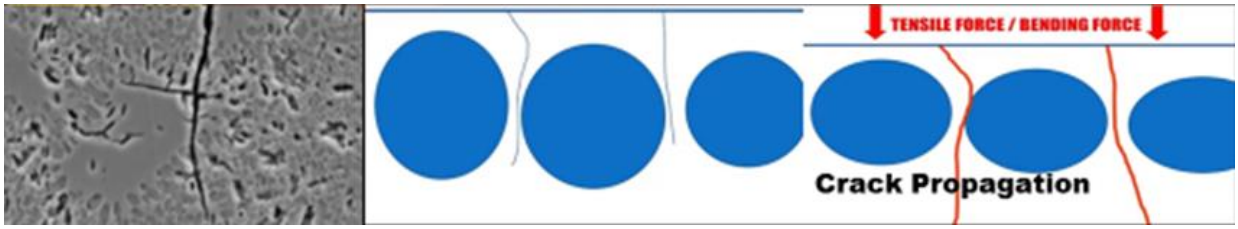
Dental Ceramic

Generally, the word ceramic is used to name any material having both metallic and non-metallic ions (usually silicon, boron, oxygen) in its compositional formula which are obtained by the action of heat and whose final structure is partially or completely crystalline (example. Cements, gypsum, porcelain and glasses).

Dental porcelain is the material from which the most esthetic restorations are made, it is compatible with the soft tissue. A ceramic material formed of infusible elements joined by lower fusing materials. Most dental porcelains are glasses and are used in fabrication of teeth for dentures, pontics & facings, crowns, inlays, onlays and other restorations. Dental porcelain in this domain is superior over polymers and reinforced polymers regarding tooth shade reproduction, translucency, biological compatibility, chemical stability and abrasion resistance. Porcelain is very hard material but it is extremely brittle, can fracture easily. To compensate this weakness, ceramics are usually supported by substructure, reinforced with particles, or made purely of polycrystalline material.



So in order to overcome this disadvantage (brittleness), porcelain fused to metal restoration is develops to combine the strength and the accuracy of cast metal with the esthetic of porcelain. ***P.F.M.*** *composed of* ***a metal copping casting (substructure) that fit over the tooth and porcelain fuse on to that copping****. This combination is* ***stronger*** *than porcelain alone. However, metal substrate can affect aesthetic by decreasing light transmission comparing to all ceramic crown, expose metal rim, and periodontal health. That's why, researches continue trying to develop new ceramic system (combine strength and esthetic) that can use without metal substructure. Development follow* ***2 path:***

1) Developing a high strength but not esthetic core, veneered with low strength esthetic ceramic.

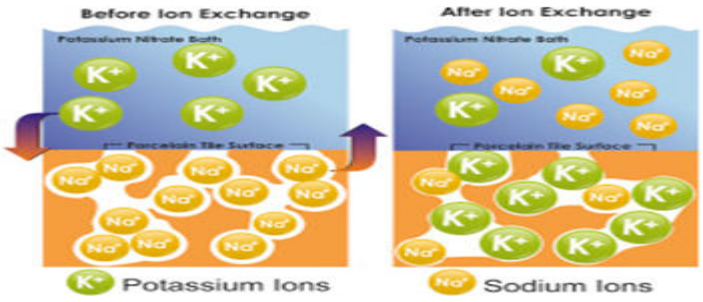
2) Developing of ceramic that combine esthetic with high strength

Methods of strengthening ceramics

- ***Extrinsic*** *involve* ***Introducing or Development of Residual Compressive Stresses within the surface of the ceramic material*** *by using one of following techniques or methods:*

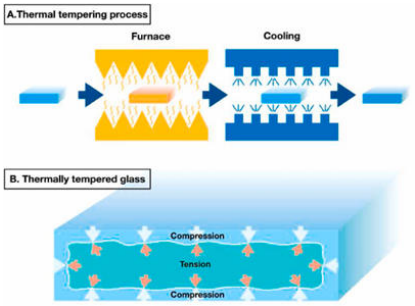
1) Ion exchange

Involves exchange of large potassium ions for the smaller sodium ions .Sodium containing glass articles is placed in a bath of molten potassium nitrate. The potassium ion is 35% larger than sodium ion. Squeezing of the potassium ions into the place of sodium ions creates a large residual compressive stress.



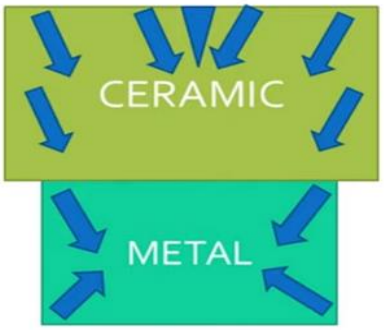
2) *Thermal tempering.*

*Creating residual stresses by rapidly cooling (**quenching**) the surface of object (glass or ceramic) while it is hot and in the softened (molten) state to induce a state of compression in the surface. This rapid cooling produces a skin of rigid glass surrounding a soft molten core. As molten core solidifies it tends to shrink, creates residual tensile stresses within the outer surface. Thermal tempering is an attractive technique for strengthening dental ceramics because the technique can be easily performed in commercial dental laboratories and the material surfaces are not degraded as a result of the tempering treatment.*



3) *Thermal compatibility*

The metal and the porcelain used in porcelain fused to metal restoration are designed with slight mismatch in their co-efficient of thermal expansion ·The coefficient of thermal expansion for metals is more than porcelain thus the metal contracts more than the porcelain on cooling provides additional strenath.



- ***Intrinsic involve Interruption of Crack Propagation by:***
  - ***Dispersion of Crystalline phase***

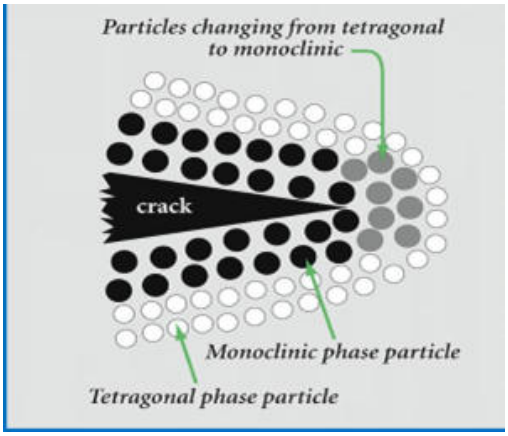
Involve adding Toughening particles AL2O3, MgO and zirconium oxide Crystals particles to a glass, the glass is toughened as the cracks cannot penetrate the alumina particles. Alumina have been added (40% Hi-Ceram) (In-Ceram 85%) to porcelain to increase its strengths enable it using alone (without metal substructure), also MgO Crystals and zirconium oxide have been added to porcelain to increase its strengths, enable it using alone as in all ceramic crowns, bridges, inlays and onlays.



  - ***Transformation Toughening***

New technique of strengthening glasses. *Toughness is ability of material to absorb energy to fracture.* ***Transformation Toughening ZIRCONIA (TTZ)*** *are often referred as ceramic steel because the strain or change in dimension, in response to stress behavior resemble that of steel in state of brittle ceramic. The energy required for the transformation is taken from the energy that allows to crack to propagate.*

(TTZ) *Involves* ***transformation*** *of* ***Zirconium oxide (ZrO2) grains from their TETRAGONAL phase to a MONOCLINIC phase*** *at the tips of cracks that are in the region of tensile stress. This transformation procedure accompanied by a volumetric expansion of the grains thus restricting the crack.* ***Since this expansion*** *is constrained by the surrounding material, the* ***net result is compressive stress on the surfaces of the crack****, which propagation is thus hindered, eventually preventing the failure of the zirconia restoration this is the reason why this phenomenon is called* ***phase transformation toughening****. Because of the strengthening and toughening mechanisms zirconium oxide was also referred to as "ceramic steel"*

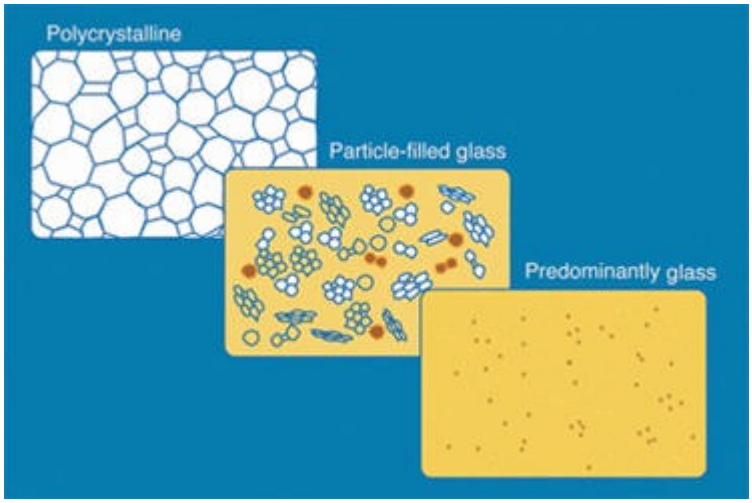


TYPES OF DENTAL CERAMICS

Kelly and Benetti, **classify ceramic according to their glass content** into three main divisions:

1) **Predominantly glassy materials,**
2) **Particle filled glasses---- Glass ceramics**
3) **Polycrystalline ceramics.**

Esthetic dental ceramics : Glassy
Substructure dental ceramics: Crystalline



1) **Predominantly glassy materials**

- *Best mimic the optical properties of enamel and dentine: Glassy material*
- *Glasses: 3D network of atoms having no regular pattern to the spacing between nearest atoms, thus they are amorphous or without form.*
- *Derived principally from a group of minerals called FELDSPAR: based on silica and alumina: Aluminosilicate glasses.*
- *Resistant to crystallization during firing, long firing ranges, biocompatible.*

2) Particle filled glasses---- Glass ceramics

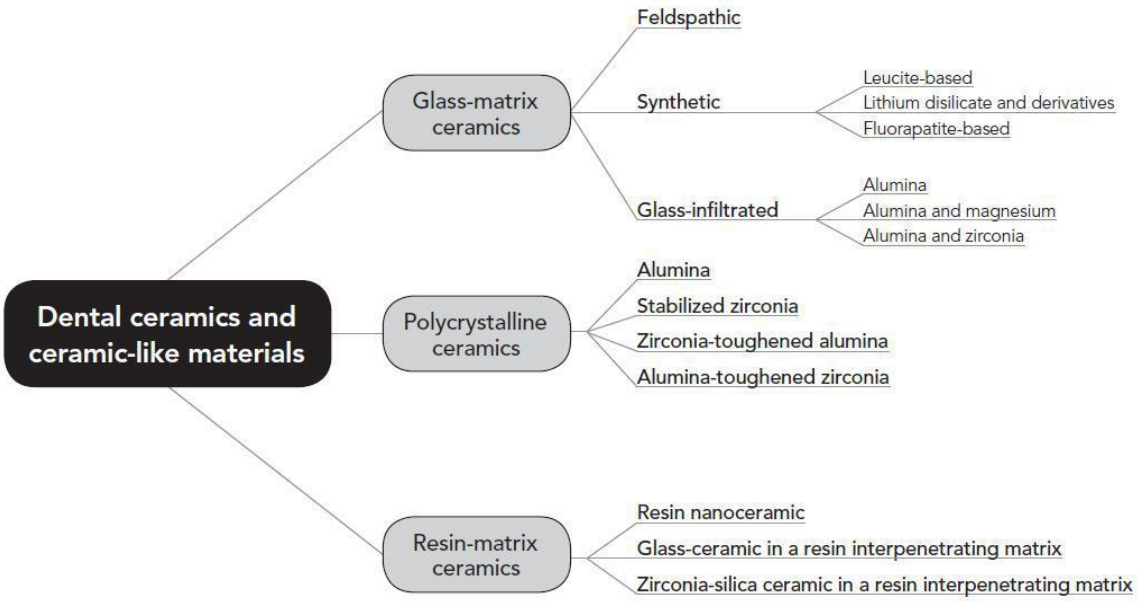
- *Filler particles are added to the base glass composition to improve mechanical properties and to control optical effects like Opalescence, Color, and opacity.*
- *This filler was added to create porcelains that could be successfully fired on metal substructure.*
- *Adding 17-25% Leucite filler (feldspar forms crystalline mineral Leucite, potassium-aluminum-silicate mineral with large coefficient of thermal expansion, when mixed with metal oxides & fired to high temperature) to base glass creates porcelains that are thermally compatible with dental alloys.*
- *Moderate strength increases can also be achieved with appropriate fillers added and uniformly dispersed: "Dispersion Strengthening"*

3) Polycrystalline ceramics

- *No glassy components, atoms are densely packed, regular network: Crack propagation difficult.*
- *Tougher and stronger than glassy ceramics.*
- *Difficult to process, CAD-CAM.*
- *Relatively opaque, core substructure.*
- *E.g. Aluminum oxide, partially stabilized Zirconia. (Procera, Cercon, Lava.)*

*The **increasing use** of **polycrystalline ceramics** (with no silicon in their composition), and the introduction of so-called **'hybrid' ceramics** (resin-matrix materials that are highly filled with ceramics) imposed the **need for a new classification system**, and, Since the existing classification systems does not include 'hybrid' ceramics, these are now available from various manufacturers and are recommended as esthetic alternative for a variety of clinical indications. In the light of this considerations a new classification system of ceramics was include. According to this classification system and **depending on the phase/phases present in their chemical composition**, all-ceramic and ceramic-like restorative materials can be **categorized into three groups:***

1. ***Glass-matrix ceramics:** nonmetallic inorganic ceramic materials that contain glass phase.*
2. ***Polycrystalline ceramics:** nonmetallic inorganic that do not contain any glass phase but only a crystalline phase.*
3. ***Resin-matrix ceramics:** polymer-matrices contain predominantly inorganic refractory compounds like porcelains, glass, ceramics and glass-ceramics.*



Composition (traditional porcelain – feldspathic porcelains)

1) **Kaolin 11—12%**
   - *It is a white clay like material (hydrated aluminum silicate).*
   - *Increases the ability of the porcelain mold before baking*
   - *Facilitates mixing with water while maintaining the form during drying and firing.*
   - *Make the material workable Reacts with the feldspar and gives rigidity*
   - *Being sticky in nature, bind the particles*
   - *Material can be carved*
   - *Give opacity to the fired porcelain*
2) **Feld Spar 70 – 90% (Alkaline aluminum potassium silicate)**
   - *It constitutes the bulk of dental porcelain*
   - *Translucent glossy matrix*
   - *Bind small particles of Kaolin and Quartz together*
   - *Alumina may replace silica –increase strength & opacity – use as core material under a regular translucent porcelain in all ceramic crown (jacket crown).*

Aluminous porcelain

The porcelain material contains 40-50% alumina crystals (Al_2O_3) in a low-fusing glass matrix (High-Ceram). The dispersed alumina particles are much stronger with higher modulus of elasticity and coefficient of thermal expansion than those of the glassy matrix. Presence of alumina makes the material opaque. (That is why it used only as coping or core beneath regular porcelain)

3) **Quartz**
   - *Form refractory skeleton about which the other material fuse and flow*
   - *A form of silica is used as filler*
   - *Help the crown holding itself during firing*
   - *Increase the strength of the material*
   - *Tissue contacts appear as normal tooth*
   - *Constitutes the crystalline face*
   - *Hardening of the mass*
4) **Fluxes**
   - *Alkalies such as sodium, potassium and calcium*
   - *Increase fluidity*
   - *Lower firing temperature*
   - *Acting as glass modifier (called glass modifiers).*
5) **Pigments**
   - *Added to color the porcelain (to provide proper shade)*
   - *Involve metal oxide such as titanium oxide – yellowish brown, iron or nickel oxide – brown, copper oxide – green, manganese oxide (lavender), cobalt oxide (blue), etc*
   - *They are fused together with regular feldspar and then reground and blended to produce a variety of colors.*
6) **Opacifiers**

Since pure feldspathic porcelain is quite colorless, opacifiers are added to increase its opacity in order to simulate natural teeth. Oxides of zirconium, titanium and tin are commonly used opacifiers.

CHARACTERS OF DENTAL PORCELAIN

1. **Biological Properties:**
   - *Inert has no interaction with surrounding soft tissue (biocompatible)*
2. **Interfacial Properties:**
   - *Not adhere chemically to dental cements*
3. **Chemical properties:**
   - *Not soluble in oral fluids and resist acid attach*
   - *Both hydrofluoric acid and stannous fluoride can cause an increase in surface roughness*
4. **Mechanical Properties:**
   - *Brittle*
   - *Low Dimensional tensile strength and fracture toughness*
   - *Hard, can cause wearing of opposing dentition*

5. **Thermal Properties:**
   - *Low thermal diffusivity*
   - *Coefficient Of thermal expansion similar or slightly higher than to that of enamel and dentine, not exhibit micro leakage (acrylic 4 –6 more).*
6. **Esthetic properties:**
   - *porcelain exhibit the best (Excellent) esthetic quality, and color matching*
   - *Difficult to be stained*
   - *Differ from acrylic which is esthetically poor because of light absorbent).*
7. **Practicability:**
   - *Sensitive manipulation technique, Requiring skilled operator and Special equipment's*
   - *Firing shrinkage is always, so operator should build up the restoration to a bigger size that allows shrinkage*
8. **Color stability;**

Porcelain is the most stable tooth colored restorative material. Glaze porcelain provide smooth glassy non porous surface that is resistant to adherent of exogenous stain (acrylic is not stable due to water absorption and porosity).

Disadvantages of dental porcelain

1) *Abrasive to antagonists.*
2) *Complex techniques need (fabrication).*
3) *Difficult to adjust and polish intra-orally.*
4) *May degrade supporting structure.*
5) *Low fracture resistance.*

Techniques of firing

1. ***Pressure technique***
2. ***Diffusible gas technique***
3. ***Vacuum firing technique***

Vacuum firing is one of greatest practical value *to the dental ceramist* ***because***

1. *It is easy to manipulate*
2. *Porcelain of grater translucence is achieved (decrease in the No. of gas bubbles)*
3. *Strength qualities somewhat more*

❖ *Porcelain reaction to firing (Phases of maturation)*

1. **Biscuit stage**
   - *Little shrinkage in the body of porcelain*
   - *Appear like opaque whit mass with porous surface, no translucency*
   - *Contamination of porcelain at this stage is easy (oil and dust)*
2. **Maturity stage**
   - *It divides into low, medium and high*
   - *Maturation of porcelain is evident at this stag*
   - *The amount of translucency and color shine depend on the degree of maturation*
   - *At the end of maturation, it will appear non porous glaze where the surface reflects light and cluster*
3. **Coalescence stage**
   - *If we continue firing, we reach this stage in which we loss the form of porcelain*

Classification

- **According to fusing temperature**
  1) **High fusing porcelain 2350 – 2500 F** (>1,300°C)
     Usually used for manufacture of porcelain denture teeth and aluminous cores production
  2) **medium fusing porcelain 2000 – 2300 F (1,101°C to 1,300°C)**
     Usually used for FPD, porcelain jacket crown, porcelain inlay and onlay.
  3) **Low fusing porcelain 1600 – 2000 F (850°C to 1,100°C)**
     Usually used for building porcelain in porcelain fused to metal restoration
  4) **Ultra-low fusing less than 850 (used with titanium) (< 850°C)**
     Usually used for building porcelain in porcelain fused to titanium restoration

- **According to type of restoration**
  1) All ceramic crown
  2) Porcelain fused to metal crown
  3) Inlay
  4) Onlay
- **According to Microstructure**
  1) Glass
  2) Crystalline
  3) Crystal containing glass
- **According to composition**
  1) Glass-matrix ceramics.
  2) Polycrystalline ceramics.
  3) Resin-matrix ceramics.
- **According to porcelain Type**
  1) Feldspathic or conventional porcelain
  2) Aluminous porcelain
  3) Leucite reinforced
  4) porcelain Glass infiltrated alumina
  5) Glass infiltrated spinell
  6) Glass ceramic
- **According to Processing Method**
  1) Sintered porcelain
  2) Cast porcelain
  3) Machined porcelain.
- **According to their clinical applications**
  1) Core porcelain:
     Used to form the basal layer of jacket crown
  2) Dentine or Body porcelain:
     More translucent, used to build the body of crowns
  3) Enamel porcelain:
     The most translucent, used to form the incisal edges

Nature of Bond between Porcelain & Metal

1. Mechanical bond

- *Achieved by minute irregularities on the surface of the metal (rough surface)*
- *Mechanical interlocking occurs only when wetting is efficient*

2. Vander woals bond

- *Represent attraction between atoms or molecules which are not primarily of same chemical nature*
- *It is more physical in nature*
- *It represents 1/3 of bonding*

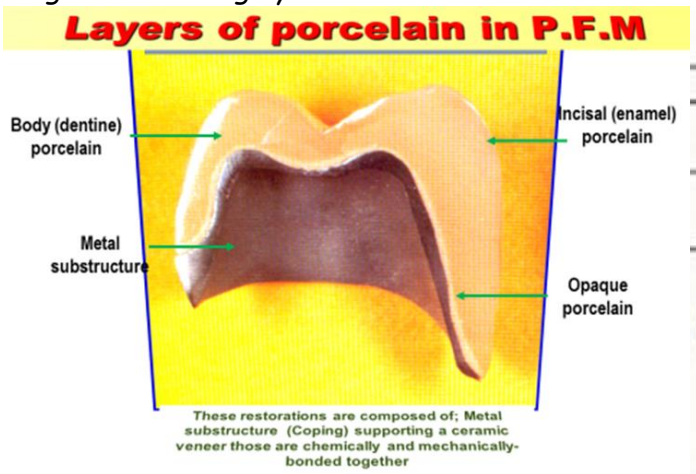
3. Chemical bond

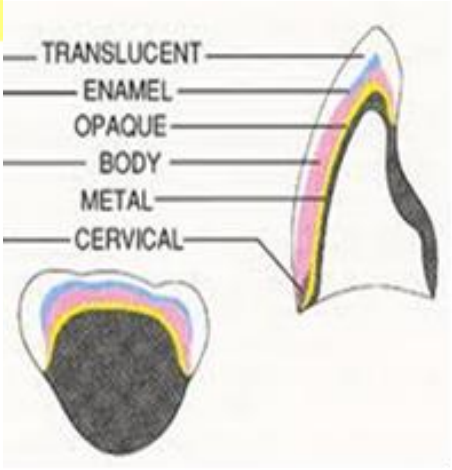
- *It is either covalent or ionic bond*
- *It means formation of anew substance between metal and porcelain which is combination of both*
- *There will be direct electron transfer between the oxygen of the glass and the oxidizable metal in the copping alloy*
- *It depends on the ability of alloy to form oxide layer between the copping and porcelain (indium and tin established this potential)*



❖ ***Layers of porcelain in P.F.M***

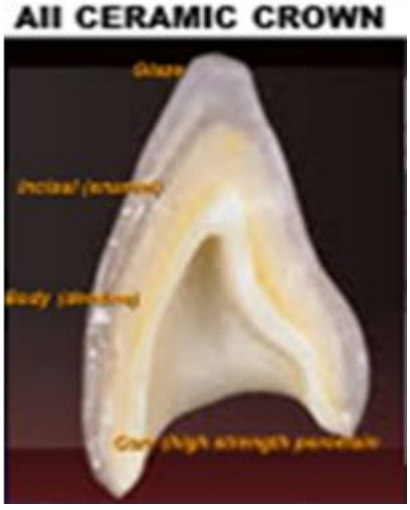
1. ***Opaque porcelain:*** *It is applied as a first porcelain layer; it initiates the development of shade. it performs two major function: it masks the color of the alloy, and it play an important role in the development of the metal porcelain bond.*
2. ***Body porcelain (Dentin):*** *this is fired onto the opaque layer, make up the bulk of the restoration, providing the most of the color or shade of the final restoration. It provides some translucency. Body porcelains are available in a wide selection of shades, to match adjacent natural teeth.*
3. ***Incisal porcelain (Enamel):*** *A translucent, lightly – pigmented dental ceramic used on a base of dentine ceramic to simulate the natural tooth enamel*
4. ***Glaze:*** *Translucent, low fusing porcelain which may applied to the surface as final stage in the firing cycle*





❖ ***Layers of porcelain in All Ceramic Crown (traditional porcelain crown)***

1. *Core (high strength porcelain)*
2. *Body (dentine)*
3. *Incisal (enamel)*
4. *Glaze*



❖ ***Requirements of the alloys***

1. *The alloy should have high melting range point to withstand the porcelain firing temperature without melting or creep*
2. *The alloy should be sufficiently rigid and have high modulus of elasticity so that it resist deformation during firing veneer bonded to the metal or during masticatory function where occlusal force acting (to support a very brittle porcelain veneer) otherwise fractures of the veneer is inevitable.*
3. *The alloy should be capable of forming a bond with the porcelain veneer in order that the latter does not become detached (capable of forming oxide layer).*
4. *The alloy should have a value of coefficient of thermal expansion similar to that for the porcelain to which it is bonded.*
5. *The alloy should have good castability*
6. *The alloy should have fine grain structure to resist corrosion*

❖ ***available alloy for porcelain bonding***

- *Noble alloys (gold platinum alloy).*
- *Low noble alloys (gold palladium alloy).*
- *Silver-palladium alloys.*
- *Nickel-chromium alloys.*

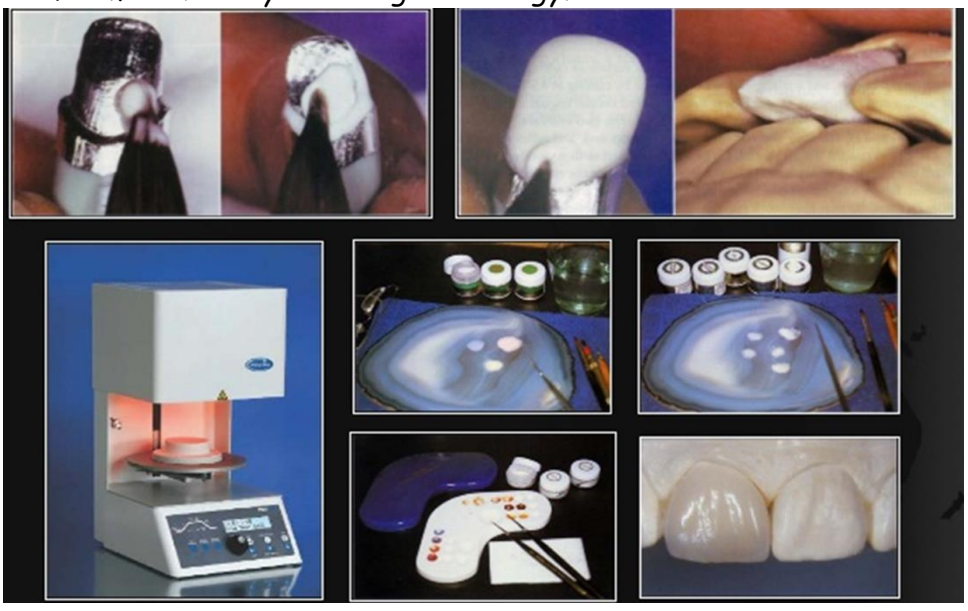
Families of all-ceramic restorations

In an all-ceramic restoration, the ceramic material may be ***monolithic (uni-layer)*** *and consist of a single ceramic material, or it may consist of a ceramic core material that is covered with a ceramic veneer and is known as* ***a bilayered all-ceramic restoration****.*

ALL CERAMIC SYSTEMS can classify According to fabrication technique into

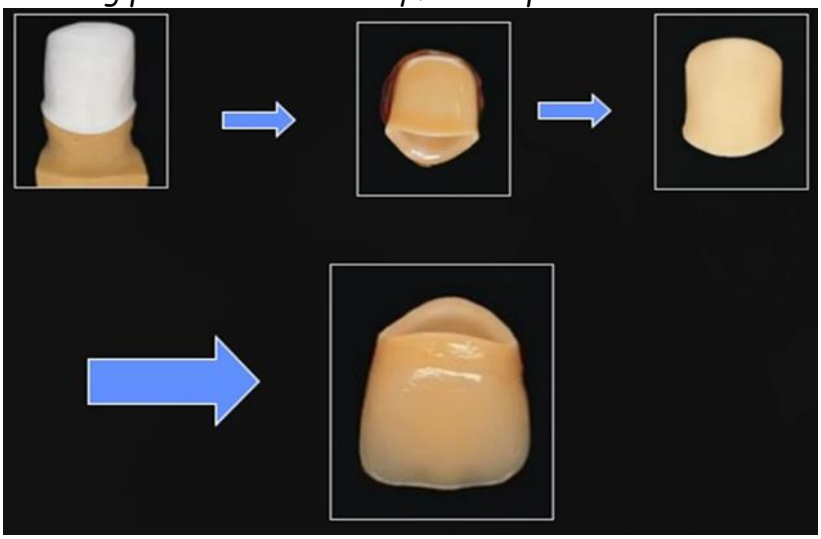
1. ***Powder-slurry (Sintering)ceramics (Conventional Ceramic Crown)***

The material presents as powder to be mixed with liquid (water) forming a slurry that is used to build the restoration up upon layer on the die of the prepared tooth to form the contour of the restoration. A slurry of densely packed ceramic particles was then sintered. ***Sintering is a process of heating closely packed particles to achieve interparticle bonding and sufficient diffusion to decrease the surface area or increase the density of the structure (heating a material to just below the melting point so that it forms on solid mass).*** *Veneers, inlays, and specific cases of crowns on anterior teeth are manufactured by sintering technology.*



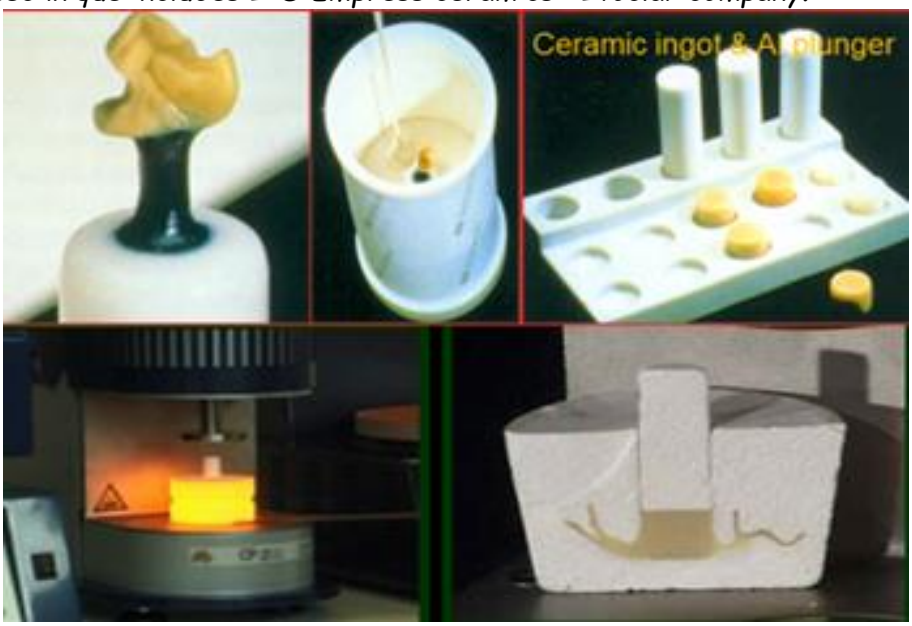
2. *Infiltrated ceramic (SLIP-CASTING TECHNIQUE)*

This technique involves the application of ceramic slurry to a porous refractory die which leads to compaction of the particles and creation of a porous infrastructure core by slip casting, which is sintered and then infiltrated with a lanthanum-based glass, producing two interpenetrating continuous networks: a glassy phase and a crystalline infrastructure (Powder is used to form a porous crystalline core by fusion of Metallic particles at high temperature, then, A Glass coat is then fused over the porous slip to infiltrate (at high temperature) into the pores (porous substrate) to give high strength restoration).Veneering porcelain is then required to provide the desired shade and contour



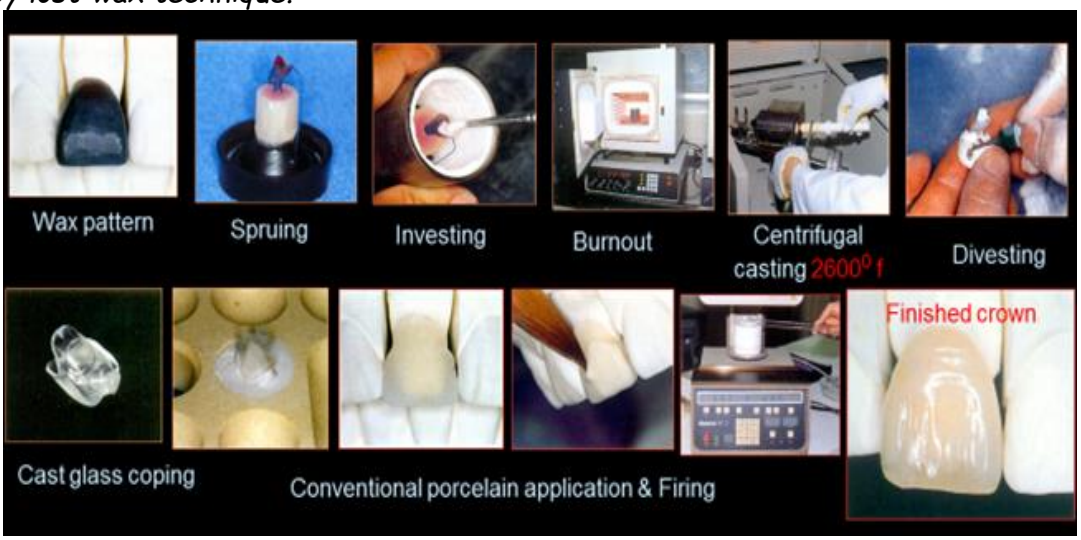
3. *Pressable ceramic (HOT-PRESSING TECHNIQUE)*

Because this method is based on the application of external pressure at high temperatures to produce the restoration, it is also known as the hot-pressing technique. The restoration fabricates by injection or pressing the molten ceramic material into a mold cavity made by lost wax technique (after waxing and investing). The first generation of heat-pressed dental ceramics contains leucite as reinforcing crystalline phase. The second generation is lithium disilicate-based. An example of the commercially available products used with the press technique includes IPS Empress ceramics—Ivoclar company.



4. *Castable ceramic*

The restoration fabricates by casting technique, to cast the molten ceramic material (the product supplied as a solid ceramic block) into previously prepared mold cavity that made by lost-wax technique.



5. Machinable ceramic

Mechanical processing (milling) of ceramic is a gradual removal of the material with rotating multi-bladed instruments (cutters or diamond heads), their cutting edges are in the interrupting contact with the processed material.

A. *Copy milling technology*

A resin pattern is directly fabricated on the prepared tooth or on the master die, scanner was then used to scan the pattern, the pattern was then used as a copping guide for the milling machine

B. *CAD/CAM system (computer aid machine / computer aid design)*

Computer aided design and computer aided manufacturing (CAD/ CAM) technologies. The prepared tooth is optically impressed (pictured using intra-oral camera). The restoration is design over that image by the aid of computer……Then Ceramic blocks are carved into restorations by the aid of computer-controlled milling machine

