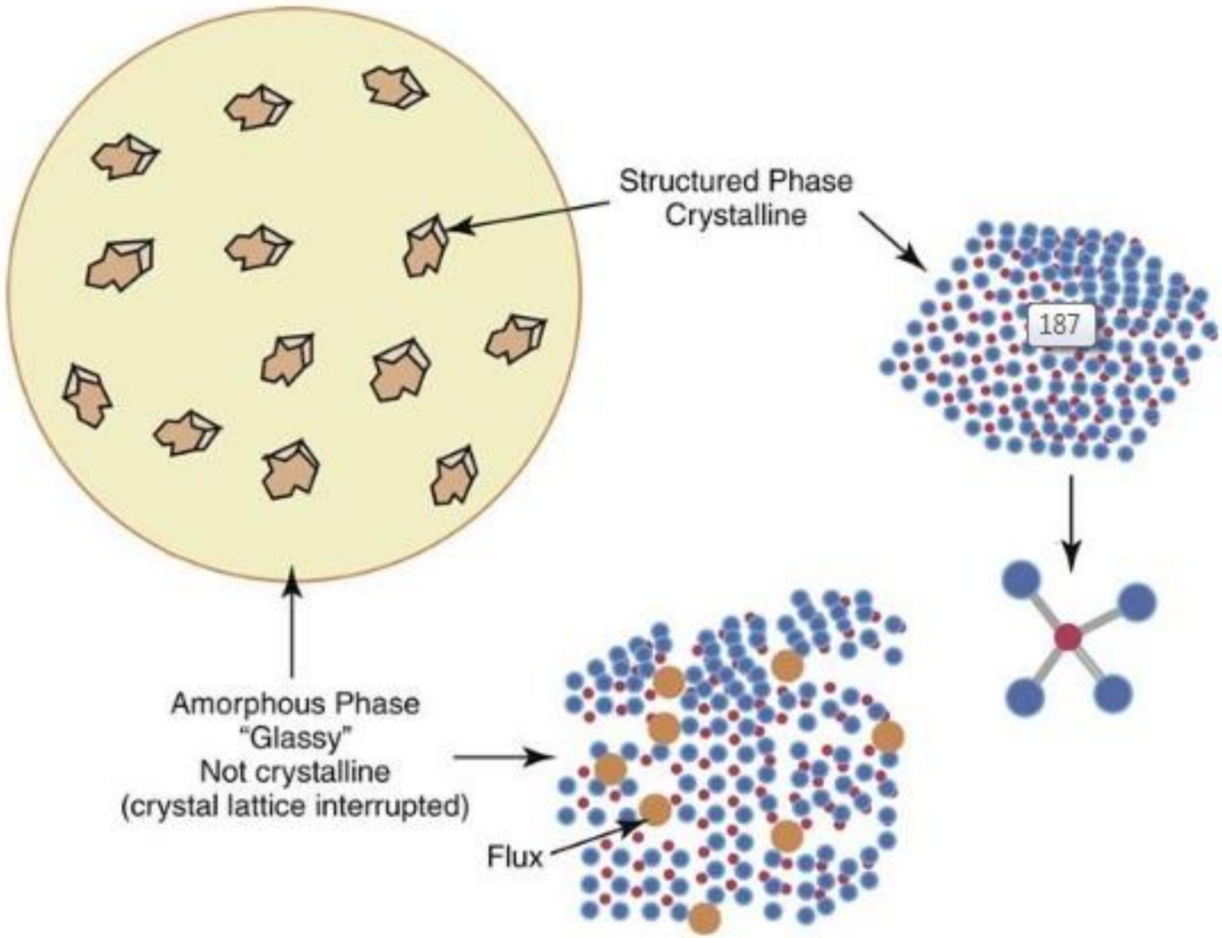
- **Flux**:
  - is a material which increases the viscosity of the molten glass and lowers the fusion and softening temperature of the glass.
- **Binders:**
  - act by holding the ceramic particles together prior to firing. As well as conveying opacity to the final product,
- Metallic oxides are added to convey opalescence and provide colour.
  - **cerium** also produces fluorescence.
  - Uranium ?

Manufacture of the ceramic powder:

- Ceramic is supplied as a powder.
- By grinding the raw materials to form fine powders.
- Blended together and then fired at a high temperature in a furnace.
- Molten mass produced is then rapidly cooled in cold water (quenched), leading to large internal stresses and cracking.
- The resulting fragments of ceramic are known as **frit**, with the process called **fritting** (which is a **pyrochemical reaction**).
- The frit is then milled to a very fine powder.
- This powder may now be mixed with distilled water by the dental technician to form a creamy paste and the restoration built up.

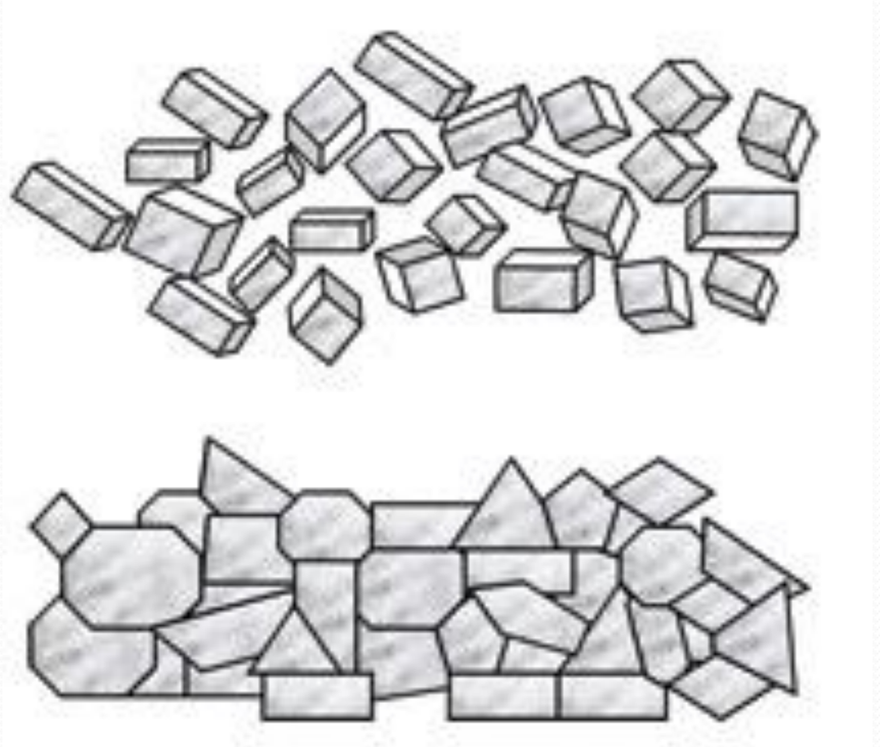
- The Frit contains two principle phases:
  - Amorphous(glassy/ vitreous) phase
  - Crystalline phase.
  - Amorphous ceramic phases are weaker and more soluble than crystalline phases.
  - A pure amorphous phase is transparent.
- The composition of ceramic powder is that;
  - No further chemical reaction is required.
  - Instead the particles of the ceramic powder fuse when it is heated to just above its glass transition temperature. This is called **sintering.**

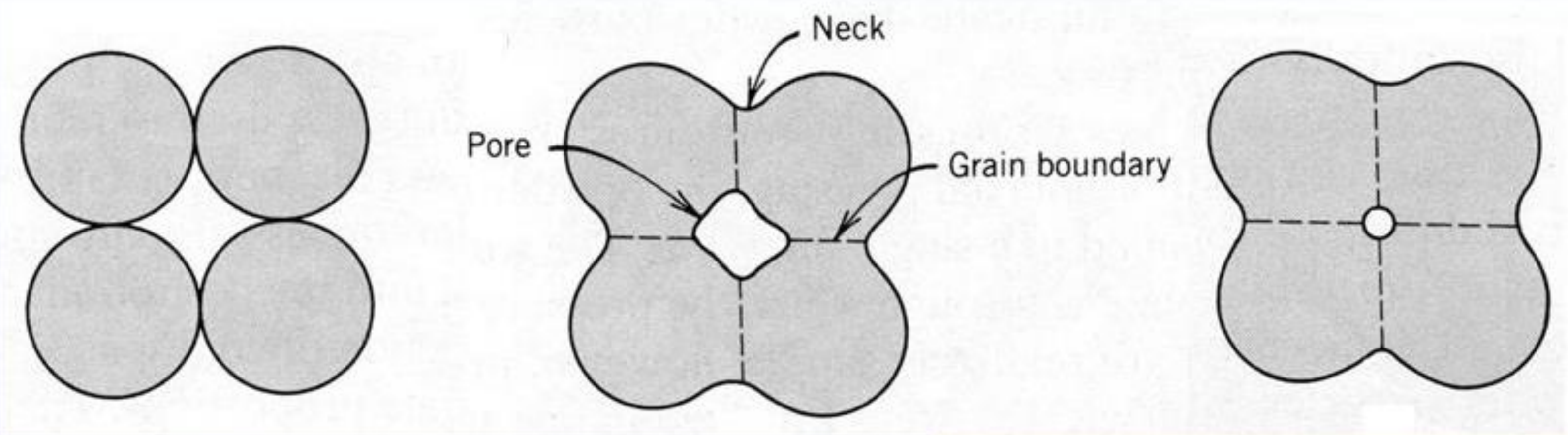



Structured Phase
Crystalline
187
Amorphous Phase
"Glassy"
Not crystalline
(crystal lattice interrupted)
Flux

Ceramic Sintering:

- Sintering:
  - The process of heating (firing) closely packed porcelain particles to a specified temperature (below the melting point of the main component) to get densified and strengthen a structure.

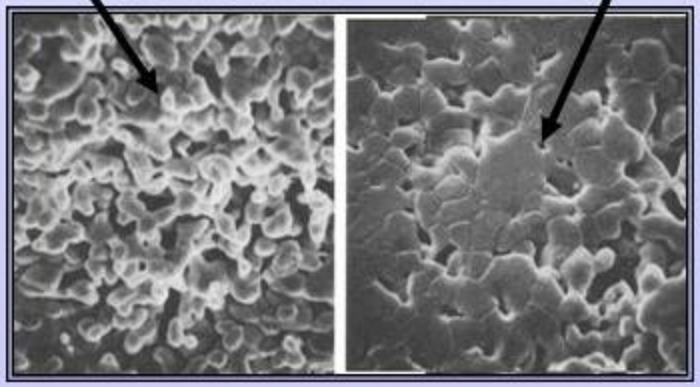


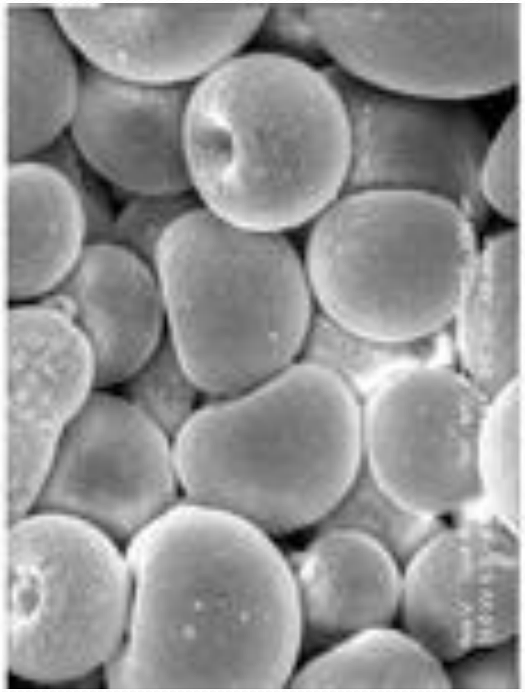
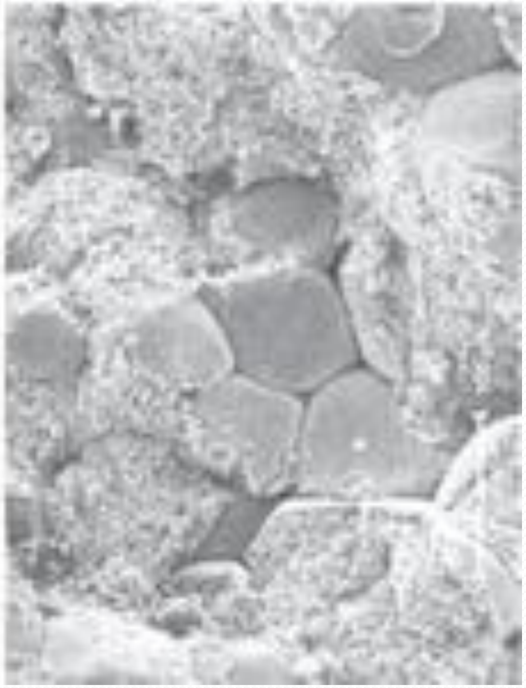


Pressed Ceramic Particles

Sintered for a short time

Sintered for a long time



Classification of Dental Ceramics

- Dental ceramics can be classified according many different ways, mainly :
  - 1. Fusion Temperature
  - 2. Application
  - 3. Fabrication Technique
  - 4. Crystalline Phase (structure)

Fusion temperature:

- According to Fusion temperature, ceramics can be classified to:
  - 1. High-fusing ceramics
    - (1315° to 1370° C)
  - 2. Medium-fusing ceramics
    - (1090° to 1260° C)
  - 3. Low-fusing ceramics
    - (870° to 1065° C)
  - 4. Ultra-low-fusing ceramics
    - (below 870° C)

Fusion Temperature

- The medium- and high-fusing ceramics are used for denture teeth •

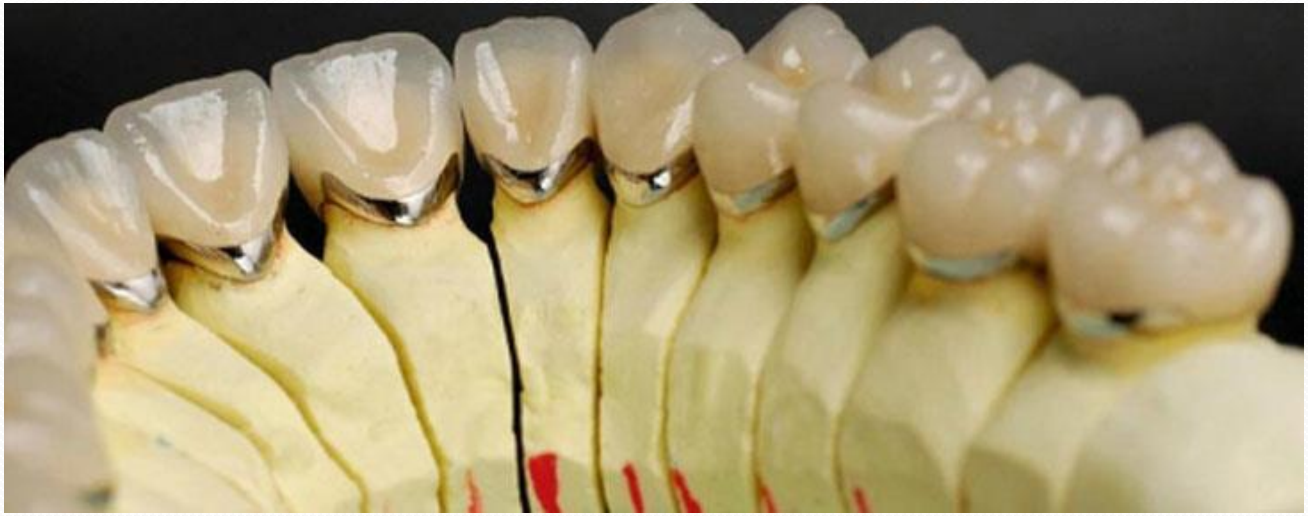
- Dental ceramics for ceramic-metal or all- ceramic fixed restorations belong to the low- or medium-fusing categories.

Applications:

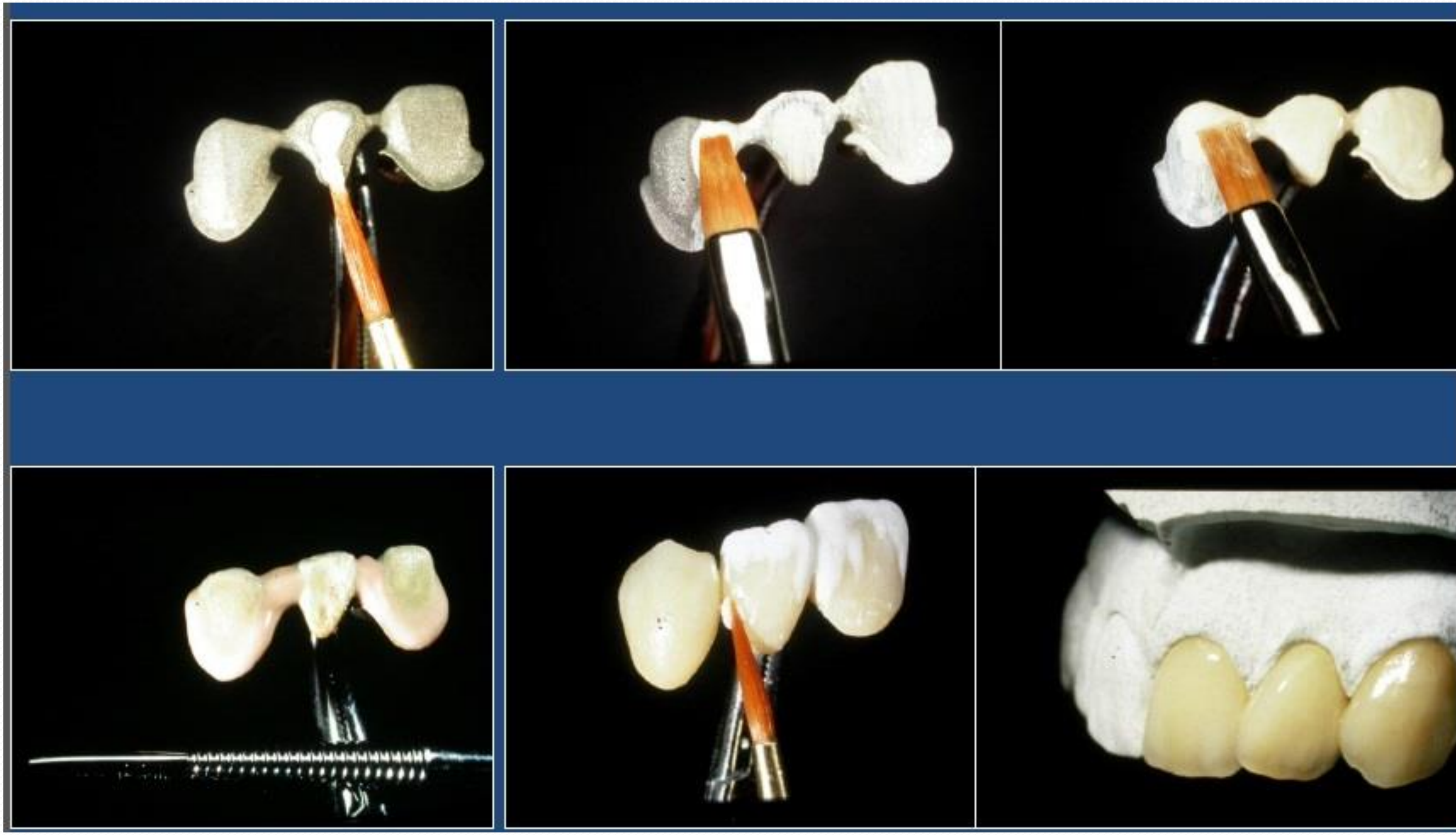
- Application Ceramics have three major applications in dentistry:
  - Ceramic denture teeth.
  - Ceramics for metal crowns and fixed partial dentures
  - **All-ceramic restorations**:
    - inlays, onlays, and veneers, when aesthetics is a priority

Ceramic-metal restorations:

- Porcelain fused to metal restorations
  - involve marrying of the good mechanical properties of cast dental alloys with the excellent aesthetic properties of porcelain.
  - Alloy substructure with bonded porcelain veneers.



- PFM is one of best ceramic restoration ; YET it has many problems.
    - Problem of hiding metal margins.
    - Shadowing of dark cervical margins
    - Corrosion and allergies,
        - High Noble alloys
    - Poor tissue response

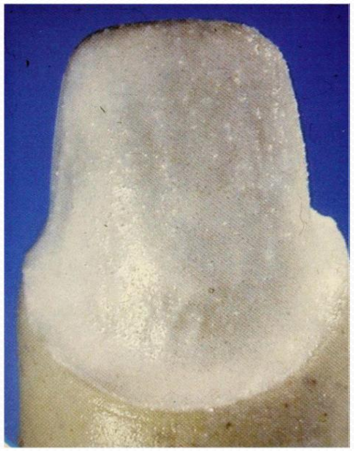


Fabrication Techniques of All-Ceramic restorations:

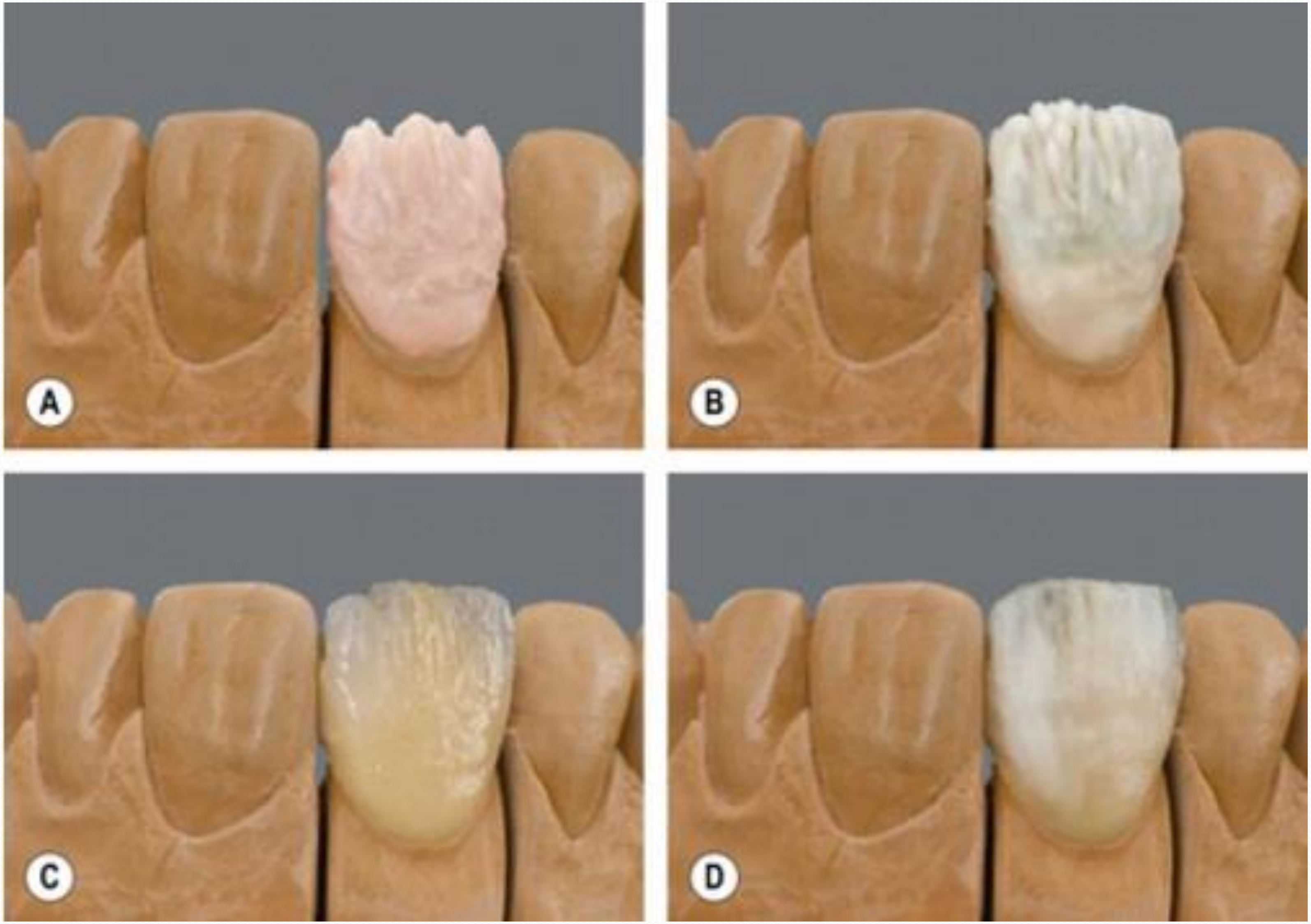
- Powder/Liquid condensation (Stacking)
- Heat Pressing
- Slip casting (Infusion)
- CAD-CAM Milling (Machining)

A) Stacking:

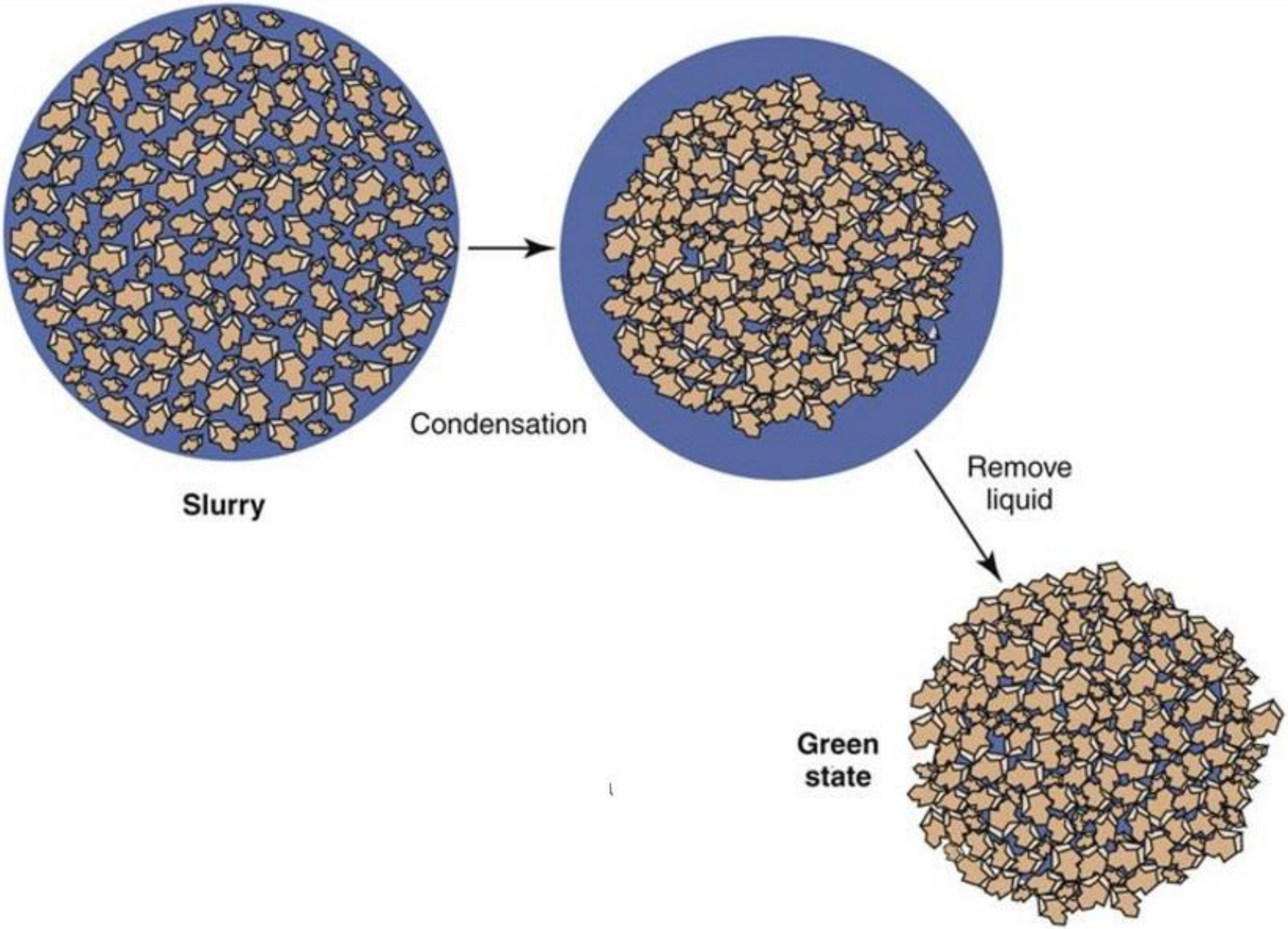
- Powder condensation and firing technique
  - One of the most common fabrication techniques for dental ceramics.
- the process of heating the ceramic to ensure densification.
- is used primarily for glassy and glass-dominated ceramics



- The layers (Opaque, dentine and enamel) of porcelain paste (powder and liquid) build up either on platinum foil or on refractory die material.
  - as with metal core in PFM.


A
B
C
D

- The ceramic powder is mixed with distilled water to form a creamy paste, Slurry.
- Ensure minimum amount of air is incorporated into the powder slurry
  - to avoid porosity and stress concentrations in the final product.
- the powder must be condensed to remove water and pull the ceramic particles closer together (Compacting)
  - achieved by either vibration, spatulation or smoothing/burnishing with a brush.
- the excess water is then blotted away using absorbent tissue.
- Achieve 'Green State':
  - Prefiring state.
  - Weak, oversized approximation of the final form.

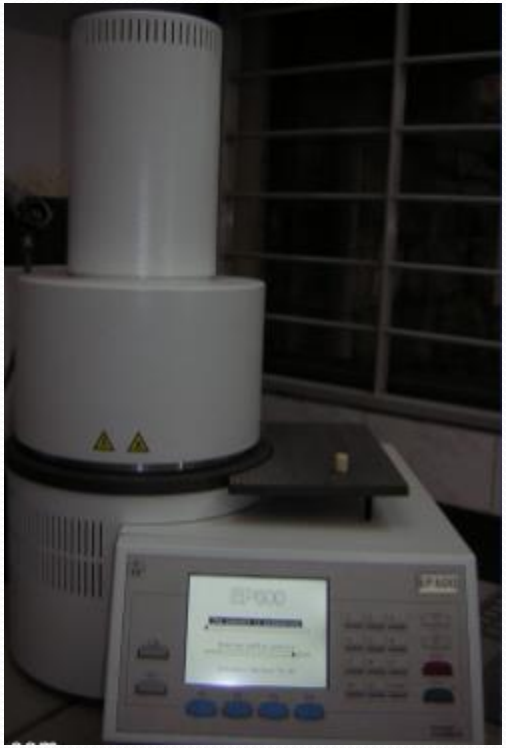


Condensation
Slurry
Remove
liquid
Green
state

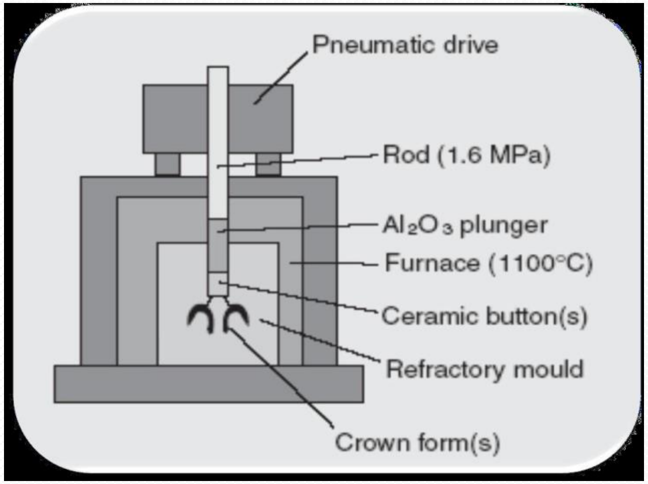
- Then Firing (Sintering):
  - by a series of 'bakes' in the furnace.
  - fired to fuse the particles together and form the final restoration,.
  - initially mass is slowly heated to eliminate the water and allow shrinkage to occur.
    - the shrinkage occurs during this firing and is in the range of 10–20%.
    - The voids in the porous mass start to disappear as the molten glass flows between the particles.
  - Subsequent bakes: higher tempreture
  - Staining.
  - Glazing:
    - produces a glassy smooth surface on the restoration, sealing it

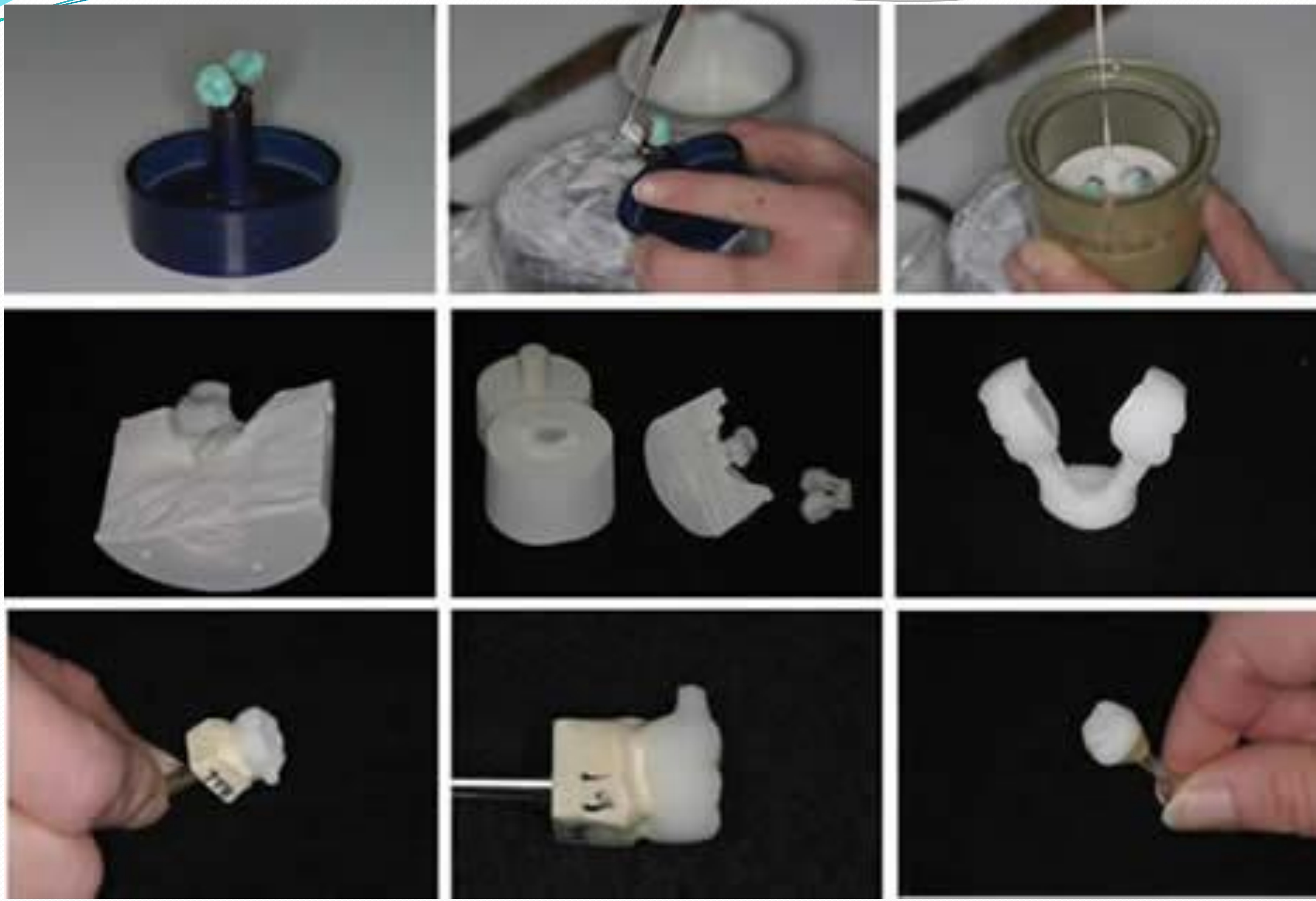
B) Heat pressing:

- Heat-pressing relies on the application of external pressure to sinter and shape the ceramic at high temperature.
- Heat-pressing is also called (high-temperature injection moulding).
- The advantages of heat- pressed ceramics include good aesthetics, high strength (but higher opacity).
- Processing times are short and margin accuracy is within an acceptable range.



- ceramics are provided as core ingots
  - heated and pressed until the ingot flows into a mould
  - Using lost wax technique.
- The restoration is first waxed-up and invested
  - the ingot, is not molten but softened before being pressed or injected using (plunger machine) into a mould under pressure at 1150C.
- Pressed form can be made into full contour or just a core.





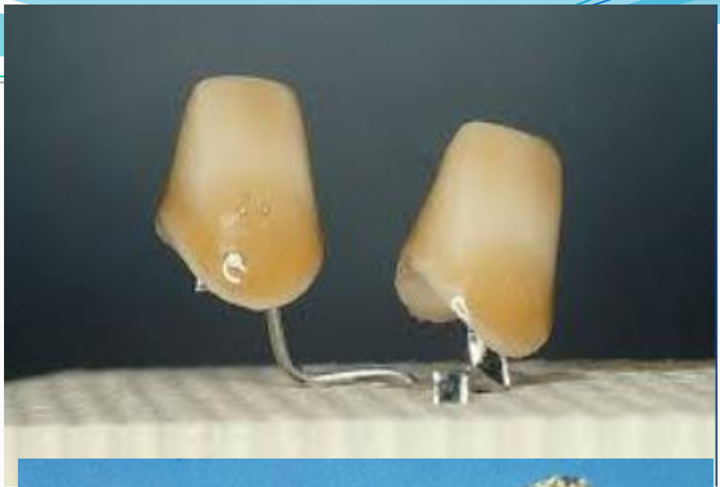
C) Slip-casting (infusion):

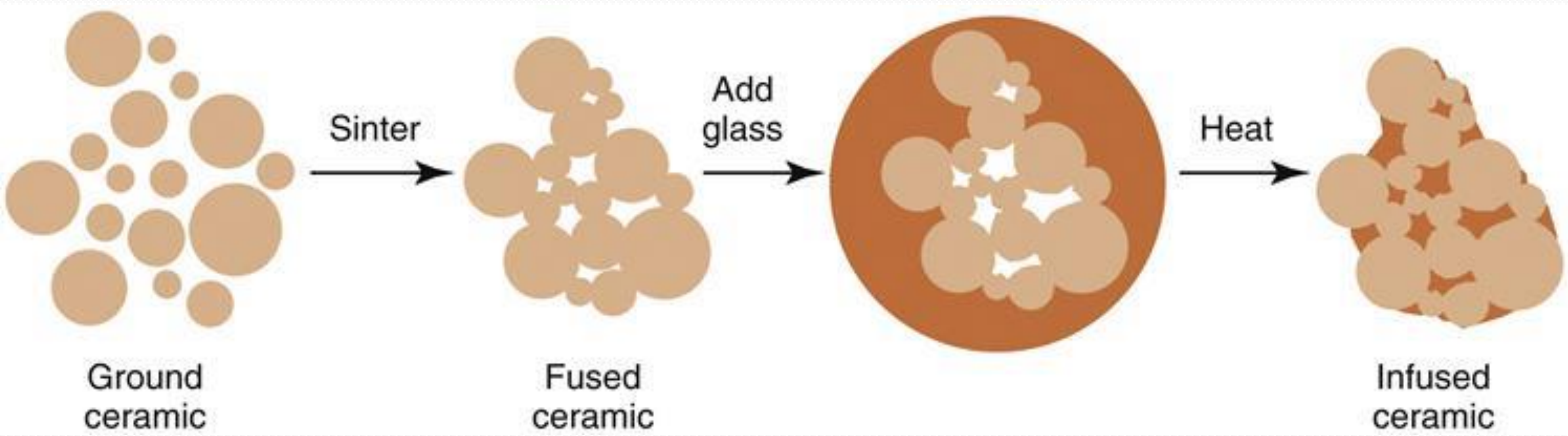
- Slip-casting involves the condensation of an aqueous porcelain slip on a refractory die.
- Slip:
  - “a low viscosity slurry or mixture of ceramic powder particles suspended in a fluid, usually water”
- The slip is applied onto a porous refractory die which absorbs the water and leads to the condensation of the slip on the die.
- the piece is then fired at high temperature (1150°C).
- During firing for four hours, the die shrinks so that it can be withdrawn from the core .
  - This process is called “slip-casting”.
- At this stage the core is a weak, porous structure consisting of partially sintered alumina particles

- Strength is conferred by painting slurry of lanthanum containing glass onto the outside of the core and re-firing it.

- During re-firing the molten glass-ceramic is drawn into porous structure thus eliminating voids and creating a glass-ceramic composite.

- The excess glass is ground away and porcelain with a matched coefficient of thermal expansion is built onto the surface.



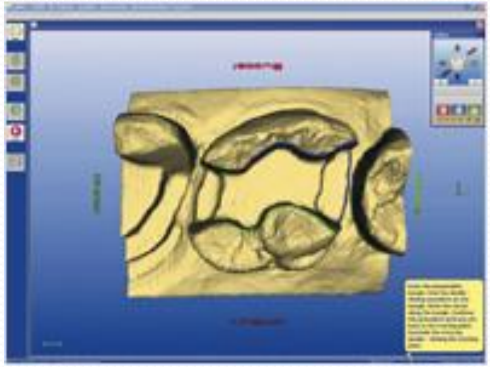

Sinter
Add
glass
Heat
Ground
ceramic
Fused
ceramic
Infused
ceramic

- Infused ceramics tend to exhibit :
  - reduced porosity,
  - fewer defects from processing,
  - higher toughness than feldspathic porcelains.
- In-Ceram is an example, consisting of a core containing 90% alumina.

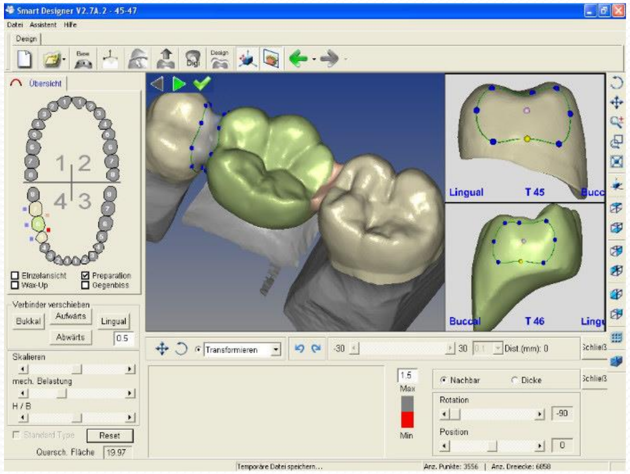
D) Machine Milling:

- Machinable ceramics can be milled to form inlays, onlays, and veneers bridge cores or monolitic crowns using special equipments.
- Machinable ceramics are supplied as ingots
- One system uses CAD/CAM (computer assisted design/computer assisted machining) technology to produce restorations in one office visit.
    - Monolithic restoration

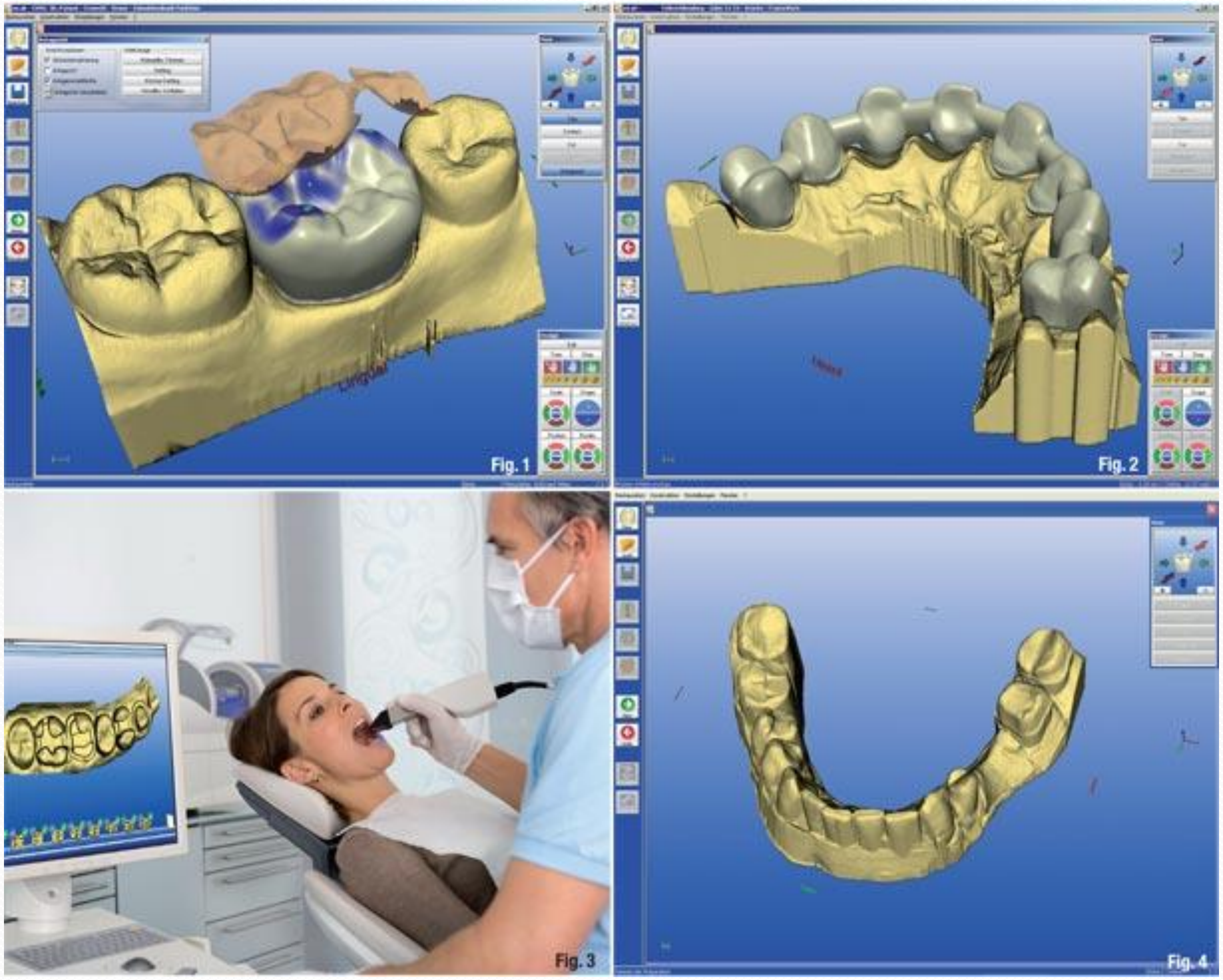
- the prepared die (or tooth) is scanned and the resultant image is sent to computer software that is connected to a milling machine to fabricate the final ceramic framework out of ready-made ceramic ingots.



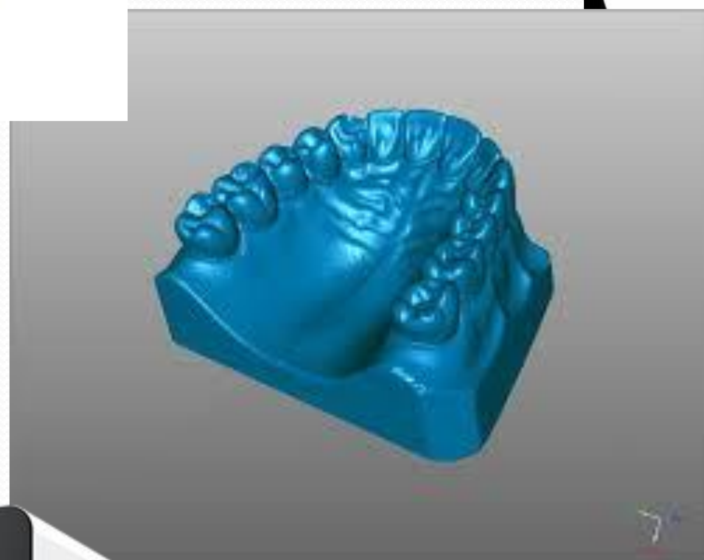
- As a rule, powder/liquid systems have much lower strength than pre-manufactured blocks do owing to a much larger amount of bubbles and flaws in the finished restoration.
- Variation in framework designing methods
  - Virtual designing and wax UP.
  - Conventional designing .



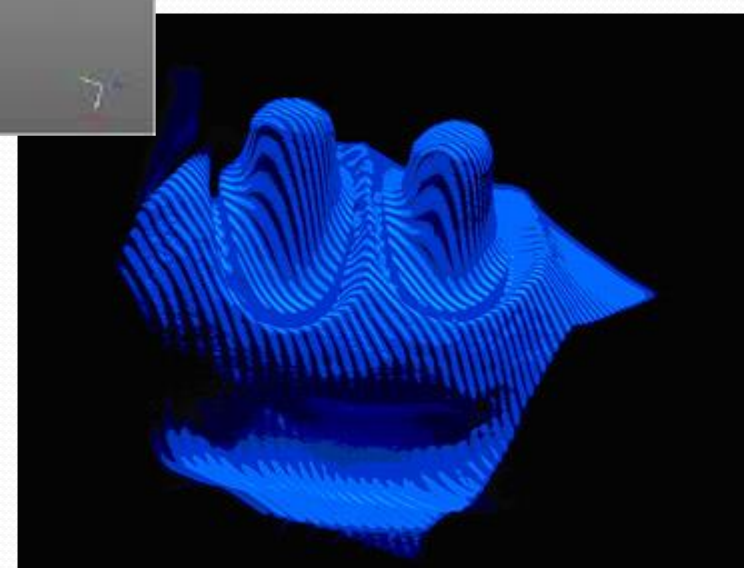
- Two techniques of Milling:
  - Direct
  - Indirect


Lingual
Fig. 1
Fig. 2
Fig. 3
Fig. 4


1>
2>
3>
4>
5>
LYTHOS



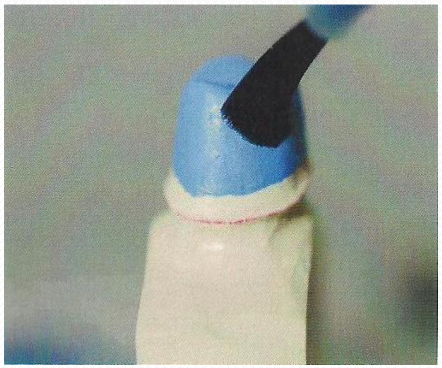

SHINING 3D
DS200+

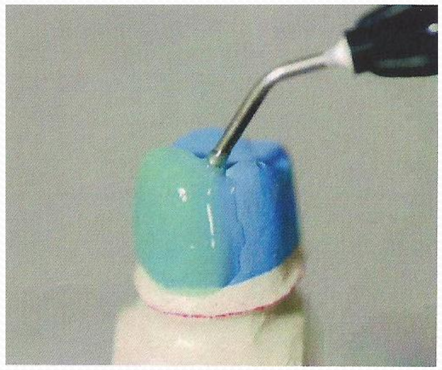


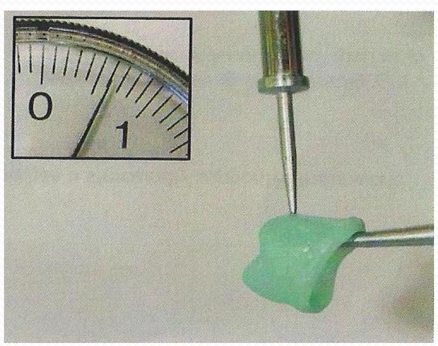
- Popular CAD/CAM Systems for the Production of All Ceramic Restorations :
  - Procera AllCeram (Noble Biocare)
  - CEREC system 3 (Sirona)
  - LAVA system (3M™ ESPE™)
  - EVERST system (KaVo)
  - Cercon system (DeguDent)

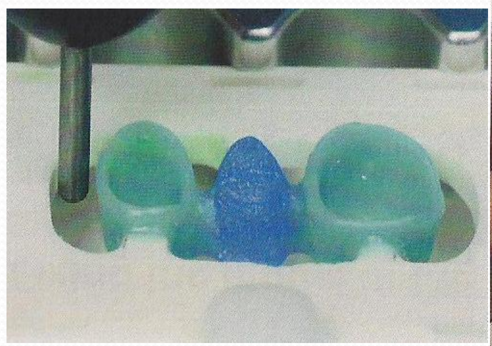

VITA
0124
2 M2C/I12
e.max CAD
HT A2 / B 40 L
e.max CAD
LT
A2
A 16 (L)
BRILLIANT
Crios
Lava™ Ultimate
A1-LT / 14L
3M ESPE
Lava™ Ultimate
A2-LT / 14L
CEREC Blocs
sirona
En
VITA ENAMIC
Empress CAD
Multi A2
I 12
ivoclar vivadent
A2 LT/12
CERASMART
GC
CELTRA
DUO
LT
A3
C14
DENTSPLY
VITA
SUPRINITY
PC

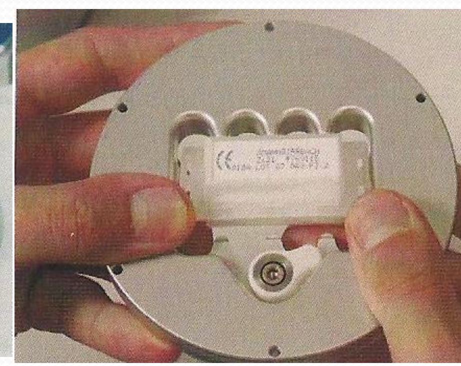
Framework designing:

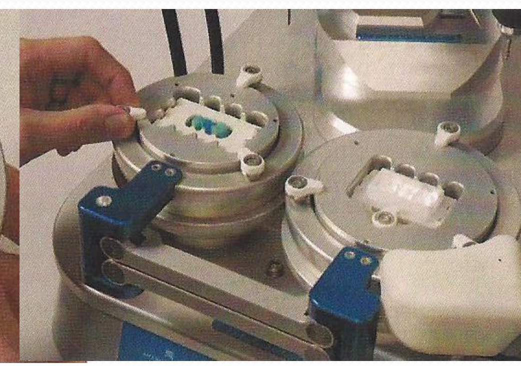










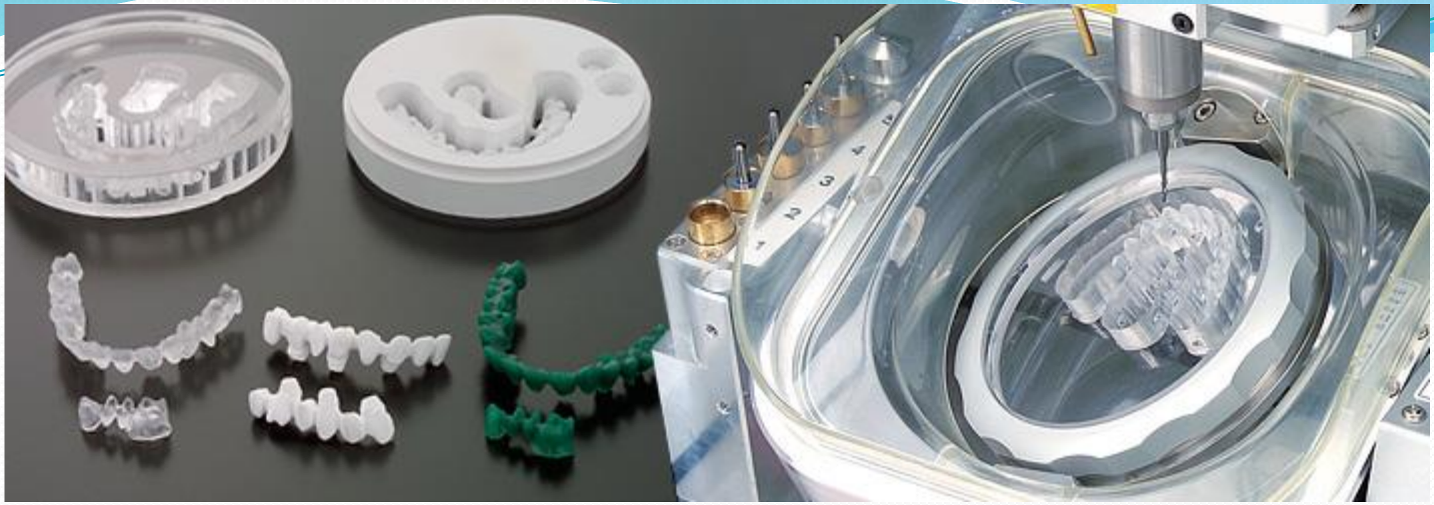


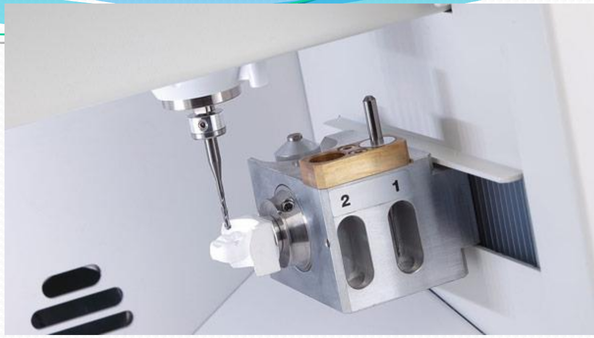

e.max CAD
LT A1 / C14


CEREC MC XL

Indirect versus direct milling

- Indirect:
  - partially sintered ceramic blocks are milled to fabricate a framework (scanned 20% larger than the original die)
  - Following milling, further sintered is done and the framework shrinks to its original dimension.
- Advantages:
  - shorter working time,
  - less wear of milling tools
  - less micro-cracks formation during milling
    - due to the use of softer ceramic block





- Direct Milling:
  - utilizes fully sintered ceramic blocks that are directly milled to the exact size of the prepared die

- Advantages:
  - Omitted expansion/shrinkage
  - Better marginal fit.

- micro-cracks may be introduced during milling .

Crystalline Phase

- Dental ceramics are composed of two phases:
  - glassy (vitreous) phase
  - crystalline phase •
- ceramics can be considered as a composite material, in which the matrix is a glass that is lightly or heavily filled with crystalline or glass particles.
  - Increasing the amount of glassy phase lowers the resistance to crack propagation but increases translucency
- Materials for all-ceramic restorations have increased amounts of crystalline phase (between 35% and 100%) for better mechanical properties

Types of dental ceramics

- Three main divisions of ceramics according composition:
  - 1. Predominantly glassy materials
    - Feldspathic
  - 2. Particle filled glasses---- Glass ceramics
    - Leucite-reinforced
    - Lithium disilicate
  - 3. Polycrystalline ceramics.
    - Alumina based
    - Zirconia based

- Aesthetic dental ceramics : Glassy
- Substructure dental ceramics: Crystalline

- Predominantly glass:
  - high content of glass
    - highly aesthetic/ the best in mimicking the optical properties of enamel and dentin.
    - Optical effects are controlled by manufactures by adding small amount of filler particles.
- Particle-filled glass:
  - Filler particles are added to the glass matrix to improve the mechanical properties.
  - Fillers can be crystalline particles of high-melting glasses.
- Polycrystalline:
  - contains no glass.
  - Atoms are packed into regular crystalline arrangement making it tougher and less susceptible to crack propagation

- All ceramics are classified into four basic compositional categories with a few subgroups:
  - **Category 1**: glass-based systems (mainly silica);
  - **Category 2**: glass-based systems (mainly silica) with fillers, usually crystalline (typically leucite or a different high-fusing glass);
  - **Category 3**: crystalline-based systems with glass fillers (mainly alumina);
  - **Category 4**: polycrystalline solids (alumina and zirconia).

Category 1: Glass-based systems

- aluminosilicate glasses
  - created by layering glass-based powder and liquid materials
- High translucency
- low flexural strength, (60–70 Mpa)
- used as:
  - veneering materials for metal or ceramic substructures
  - Aesthetic veneers



Category 2:Glass-based systems with crystalline second phase

- varying amounts of different types of crystals have been added or grown in the glass matrix
  - a very large range of glass–crystalline ratios and crystal types.
- primary crystal types today are:
  - leucite:
    - Created by increasing the potassium oxide (K_2O) content of the aluminosilicate glass.
  - lithium disilicate :
    - created by adding lithium oxide (Li_2O) to the aluminosilicate glass
  - Fluorapatite
    - Created by a mechanism of controlled volume crystallisation to fluoro-alumino-silicate.

2.1 Subcategory:

- **Low to moderate leucite-containing feldspathic glass**:
  - be called “feldspathic porcelains” by default.
  - Leucite :
    - alter the coefficient of thermal expansion (CTE) of the material,
    - inhibit crack propagation, improves the strength.
    - Fairly large size (>100 um), random distrubution.
      - contribute to low fracture resistance and abrasive properties relative to enamel.
  - The most common use of these materials is as veneer porcelains for metal–ceramic restorations.
  - Developed in Powder/ liquid (e.g. Vita VM 13)

2.2 Subcategory:

- **High leucite-containing (approximately 50 %) glass: (glass- ceramic)**
  - heat treatment to homegenous glass nucleates and grows crystals .
  - **Improved mechanical and physical properties**
    - increased fracture resistance, improved thermal shock resistance, and resistance to erosion.
- Improvements dependent upon the interaction of the crystals and glass matrix, as well as on the crystal size and amount.
- developed in both powder/liquid, machinable and pressable forms.
  - E.g. IPS Empress (Ivoclar Vivadent) / pressable.

2.3 Subcategory:

- **Lithium disilicate glass-ceramic:**
  - aluminosilicate glass has lithium oxide added.
  - introduced by Ivoclar as IPS Empress® II
    - (now called IPS e.max) (pressable/machniable)
  - Increased the crystal content to about 70 % with refined size.
    - flexural strength ~ 360 MPa, x3 that of IPS Empress.
  - even with the high crystalline content, This material is very translucent due to
    - relatively low refractive index of the lithium disilicate crystals.
  - Full contoured VS. veneered with fluorapatite ceramic


e.max® Press
HT
A1

3. Category 3:

- **Crystalline-based systems with glass fillers** (Interpenetrating phase ceramic).
- Glass-infiltrated, partially sintered alumina.
- The system utilises a sintered crystalline matrix of a high modulus material (85 % of the volume), in which there is a junction of the particles in the crystalline phase.
  - Differens than glass ceramic as there is no junction of crystals.
- improved mechanical and physical properties:
  - owing to the geometrical and physical constraints that are placed on the path that a crack must follow to cause a fracture.
- E.g. In- Ceram (Vita), slip casting.
  - In-Ceram SPINELL (350 MPa)
  - In-Ceram ALUMINA (450 MPa)
  - In-Ceram ZIRCONIA (650 Mpa)

Category 4: Polycrystalline solids

- Solid sintered monophase ceramics
  - formed by directly sintering crystals together without any intervening matrix to form a dense, air-free, glass-free polycrystalline structure.
- Fabricated as either solid-sintered alumina or zirconia frameworks.
- Examples:
  - Procera AllCeram alumina (Nobel Biocare) (600 Mpa)
  - Lava Zirconia (3M ESPE) (900 to 1,100 Mpa)

Alumina:

- High purity of Alumina (99.5%)
- High hardness and strength
- Highest elastic modulous of all ceramic
  - Leads to bulk fracture
- Introduction of Zirconia leads to reduced use of alumina ceramics.

Dental Zirconia:

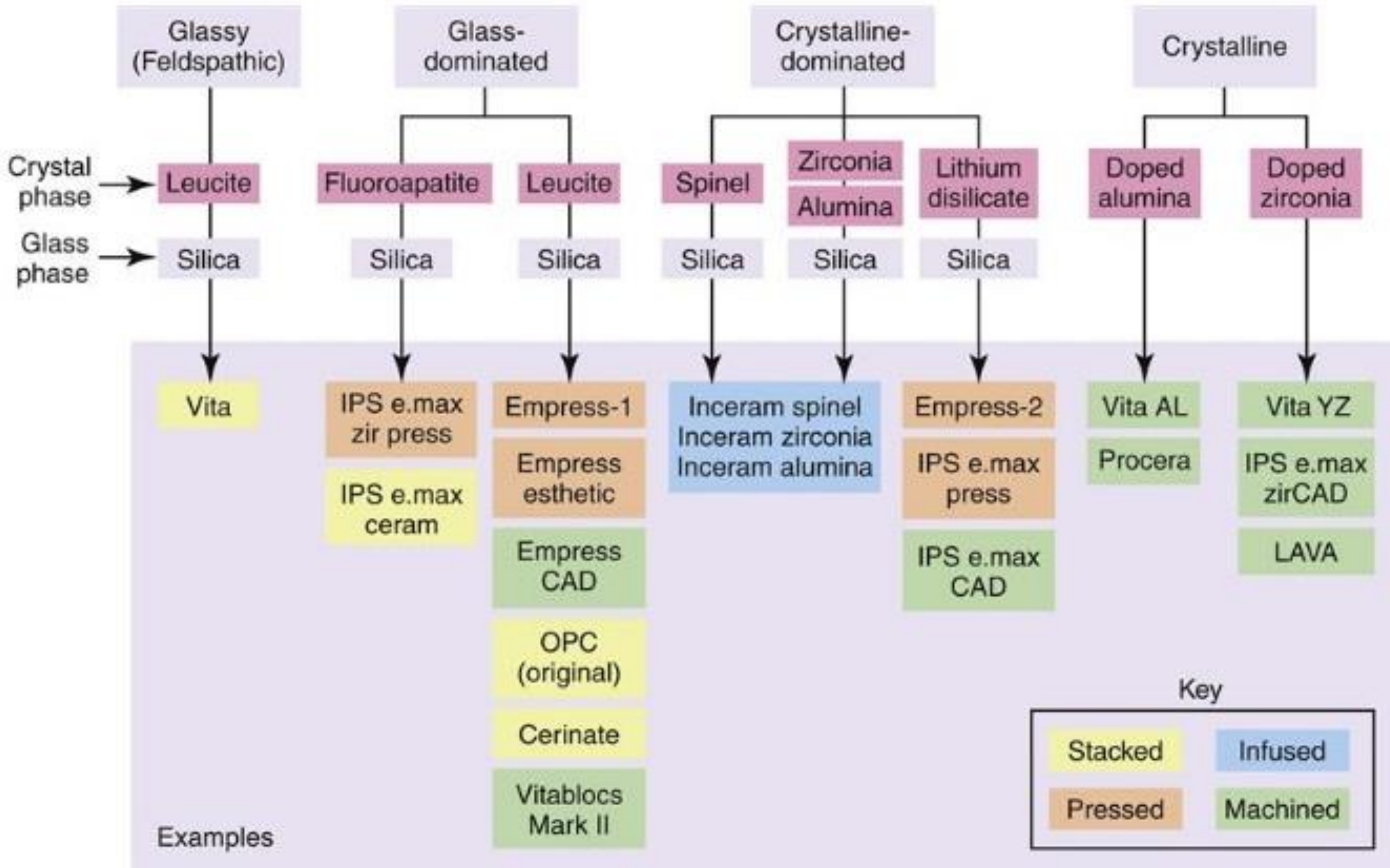
- is not pure zirconia;
  - it is partially stabilised by the addition of small amounts of other metal oxides, like :
    - calcia (CaO), magnesia (MgO), yttria (or yttrium oxide, Y_2O_3) , and ceria (or ceriumoxide, CeO_2).
    - 3 wt% Yttria is the most common.
- x2 as strong and tough as alumina-based ceramics.
- Highest fracture toughness
  - used for multi-unit anterior and posterior fixed partial dentures.
- Low temperature degradation.

- Pure ziconia found in three allotrpic forms:
  - Monoclinic (stable up to 1170 C) then transforms to
  - Tetragonal
  - Cubic (2370 C) .
- Tetragonal to Monoclinic transformation is accompanied by a shear strain and volume increase (4%).
  - This can close cracks leading to large increase in fracture toughness.
- Tetragonal /cubic phase must be stabilized at room temperature to use this toughening mechanism.
- Dental zirconia is mostly yttria -Tetragonal zirconia polycrystals (Y-TZP).

- Used as Framework or Monolithic.
- Also Available as
  - A Monochromatic uniform material , can be stained by infiltration
  - Polychromatic CAD/CAM blocks/disks to imitate dentin enamel .
  - With increasing translucency

New polycrestlaine materials:

- Zirconia-toughened alumina (ZTA)
  - > 50% wt AL
- Alumina –toughened zirconia (ATZ)
  - > 50% wt Zr
- Advantages:
  - Resistance to low tempreture degradation
  - Higher strength
  - x2 Higher fatigue than Y-TZP
- Graded alumina
- Graded Zirconia



Empress and IPS products are manufactured by Ivoclar Vivadent Inc.
Vita, Vitablocs, and Inceram products are manufactured by Vident.
OPC is manufactured by Pentron Clinical Technologies, LLC.
LAVA is manufactured by 3M ESPE.
Procera is manufactured by NobelBiocare USA, LLC.
Cernate is manufactured by Den-Mat Holdings, LLC.

New Ceramic like Materials:

- Resin matrix Ceramics
  - Resin matrix materials highly filled with ceramics.
  - According ADA, these materials are ceramics.
- Organic phase (polymer) surrounding crystalline inorganic phase.
  - inorganic phase is predominate (>50%)
- Specifically designed for CAD/CAM milling.

- Rationale of production:
  - More Closely simulates the modulus of elasticity of dentin.
  - Easier to mill and adjust
  - Facilitate repair or modification with composite.
- Subdivide into different families according to inorganic composition:
  - Resin Nanoceramic (Lava Ultimate) (Cerasmart GC)
  - Glass ceramic in resin interpentrating matrix (Enamic Vita)
  - Zirconia-silica ceramic in resin interpentring matrix (MZ 100 block, 3M ESPE Shofu Block HC)

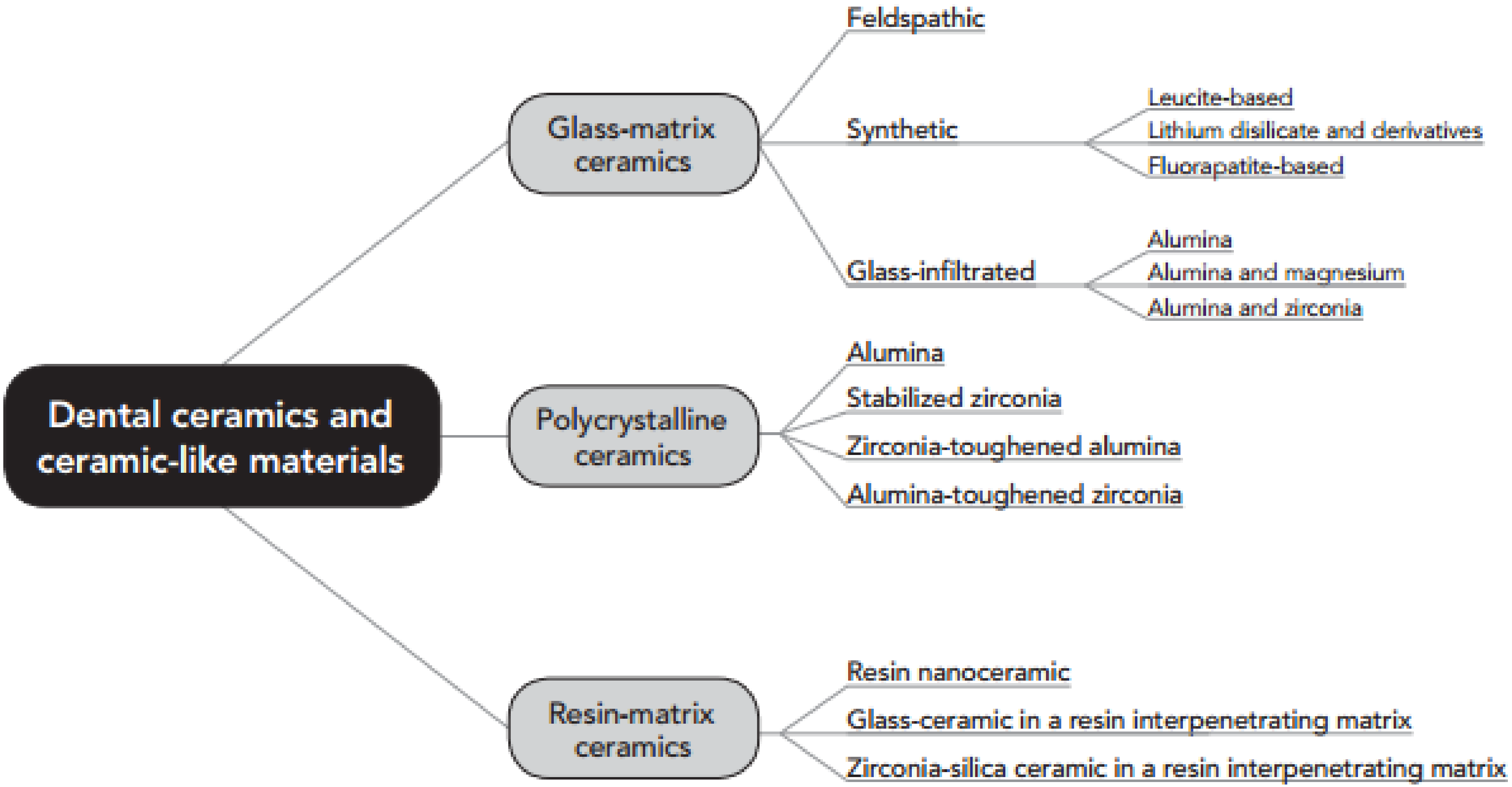

3M ESPE
Lava™ Ultimate
A1-LT / 14L


A2 LT/12
CERASMART
GC
GC CERASMART


En
VITA ENAMIC

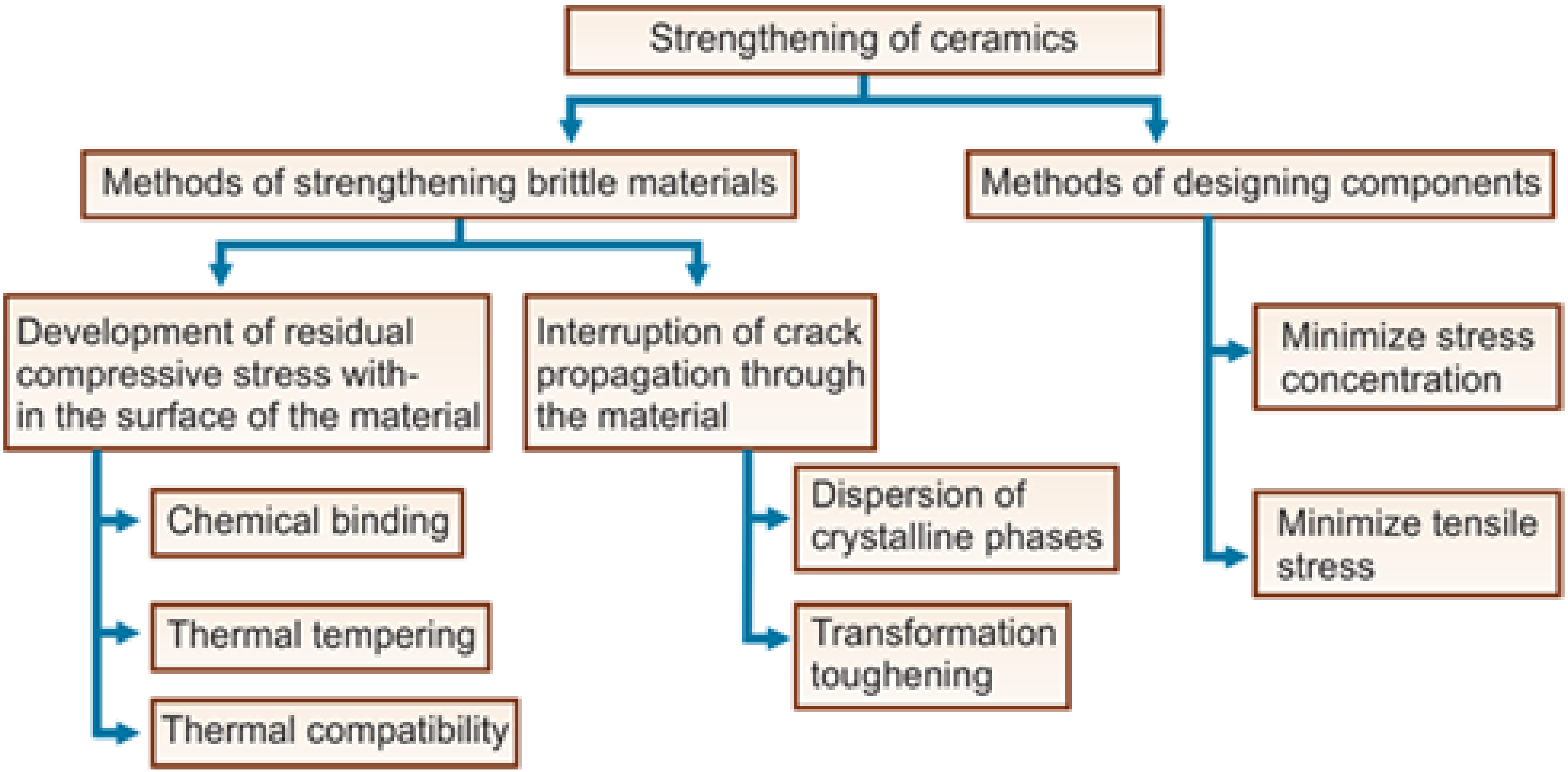

SHOFU
BLOCK HC
A2-HT/M


3M ESPE
Paradigm™
A1


Dental ceramics and ceramic-like materials
Glass-matrix ceramics
Feldspathic
Synthetic
Leucite-based
Lithium disilicate and derivatives
Fluorapatite-based
Glass-infiltrated
Alumina
Alumina and magnesium
Alumina and zirconia
Polycrystalline ceramics
Alumina
Stabilized zirconia
Zirconia-toughened alumina
Alumina-toughened zirconia
Resin-matrix ceramics
Resin nanoceramic
Glass-ceramic in a resin interpenetrating matrix
Zirconia-silica ceramic in a resin interpenetrating matrix

Strengthening of Dental Ceramics:

- As ceramics contain many flaws:
  - Fabrication defects (e.g. voids)
  - Surface cracks (micro-cracks)
    - during cooling in leucite-containing ceramics
    - due to thermal contraction mismatch between the crystals and glassy matrix.
- Leads to brittleness low fracture toughness and low tensile strength.
- Several methods used to overcome drawbacks and strengthen all-ceramics:


Strengthening of ceramics
Methods of strengthening brittle materials
Methods of designing components
Development of residual compressive stress with-in the surface of the material
Interruption of crack propagation through the material
Minimize stress concentration
Minimize tensile stress
Chemical binding
Thermal tempering
Thermal compatibility
Dispersion of crystalline phases
Transformation toughening

Strengthen by designing components:

- To minimize stress concentration and tensile stress.
- 1) Minimize the effect of stress raisers
  - The design of the ceramic dental restoration should avoid stress raisers in ceramics, abrupt changes in shape or thickness in the ceramic contour can act as stress raiser and make the restoration more prone to failure.

- 2) Minimize the number of firing cycles:
- increase in Lucite crystals after multiple firing will increase their thermal expansion coefficient. the expansion mismatch between porcelain and the metal can produce stresses during cooling that are sufficient to cause immediate or delayed crack in the porcelain.

Development of residual compressive strength:

- Residual compressive stresses are introduced within the surface of glass and ceramic objects in order to gain strength.
- introduced stresses help in neutralizing the tensile stresses developed during service.
- can be introduced by either of the three mechanisms
  - chemical tempering,
  - thermal tempering
  - thermal compatibility

chemical strengthening:

- AKA Ion Exchange
- creates a thin surface layer of high-compressive stress by the exchange of smaller glass modifying ions (Na^+) with larger ones (K^+). 35% larger.
  - create larger residual compressive stresses (700 MPa)

Thermal tempering:

- involves rapid cooling of the restorations' surface from the molten state.
- This cooling produces skin of glass surrounding soft (molten) core, which will shrink later during solidification which creates the residual tensile stress in the core and residual compressive stresses within the outer surface.

- Strengthening occurs by inhibiting crack initiation instead of propagation.
- The thermal tempering effect for porcelain reaches for 150um depth.

Thermal compatibility:

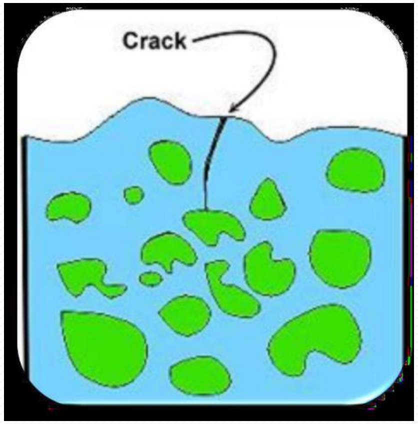
- applies to porcelain fused metals.
- metal and porcelain should selected with slight mismatch in their thermal contraction coefficient.
  - This causes the metal to contract slightly more than does the ceramic during cooling after firing the porcelain which results in development of residual compression in the ceramic surface.

Glazing:

- The addition of a surface glaze can also be used to strengthen ceramics.
- The principle is the formation of a low-expansion surface layer formed at high temperature.
  - Upon cooling, the low-expansion glaze will be placed on the surface of the ceramic and reduces the depth and width of surface flaws.
- However, self-glazing does not significantly improve the flexure strength of feldspathic dental porcelain

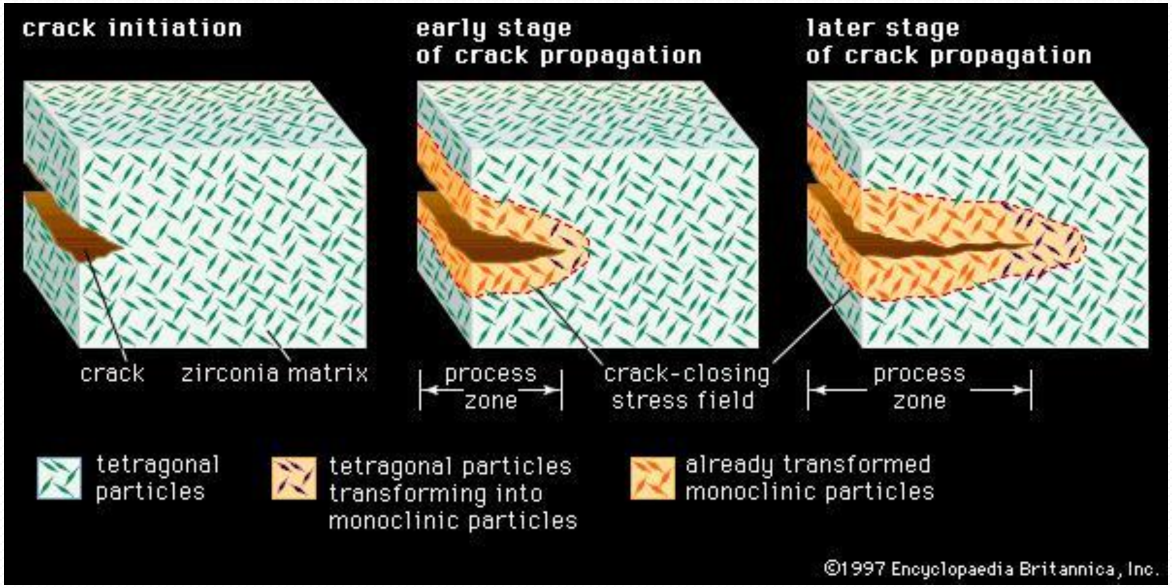
Dispersion strengthening:

- Crystalline reinforcement
  - improve strength by adding a second phase (crystals alumina) to a glass material, causing dispersion strengthening.
- Crystals act as roadblocks to crack propagation.
- A crack spreading from a defect must go through or around the crystal, which takes some energy away from the propagating crack and may stop its progress.
  - Thus, the restoration may continue to function instead of being cracked in half.
- In addition to the roadblock effect, compressive stresses around the growing crystals may help pin cracks and further enhance fracture resistance.



Transformation toughness:

- Specific for partially stabilized zirconia (PSZ).
- Stops crack propagation by transforming tetragonal crystals to the larger monoclinic crystal.



Cementation of all-ceramic:

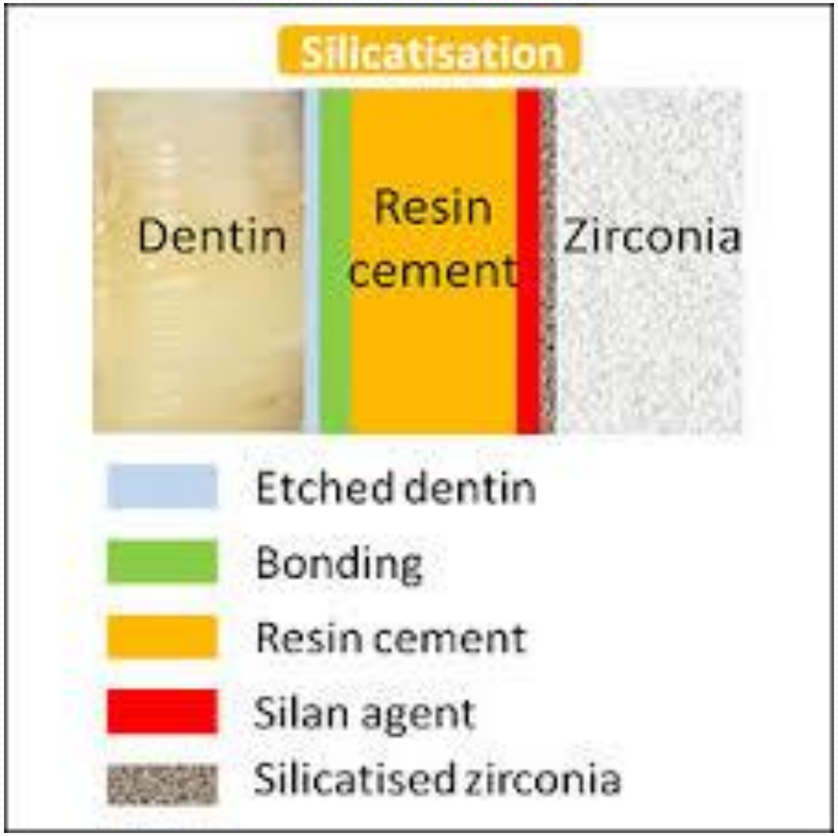
- The protocol for cementation is essential for success.
  - Improves longevity of restoration
  - 97% after 5-15 years.

- Etchable ceramics: silica-based all-ceramics
- Non-etchas.ble : Zirconia and alumina-based all ceramic

- Glass-based ceramics benefiting from adhesive luting agents (increase in retention and fracture toughness)
- need special surface treatment before cementation.
  - acid etching with hydrofluoric acid (mostly 9%)
    - Upon etching surface texture is obtained , as the glass matrix is selectively eliminated and the crystal particles are exposed.
  - then coating with a silane coupling agent.
    - Increase wettability
    - bifunctional molecule: react with ceramic and copolymrize with resin.
- luting agents with acid-base setting reaction are not recommended.

- alumina-based ceramics surfaces can be either
  - abraded with air-borne particles or
  - treated with tribiochemical silica coating
- This can enhance the strength with adhesive cements.

- Zirconia based ceramics:
  - Neither acid etching nor air abrasion is effective
    - lack the silica layer (not etchable)
    - phase transformation upon air-abrasion
- Both adhesive and conventional luting agents can be used to cement this type of dental ceramics .


Silicatisation
Dentin
Resin cement
Zirconia
Etched dentin
Bonding
Resin cement
Silan agent
Silicatised zirconia


Calibra
Operatory Kit
Calibra
DENTSPLY
CAULK
Calibra

3M ESPE Dental Cementation Recommendations

For ultimate bond strength coupled with ease of use

RelyX™ Ultimate Adhesive Resin Cement
with Scotchbond™ Universal Adhesive

OR

Simplicity powered by performance

RelyX™ Unicem 2 Self Adhesive Resin Cement

3M ESPE

Thank You

كلية طب الأسنان
SCHOOL OF DENTISTRY

- Ala'a Al-Haddad
- E-mail: A.Haddad@ju.edu.jo