

# REVIEW ON RECENT ADVANCES IN ALL-CERAMICS FOR DENTAL PRACTICE

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## Abstract

Dental ceramics are the preferred alternatives to traditional materials to meet the patient and dentist demand for improved aesthetics. Over the last few decade, there has been increasing interest in ceramic materials in dentistry. While porcelain based materials are still a major component in dental practice, however there has been some move to replace metal-ceramics with all-ceramic systems due to advances in fabrication technology and bonding techniques. The application of high technology processes lead to development of newer materials like Heat Pressed- Injection molded, Slip cast- Glass infiltrated, Glass ceramics. In this brief review, discussion about advances in all-ceramics and fabrication techniques. microstructure property relationship will also be addressed.

**Key Words** All ceramics, sintering, slip cast, CAD CAM, Zirconia.

## INTRODUCTION

Ceramics represents one of the four major classes of materials used for restorative and prosthetic dentistry, other three being metals, polymers and composites.

The first use of porcelain dates back to 1774 by Alex Duchateau in complete denture. Porcelain suitable for metal-ceramic restoration were introduced in 1962 by Weinstein.

Aluminous core and veneer porcelain was first described by Mclean and Hughes 1965.

Dental ceramic science and technology represents the fastest growing field of dental materials research & development. In the last few decades, application of high technological processes to dental ceramics lead to development of newer materials such as heat pressed, injection molded, Slip-cast, glass ceramics.

## BACKGROUND

A ceramic is an earthy material, silicates nature and are usually combination of one or more metals with non-metals, usually oxygen.

The word ceramic comes from the Greek word "**Keramos**" which means burnt stuff.

Dental ceramic are non-metallic, inorganic structures, primarily containing compounds of oxygen with one or more metallic or semi-metallic elements (sodium, calcium, potassium, aluminium, boron, cerium, lithium, magnesium, phosphorus, silicone, titanium, zirconium).

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Dental ceramics consists of silicate glasses, dental porcelains, glass-ceramics, or the highly crystalline solids.

**Silicate glasses** differs from non-silicate glasses in that, silicon is the central divalent cation that is bound to four relatively large oxygen anions forming tetrahedra, which links randomly to other tetrahedrons by each oxygen atom present at the corner of tetrahedra, to form polymeric type  $(SiO_2)_n$  chains.

**Dental porcelains or feldspathic porcelain** are vitreous ceramic based on silica  $(SiO_2)$  network and potash feldspar  $(K_2O-Al_2O_3-6SiO_2)$ , soda feldspar  $(Na_2O-Al_2O_3-6SiO_2)$ , or both along with other crystalline additives like  $LiO_2$ ,  $TiO_2$ , etc. The earliest dental porcelain had kaolin, feldspars and quartz, where kaolin acts as the binder. But the newer generations do not have kaolin, hence they are named as feldspathic porcelain.

**Glass ceramics** are partially crystalline glasses that are formed by controlled devitrification of glass matrix using heat treatment, resulting in nucleation and growth of crystals inside the matrix phase. This process is called "ceramming".

In earlier days glass ceramic was made by lost-wax pattern casting procedures. but now hot-pressing and CAD-CAM processing are used to produce glass ceramic core frameworks.

**Polycrystalline ceramics** are solid core ceramics of alumina, zirconia having single phase(mono-phase), formed by directly sintering crystals together without any intervening glass matrix. They are strengthened by transformation strengthening.

## APPLICATION OF CERAMICS IN DENTISTRY

In dentistry ceramics are widely used for making inlays, on-lays, crown and bridges, porcelain denture teeth, intra-radicular post, abutments and implants, veneers over metal sub-structures.

## ADVANTAGES

Ceramics have excellent aesthetics, chemical inertness, biocompatibility, high compressive strength, has flexural strength like that of steel, resilient, temperature resistant, excellent wear resistance .

## LIMITATIONS

However ceramics are brittle, low tensile strength , fracture toughness, and may fracture under a very low strain (0.1%, 0.2%), poor ductility or

elongation.

## STRENGTHENING OF CERAMICS

Ceramics can be strengthened by the following:

**A. Development of residual compressive stresses within the surface of the material**

**B. Ion exchange**

**C. Thermal tempering**

**D. Reduced number of firing cycles**

**E. Optimal design of the prosthesis to minimize the tensile stresses.**

**F. Interruption of crack propagation by:**

**(1) Dispersion strengthening ;**

**(2) Transformation toughening.**

**G. Glazing results in low expansion surface** - when cooled produces surface compressive layer which reduces depth, width of surface flaws.

## REVIEW OF NEW MATERIALS AND PROCESSES

Within the last ten years, an increasing number of ceramic materials for all-ceramic restorations has been developed. Each uses different approach to improve the mechanical properties without being ceramic.

They can be classified according to:

**A. Processing techniques:**

1. Conventional Sintered,
2. Castable ceramics
3. Slip-cast ceramics
4. Pressable ceramics
5. Machinable ceramics

**•B. Major crystalline phase and their micro - structure.**

- Glass based systems- mainly silicate glasses
- Glass based systems with fillers ( like leucite, lithium di-silicate).
- Crystalline based systems with glass fillers - {includes In-ceram spinell, alumina, zirconia (made by slip cast method)}.
- Polycrystalline ceramics - (alumina, zirconia).

## 1. SINTERED PORCELAINS

Sintering is a complex sequence of high temperature reactions occurring above the softening point of porcelain, resulting in leading to partial melting of glassy matrix with coalescence of powder particles.

Sintering promotes physio-chemical reaction responsible for the final properties of ceramic products. During sintering density of porcelain increases and results in volumetric shrinkage of 30-40%.

The amount of porosity decreases in the last stage of sintering. It is mainly influenced by sintering temperature, time, viscosity of melt. It is less if done in vacuum.

Sintered porcelain includes:

- Leucite reinforced feldspathic porcelain
- Alumina based porcelain
- Magnesia based porcelain
- Zirconia based porcelain
- Hydrothermal low fusing

### LEUCITE-REINFORCED FELDSPATHIC PORCELAIN

OPTECH HSP (Jeneric/ Pentron) is commercially available form of feldspathic porcelain which is reinforced with approximately 45% volume of tetragonal leucite crystals, which are responsible for high compressive strength, high modulus of rupture and high thermal contraction coefficient ( $25 \times 10^{-6}/^{\circ}\text{C}$ ) which is more than glass matrix ( $8 \times 10^{-6}/^{\circ}\text{C}$ ). This results in development of tangential compressive stresses in glass around leucite crystals when cooled. These stress acts as crack deflectors and increases resistance to crack propagation.

Improved flexure strength (160-300 MPa) due to high crystalline content.

The low refractive index of the crystals makes it translucent even with high crystal content.

They are mainly used in fabrication of inlays, on-lays, veneers, crowns in low stress areas.

### ALUMINA BASED PORCELAINS

It was first introduced in 1965 by Mclean and Hughes. This is reinforced by addition of Alumina ( $\text{Al}_2\text{O}_3$ ), strongest and hardest known oxide by the mechanism called "**Dispersion strengthening**".

The first aluminous core porcelain contained 40-50% alumina by weight (Mclean & Hughes, 1965). The core was baked on platinum foil and later veneered with match expansion porcelain.

A more recent development by Mclean in 1994, where porcelain is baked directly on to a refractory die.

It has high modulus of elasticity (350 GPa), fracture toughness, high melting point with great stability, co-efficient of thermal expansion (CTE) similar to glass matrix, produces highly accurate margins.

Commercially available as Hi Ceram (Vivadent, Baldwin Park, CA). Used in anterior crowns, posterior crown where occlusal harmony maintained, person who are allergic to metals.

### MAGNESIA BASED PORCELAINS

Magnesia core ceramics was developed as an experimental material in 1985 (O'Brien). Its high thermal coefficient ( $14.5 \times 10^{-6}/^{\circ}\text{C}$ ) matches the body and incisal porcelains, designed for bonding with the metal ( $13.5 \times 10^{-6}/^{\circ}\text{C}$ )

The core is made by reaction of magnesia (40-60%) with silicate glass at 1100-1150 $^{\circ}\text{C}$  resulting in precipitation of forsterite ( $\text{Mg}_2\text{SiO}_4$ ) crystal which is responsible for strengthening ceramics.

Thus the matrix is strengthened by both (1) dispersion strengthening with magnesia and (2) crystallization within matrix by forsterite.

The flexure strength of unglazed porcelain is twice high (131 MPa) as that of conventional feldspathic porcelain (65 MPa).

The magnesia core material can be further strengthened by glazing, which places ceramic surface under residual compression stresses.

Usually used as core material for metal ceramic veneer porcelain.

### ZIRCONIA BASED PORCELAIN

It is a biomaterial since 1970 used in hip replacement, but used in dentistry since 2004.

Zirconia ( $\text{ZrO}_2$ ) is a white poly crystalline material, that is included in the conventional feldspathic porcelain in order to strengthen this feldspathic porcelain (Mirage II) by "transformation strengthening".

Zirconia shows crystallographic transformation. It exist in cubic form above 2680 $^{\circ}\text{C}$  and in meta-stable state with tetragonal structure between 1170-2370 $^{\circ}\text{C}$  and below 1170 $^{\circ}\text{C}$  it exist in stable monoclinic form.

In transformation toughening, this property of crystallographic transformation of Zirconia is utilized. Zirconia is partially stabilized by using stabilizing agents like CaO, MgO,  $\text{Y}_2\text{O}_3$ , CeO, which allows the high temperature tetragonal phase to be retained at room temperature, and also controls the volume expansion. This partially stabilized zirconia has high initial flexural strength and fracture toughness.

Now when this partially stabilized zirconia is subjected to any stress (like tensile stresses in oral environment or during fabrication of prosthesis), there is crystallographic transformation of partially stabilized tetragonal phase to more stable monoclinic phase with 3-5% localized volume expansion. As a result of this transformation, compressive stresses are established on the crack surface, thereby arresting its growth. This mechanism is called transformation toughening of ceramic.

Though addition of zirconia increases the fracture toughness, strength, thermal shock resistance, but it adversely affects the translucency of the ceramic and also reduces the fusion temperature.

Due to their increased strength and fracture toughness these zirconia based porcelains are used as coping material for all ceramic restorations in post, crowns and bridges.

## HYDROTHERMAL CERAMICS

These are low fusing feldspathic porcelain with hydroxyl group in glassy matrix. These hydroxyl ions get incorporated into matrix through exposure to water or water vapour.

These ceramics are two types:-

1. Simple phase porcelain (Duceram LFC) - fired at 660°C. It contains amorphous fluorine glass with hydroxyl ions and the base layer is Duceram metal ceramic leucite containing porcelain.
2. Leucite containing two phase material (DuceraGold).

These ceramics have increased mechanical and flexural strength (11MPa), fracture toughness, thermal expansion.

They can be repaired and corrected.

Only disadvantage is special die material needed.

They are used to fabricate inlays, onlays and veneers.

## 2. CASTABLE GLASS CERAMICS

Glass ceramics are polycrystalline solids prepared by controlled crystallization of glasses. It is also called castable glass ceramics as they are processed by using lost wax pattern casting procedure.

The first glass ceramic was developed in late 1950s (Stookey 1959) and first commercially available material for dental use is DICOR.

Advantage of the glass ceramics are increased homogeneity of final product compared to conventional sintered porcelains.

Machinability is another desirable property for maximum utility.

These ceramics have "chameleon effect", in which a part of the colour of ceramic is picked up from the adjacent tooth structure, making it more aesthetic.

Glass ceramics prosthesis fabrication are done first by fabrication of vitreous, non crystalline state and then converted to a crystalline state by controlled devitrification process using heat treatment (1100°C called "ceramming").

This ceramming takes place in two phase : crystal nucleation followed by crystal growth.

Glass ceramics includes:

- Mica based
- Hydroxyapatite based
- Lithia based

## MICABASED GLASS CERAMICS

It was the first commercially available castable glass (DICOR) ceramics used for dental purpose.

It was made of 55% volume of tetrasilicic fluomica ( $KMg_{2.5}Si_4O_{10}F_2$ ) as the major crystal, which is also responsible for machinability of DICOR glass ceramics.

Mica are classified as layer-type silicates. Cleavage planes are present along the layers.

Mica crystals are usually randomly oriented highly interlocked within glassy matrix having a "house of cards" microstructure, which provide fracture resistance.

Crack propagation does not occur across these mica crystals, rather it occur along the cleavage planes present between the layers.

It has high flexural strength (110-172 MPa), high fracture toughness, improved aesthetic with chameleon effect.

## HYDROXYAPATITE BASED GLASS CERAMICS

Ceraparl, is a castable glass ceramic which has a crystalline phase containing oxyapatite, which can be transformed into hydroxyapatite when exposed to moisture.

It melts at 1460°C and can be casted. The casting has an amorphous microstructure and when reheated at 870°C for 1 hour, it becomes crystalline oxyapatite. This apatite is clinically unstable and gets transformed into hydroxyapatite on exposure to moisture.

It has crystalline arrangement similar to enamel, but the crystals are themselves irregular providing superior mechanical strength.

It is indicated for crowns and inlays.

## LITHIABASED GLASS CERAMICS

Glass-ceramics can be obtained from a wide variety of compositions, leading to a wide range of mechanical and optical properties, depending on the nature of the crystalline phase nucleating and growing within the glass.

Experimental glass-ceramics in the system  $\text{Li}_2\text{O}-\text{Al}_2\text{O}_3-\text{CaO}-\text{SiO}_2$  are currently the object of extensive research work. The choice of adequate additives is critical in the development of tougher and higher-strength glass ceramics (Anusavice et al. 1994b).

Differential thermal analysis can be efficiently used to determine the heat treatment leading to the maximum lithium disilicate crystal population in the shortest amount of time, thereby optimizing the nucleation and crystallization heat treatment of this type of glass-ceramic (Parsell and Anusavice, 1994).

## 3. SLIP CAST GLASS INFILTRATED CERAMICS

It involves pouring of an aqueous porcelain slip on a refractory die.

The porosity of refractory die helps in condensation by absorption of water from slip by capillary action.

Then refractory die is fired at high temperature i.e.  $120^\circ\text{C}$  for 2 hr followed by  $1120^\circ\text{C}$  for 10 hr. During this heat treatment, refractory die shrinks more than the condensed slip which helps in easy separation.

The resulting ceramic is very porous and must be infiltrated with molten glass or fully sintered before the final veneering porcelain is applied.

These ceramics contains 2 inter-penetrating phase i.e. core framework and infiltrated glass.

The core is usually made of (1) spinell (2)zirconia (3)alumina.

The infiltrated glass is Lanthanum alumino-silicate glass, which is less viscous and promotes proper infiltration.

## IN-CERAM SPINELL

Spinell ( $\text{MgAl}_2\text{O}_4$ ) is a natural mineral that is normally found together with limestone and dolomite.

It is of dental significance because of its extremely high melting point ( $2135^\circ\text{C}$  combined with its high strength).

Spinell is also chemically inert and has low electrical and thermal conductivity but, most importantly, it has unique optical properties.

It has moderate strength of about 350 MPa and good translucency. It is more than twice as

translucent as In-Ceram alumina due to the refractive index of its crystalline phase being close to that of glass.

Glass infiltrating in a vacuum environment results in less porosity, ensuring this high level of translucency. Often, however, this level of translucency can be excessive and can lead to an overly glassy, low-value appearance.

## IN-CERAM ALUMINA

Aluminum oxide ( $\text{Al}_2\text{O}_3$ ) is most widely known under the term corundum. As a result of the homogeneous framework structure made of ultrafine  $\text{Al}_2\text{O}_3$  particles, whose cavities are filled with a special glass, the degree of tensile bending strength is significantly higher than that of all other ceramic systems.

With a weight percentage of 10–20%, aluminum oxide is a component of feldspar, which is the starting material for metal–ceramic veneering materials.

The ceramic materials for substructures of jacket crowns have been enriched by up to 60% by weight with aluminum oxide crystals with a grain size of 10–30  $\mu\text{m}$  to increase stability.

Because of the large difference in the refraction index (feldspar  $n = 1.53$ ; corundum  $n = 1.76$ ), intense refraction of light occurs at the aluminum oxide crystals in the feldspar, which results in the opaque effect of such  $\text{Al}_2\text{O}_3$ -enriched ceramic materials. Therefore, they are only suitable for fabrication of crown frames with subsequent veneering.

In-Ceram alumina has a strength of around 500 MPa and poor translucency.

Synthetically produced corundum with a grain size of 2–5  $\mu\text{m}$  is used for In-Ceram alumina. In the solid phase, it is sintered at  $1100^\circ\text{C}$ , well below the melting point of  $2040^\circ\text{C}$ , and it is then infiltrated with dentine-coloured glass at  $1120^\circ\text{C}$ .

## IN-CERAM ZIRCONIA

The zirconia system uses a mixture of zirconium oxide and aluminum oxide as a framework to achieve a marked increase in the flexural strength in the core framework.

Aluminum oxide makes up about two-thirds of the crystalline structure as seen in the scanning electron micrograph to the right.

The remaining crystalline structure consists of tetragonal zirconium oxide (round white particles).

The proportion of glass phase amounts to approximately 20–25% of the total structure. This leads to the high strength as already seen in In-Ceram alumina. The increase however over alumina is due to the zirconium oxide particles that protect the structure against crack propagation. It has a very high

strength of around 700 MPa and very poor translucency.

#### 4. PRESSABLE CERAMICS

These are also called Hot Pressed, Injection-molded ceramics.

Pressable ceramics fabrication involves the application of external pressure at elevated temperatures to obtain sintering of the ceramic body. So based on the processing technology these ceramics are also called as "hot-pressed" ceramics or "heat-pressed" ceramics.

This fabrication technique prevents the porosity, and extensive grain growth or secondary crystallization in ceramics with associated increase in density and superior mechanical properties.

Pressable ceramics are categorized into two generations:

- First generation of heat-pressed dental ceramics contains leucite as reinforcing crystalline phase (IPS Empress and
- Second generation is lithium disilicate-based (IPS Empress2).

**First generation heat-pressed ceramic such as IPS Empress1** - is dispersed with 35 to 45 vol% leucite crystalline phase.

The strengthening mechanism involves the dispersion strengthening of leucite crystals, formation of stable tetragonal phase at processing temperature and also involves in the development of tangential compressive stresses around the crystals upon cooling, due to the difference in thermal expansion coefficients between leucite crystals and glassy matrix.

However, the strength and fracture toughness may be diminished when the micro cracks joins with each other results in decoupling the crystals from the glass matrix.

The amount of porosity is approximately about 9%. Dong et al suggested that that the flexural strength of these ceramics can be significantly improved after additional firings, due to additional leucite crystallization.

**Second generation heat-pressed ceramic such as IPS Empress2** -

It contains about 65 vol % lithium disilicate as the main crystalline phase.

Numerous studies have revealed that it forms two different phases such as lithium metasilicate ( $\text{Li}_2\text{SiO}_3$ ) and cristobalite ( $\text{SiO}_2$ ) during the crystallization process, prior to the growth of lithium disilicate ( $\text{Li}_2\text{Si}_2\text{O}_5$ ) crystals. The final micro structure consists of highly interlocked lithium

disilicate crystals and layered crystals which contribute to strengthening.

The mismatch in COTE between lithium disilicate crystals and glassy matrix is also likely to result in tangential compressive stresses around the crystals, potentially responsible for crack deflection and strength increase.

Crack propagation can take place easily in directions parallel to crystal alignment and has high resistance to crack propagation in the direction perpendicular to crystal alignment.

IPS Empress 2 ceramics were characterized with about 1% porosity.

More recently, IPS e.max Press (lithium disilicate glass-ceramic ingot for the press technique) and IPS e.max ZirPress (fluorapatite glass-ceramic ingot for the press-on technique) ceramic systems were developed by Ivoclar Vivadent.

IPS e.max Press is processed in the dental laboratory with the known Empress pressing equipment. This equipment is distinguished for providing a high accuracy of fit.

The microstructure of IPS e.max Press is characterized as needle-like lithium disilicate crystals, which are embedded in a glassy matrix.

The flexural strength of IPS e.max press is more than IPS Empress, comparatively.

**THE "SHRINK-FREE" CERESTORE SYSTEM** was introduced with injection-molded technology.

The commercial material available with this system is Alceram (Innotek Dental Corp, Lakewood, CO) which contains a magnesium spinel ( $\text{MgAl}_2\text{O}_4$ ) as the major crystalline phase.

This material has the excellent marginal fit of the restorations.

Although fired copings has much higher crystalline content than aluminous porcelain, there is no difference in strength. rather its micro-structure reveals large number of porosities which decreased its strength.

#### 5. MACHINABLE CERAMICS

The evolution of CAD-CAM (Computer aided design and Computer aided machining) technology for the production of machined inlays, onlays, and crowns led to the development of a new generation of machinable ceramics.

The advantages of this system include; impressions are not needed, which saves the dentist chair time and also avoids cross-contamination between the patient-dentist operational field and the dental technician.

Dr. Duret was extensively worked on the development of CAD-Cam System. He has developed Sopha system, which had led to the development of CAD-CAM system in dentistry.

Most popular systems available for machining all-ceramic restorations include

- **CEREC** (Siemens, Bensheim, Germany) system,
- **CELAY** (Mikrona Technologie, Spreitenbach, Switzerland) system and
- **PROCERA ALCERAM** (Noble Biocare, USA) system.

### THE CEREC SYSTEM

It was developed by Dr. Moermann. CEREC stands for "*Chair side Economic Restoration of Esthetic Ceramics*" and it was the first fully operational CAD-CAM ceramic.

There are two commercial materials available in this system:-

- They are Vita Mark II (Vident, Baldwin Park, CA) and
- Dicor MGC (Dentsply International, Inc., York, PA).

Vita mark II contains sanidine (KAlSi<sub>3</sub>O<sub>8</sub>) as a major crystalline phase. Sanidine imparts more opacity to the ceramic.

Dicor MGC is a machinable glass ceramic similar to Dicor, with the exception in the fabrication technique. This material contains 70 vol% of tetrasilicic fluoromica crystals. This higher vol% of crystalline phase addresses its superior mechanical properties.

The fabrications of ceramic prosthesis involve the scanning of prepared tooth structure and digitize the information in to the computer. Design the restoration in the computer and activate the milling machine to cut the ceramic into the required shape.

Adhesive resin cements are most commonly suggested for luting of these all-ceramic crowns to improve the fracture resistance.

However, numerous studies have shown that the overall fracture resistance of Dicor MGC was independent of cement film thickness.

### THE CELAY SYSTEM

It uses a copy milling technology to manufacture ceramic inlays or onlays from resin analogs.

This system is a machinable device based on pantographic tracing of resin inlay or onlay fabricated directly on to the prepared tooth or die.

Commercially available Celay system material is Vita-Celay (Vident, Baldwin Park, CA). Sanidine is the major crystalline phase in this material.

Recently, In-Ceram pre-sintered slip cast alumina blocks (Vident, Baldwin Park, CA) have been developed and they can be machined with the Celay copy-milling system. This material is mainly used to make crowns and fixed partial dentures.

### PROCERA ALL CERAM SYSTEM

PROCERA ALL CERAM SYSTEM (Nobel Biocare, USA) was introduced by Dr. Andersson, it was the first system which provided outsourced fabrication using a network connection.

The master die is scanned and the scanned images are sent to processing center/laboratory through an internet. In the processing center/laboratory, an oversized die is milled to compensate the firing shrinkage.

The die is milled by a computer controlled milling machines using scanned images. Aluminum oxide powder is compacted on the die and coping is milled by a computer controlled milling machines.

### OTHER SYSTEMS :

These were developed using milling technique were

- DCS Precident system with a laser scanner,
- Cercon System with no CAD component, and
- CICERO (Computer integrated crown reconstruction) system.
- More recently, Lava CAD/CAM System (3M ESPE, St. Paul, Minnesota) was introduced. It is used for fabrication of zirconia framework for all ceramic restorations using yttria stabilized tetragonal zirconia polycrystals which have greater fracture resistance than conventional ceramics.

Lava system uses a laser optical system to digitize information. The Lava CAD software automatically finds the margin and suggests a pontic and CAM produces an enlarged framework to compensate shrinkage.

The machinable ceramic prostheses can be delivered to patient with in a single appointment.

However, the drawbacks of this system include; requires expensive equipment and also the dentist/technician should have the adequate knowledge to use and operate the system.

Most dental zirconia ceramics are opaque and copings need to be veneered for high aesthetics. The colour difference between zirconia core and adjacent natural tooth should be reduced through layering technique for the veneering porcelain.

Appropriate shade selection also plays an important role in the defining of final aesthetic properties.

Bona et al evaluated the colour differences between various CAD-CAM ceramic restorations and suggested that adjustments should be made carefully to the final shade of CAD-CAM ceramic restorations to reach a clinically acceptable shade match.

Various surface treatments have been suggested in the literature to improve the bond strength between ceramic and the natural tooth. Various surface treatments include abrasion/sand blasting, a diamond stone bur, sand paper disks, LASERS, etching, atmospheric plasma, UV, and treatment with ceramic primer.

## MICROSTRUCTURAL CLASSIFICATION

At the micro-structural level, we can define ceramics by the nature of their composition of glass-to-crystalline ratio. There can be infinite variability of the microstructures of materials, but they can be broken down into four basic compositional categories, with a few subgroups:

- composition category 1 – glass-based systems (mainly silica),
- composition category 2 – glass-based systems (mainly silica) with fillers, usually crystalline (typically leucite or, more recently, lithium disilicate),
- composition category 3 – crystalline- based systems with glass fillers (mainly alumina) and
- composition category 4 – polycrystalline solids (alumina and zirconia).

**Composition category 1** – Glass-based systems : They are made from materials that contain mainly silicon dioxide (also known as silica or quartz), which contains various amounts of alumina.

Alumino silicates found in nature, which contain various amounts of potassium and sodium, are known as feldspars. Feldspars are modified in various ways to create the glass used in dentistry. Synthetic forms of aluminosilicate glasses are also manufactured for dental ceramics.

### **Composition category 2 – Glass-based systems with fillers**

This category of materials has a very large range of glass–crystalline ratios and crystal types, so much so that this category can be subdivided into three groups. The glass composition is basically the same as the pure glass category. The difference is that varying amounts of different types of crystals have either been added or grown in the glassy matrix. The

primary crystal types today are leucite, lithium disilicate or fluoroapatite.

### **Subcategory 2.1**

Low-to- moderate leucite - containing feldspathic glass – these materials have been called “feldspathic porcelains” by default. Even though other categories have a feldspathic-like glass, this category is what most people mean when they say “feldspathic porcelain.”

### **Subcategory 2.2 :**

High-leucite-containing (approximately 50%) glass. Again, the glassy phase is based on an aluminosilicate glass. These materials have been developed in both powder/liquid, machinable and pressable forms.

### **Subcategory 2.3:**

Lithium-disilicate glass ceramic is a new type of glass ceramic introduced by Ivoclar as IPS Empress® II (now called IPS e.max®), where the alumino-silicate glass has lithium oxide added.

### **Composition category 3 – Crystalline-based systems with glass fillers**

Glass-infiltrated, partially sintered alumina was introduced in 1988 and marketed under the name In-Ceram. The system was developed as an alternative to conventional metal ceramics and has met with great clinical success.

### **Composition category 4 – Polycrystalline solids**

Solid-sintered, monophase ceramics. They are formed by directly sintering crystals together without any intervening matrix to form a dense, air-free, glass free, polycrystalline structure. There are several different processing techniques that allow the fabrication of either solid-sintered aluminous- oxide or zirconia oxide framework.

## STRENGTH AND FRACTURE TOUGHNESS

There are two interrelated properties that often are quoted regarding ceramics intended for structural purposes:

1. Strength and
2. Fracture toughness

### **Strength**

Mechanical failure of ceramic materials is almost completely controlled by brittle fracture. Usually, this brittle behaviour combined with surface flaws resulted in relatively low ceramic strengths.

Increased crystalline-filler content within the

glass matrix, with a more even distribution of particles and finer particle size, has yielded significant improvements in the flexural strength of ceramic materials.

However strength improvements are still limited by the inherent weakness of the glass matrix. All ceramics fail because of crack propagation at a critical strain of 0.1%. Applied stresses can cause a crack to grow throughout the matrix, causing the ultimate failure of that restoration.

### **Fracture toughness**

A more important physical property is fracture toughness, which has been reported to be between 8 MPa m<sup>1/2</sup> and 10 MPa m<sup>1/2</sup> for zirconia. This is significantly higher than any previously reported ceramic, and roughly twice the amount reported for the alumina materials.

Fracture toughness is a measure of a material's ability to resist crack growth (i.e., a measure of the amount of energy necessary to cause crack growth).

Clinically, restorations are not loaded to failure as is done in a flexural strength test; instead, millions of subcritical loads (chewing) are applied. Materials ultimately fail because of this cyclic fatigue by crack propagation. Thus, materials with higher fracture toughness are more ideal clinically as it takes more energy to cause crack growth.

Other factors such as stress corrosion (chemically assisted crack growth) and residual flaws in the material greatly affect the final strength of a finished material.

Mechanisms that can lead to toughened or strengthened ceramics can be categorized into the following three types:

### **Crack tip interactions**

These occur when obstacles in the microstructure act to impede the crack motion. These are generally second phase particles and act to deflect the crack into a different plane so that it is no longer subject to the normal tensile stress that originally caused its propagation.

### **Crack tip shielding**

These are a result of events that are triggered by high stresses in the crack tip region that act to reduce these high stresses. Transformation toughening and micro crack toughening are two mechanisms that have been identified as leading to crack tip shielding.

### **Crack bridging**

This occurs when the second-phase particles act as a ligament to make it more difficult for the cracks to open. Crack bridging is best understood for

bonded fibre composites. This mechanism has been shown to be important in large-grain Al<sub>2</sub>O<sub>3</sub> and possible whisker reinforced ceramic materials.

## **CONCLUSION**

The evolution in fabrication technology of dental ceramics has been outstanding over the past few decades; tremendous progress has been made in terms of mechanical performance, with a ten-fold increase in flexural strength and fracture toughness.

These new generations of all-ceramic materials present interesting options, both in terms of material selection and fabrication techniques.

Success of the ceramic restoration depends on clinician's ability to select the appropriate material to match intraoral conditions and aesthetic demands.

## **REFERENCE**

1. Anusavice KJ, Phillip's Science of Dental Materials, Elsevier, A division of Reed Elsevier India Pvt Ltd, New Delhi, India, 2010, 11th Edition, 655-720.
2. Denry IL, Recent advances in ceramics for dentistry, Crit Rev Oral Biol Med 7(2):134-143, 1996
3. Sakaguchi RL, Powers JM, Craig's Restorative Dental Materials, Elsevier, Mosby, A division of Reed Elsevier India Pvt Ltd, New Delhi, India, 2007, 12th Edition, 443-464.
4. Shenoy A, Shenoy N, Dental Ceramics: An Update, J Cons Dent, 13(4):195-203, Oct 2010
5. Srinivasa Raju Datla<sup>1</sup>, Rama Krishna Alla<sup>2</sup>, Dental Ceramics: Part II – Recent Advances in Dental Ceramics. American Journal of Materials Engineering and Technology, 2015, Vol. 3, No. 2, 19-26.
6. Usha G, Prashanth T.R , Advanced Ceramics Review of Material sciences. Journal of Dental Science and Research, Vol 15: Issue 2: September 2014.