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Review Article

METAL FREE ALL CERAMIC MATERIALS- A BOON TO ESTHETIC RESTORATIVE DENTISTRY

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ABSTRACT

Over the past forty years, the technological evolution of ceramics for dental applications has been remarkable, as new materials and processing techniques are steadily being introduced. The improvement in both strength and toughness has made it possible to expand the range of indications to long-span fixed partial prostheses, implant abutments and implants. Successful application of all-ceramic materials depends on the ability of the clinician to select the appropriate material and its manufacturing technique, to match intraoral conditions and esthetic requirements followed by cementation or bonding procedures. So, this review article highlights the various All-ceramic materials available in Indian market, their properties and clinical applications.

Keywords: Ceramic, Implant, Fixed partial prosthesis, Esthetics.

INTRODUCTION

Over the last 3 decades, a trend to shift toward metal-free restorations has been observed in the dental field. The use of ceramics is encouraged due to their: biocompatibility, aesthetics, durability, easier customization, ability to mimic the natural tooth in colour and translucency along with strength[1]. However, the clinical shortcomings of these materials, such as brittleness, crack propagation, low tensile strength, wear resistance, and marginal accuracy, discontinued its use[2]. More recently, the glass ceramics have been developed with increased filler content, providing a more even distribution and finer particle size of crystals with in glass matrix than conventional feldspathic ceramics. This has yielded significantly improved flexural strength. Unfortunately, strength improvements are limited by inherent weakness of glass matrix because all-ceramic materials fail as a result of crack propagation at a critical strain rate of 0.1%. Recently developed ceramics with minimal or no glassy phase have demonstrated increase in the physical properties. All-ceramic restorations combining esthetic veneering porcelains with strong ceramic cores are now becoming popular.

Treatment planning with ceramic materials should follow a very systematic process, and use several specific guidelines. Aim should be at maintaining the long-term biologic and structural health of the patient in the least destructive way.

So, this article reviews about multiple all-ceramic materials and systems that are currently available in Indian market along with their properties and their clinical recommendations.

All ceramic systems based on their manufacturing techniques:

A) Powder Condensation

This traditional method of forming ceramic prostheses involves applying a moist porcelain powder with an artist's brush and removing excess moisture to compact the powder particles and is further compacted by viscous flow of the glassy component during firing under vacuum.

Disadvantages:

- Large amount of residual porosity.
- The crystalline particles that strengthen the material on a microscopic scale are not connected to each other but are separated by glassy regions resulting in low strength and a wide variation in strength.

Flexural strength- 60- 70 MPa.

Advantage:

Greater translucency, so applied as the esthetic veneer layers on stronger cores and frameworks.

Increased strength in glassy ceramics can be achieved by adding appropriate fillers that are uniformly dispersed throughout the glass, a technique termed Dispersion strengthening. These are:

1. Alumina-Based Ceramic

The technique devised by McLean use aluminous porcelain, which is composed of aluminum oxide (alumina) crystals dispersed in a glassy matrix. The resulting restorations were approximately 40% stronger than those using traditional feldspathic porcelain.

Advantages:

- Increased flexural strength,
- Increased elasticity and toughness,
- High modulus of elasticity(350 gpa),
- High fracture toughness (3.5 to 4 mpa).

Disadvantages:

- Extensive reduction,
- Limited bonding ,
- High failure rates.

Examples: Hi-Ceram ((Vident))

2. Leucite reinforced feldspathic porcelain

In this type, the leucite crystals (Potassium aluminium Silicate) are dispersed in a glass matrix. The leucite and glass components are fused together during baking process at 1020^0C. Leucite concentration is 50 % wt.

Advantages:

- Higher modulus of rupture and compressive strength and does not require core unlike aluminous PJC.

E.g Optec HSP (Jeneric/ Pentron).

3. Low fusing ceramics (LFC)

a) Hydrothermal ceramics are a new category by introducing hydroxyl groups into the ceramic structure under heat and steam.

Advantages:

- Melting, softening and sintering temperatures had reduced
- Increase in thermal expansion and
- Mechanical strength without a compromise in their chemical solubility
- Greater density, Higher flexural strength,
- Greater fracture resistance, lower abrasion than feldspathic porcelain ,

Example: Duceram LFC**:**

Uses:

All ceramic prostheses,

Ceramic / metal-ceramic inlay and partial crowns

Disadvantages:

Low coefficient of thermal expansion. Thus, an inner lining of conventional high-fusing ceramic is required.

b) <u>Finesse all ceramic system:</u>

The finesse all ceramic ingots are designed to be used only with the finesse low fusing porcelain to fabricate highly esthetic restorations.

Indications:

- Single unit anterior and
- posterior premolar restorations
- Laminate veneers Inlays Onlays .

Advantages:

- Color coordinated and
- Thermally matched only to the finesse low fusing porcelains.

Contra-Indications:

High fusing and other low fusing porcelains are not thermally matched and will not have the correct co-efficient of thermal expansion and therefore should not be used.

B) Slip casting

Slip casting involves forming a mold or negative replica of the desired framework geometry and pouring a slip into the mold. The mold is made of a material (usually gypsum) that extracts some water from the slip into the walls of the mold through capillary action, and some of the powder particles in the slip become compacted against the walls of the mold forming a thin layer of green ceramic that is to become the framework. The remaining slip is discarded, and the framework can be removed from the mold after partial sintering to improve the strength to a point where the framework can support its own weight. The resulting ceramic is very porous and must be either infiltrated with molten glass or fully sintered before veneering porcelain can be applied[3].

Advantage:

Have higher fracture resistance than those produced by powder condensation.

Disadvantages:

- Limited to one series of three products for glass infiltration (In-Ceram, Vita Zahnfabrik).
- Method requires a complicated series of steps, which provide a challenge to achieving accurate fit and may result in internal defects that weaken the material from incomplete glass infiltration .

Flexural Strength:

In-Ceram Alumina-350 MPa,

In-Ceram Spinell -500 MPa and

In-Ceram Zirconia-700 MPa.

Indications:

In-Ceram Spinell (alumina and magnesia matrix) for anterior crowns.

In-Ceram Alumina (alumina matrix) has high strength and moderate translucency and is used for anterior and posterior crowns.

In-Ceram Zirconia (alumina and zirconia matrix) has very high strength and lower translucency and is used primarily for three-unit posterior bridges

C) Hot Pressing

Pressable ceramics are available from manufacturers as prefabricated ingots made of crystalline particles distributed throughout a glassy material. Because the ingots are manufactured from non-porous glass ingots by applying a heat treatment that transforms some of the glass into crystals. This process can be expected to produce a well controlled and homogeneous material.

Advantages:

- Do not contain much porosity and can have a higher crystalline content
- good accuracy of fit.
- The higher crystalline content and lack of porosity do not lead to increased fracture resistance or decreased variability of strength .

Indications:

As core and framework materials.

Hot pressed ceramics: 2 types

- IPS Empress: Leucite reinforced
- IPS Empress 2: Lithium Disilicate reinforced

Leucite reinforced: Leucite crystals are formed through a controlled surface crystallization process in the SiO_2-Al_2O_3-K_2O glass system. Tangential compressive stresses develop around the crystals on cooling because of the difference in the coefficient of thermal expansion (CTE) between leucite crystals and the glassy matrix. These stresses contribute to crack deflection and improved mechanical performance.

Flexural strength- 120 to 180 MPa

Uses:

Inlays, onlays, veneers, and crowns.

Lithium Disilicate reinforced: A significantly higher strength of 350 MPa was achieved with a glass ceramic by precipitating lithium disilicate ($Li_2Si_2O_5$) crystals. The crystal content of up to 70 vol% is considerably higher than that of leucite materials. Thermal expansion mismatch between lithium disilicate crystals and glassy matrix results in tangential compressive stresses around the crystals, potentially responsible for crack deflection and strength increase. The lithium disilicate ceramic was introduced as IPS Empress 2 (Ivoclar Vivadent) in 1998 .

A newly developed pressable lithium disilicate glass ceramic (IPS e.max Press, Ivoclar Vivadent) with improved physical properties (flexural strength, 440 MPa) and can be used in monolithic application for inlays, onlays, and posterior crowns or as a core material for crowns and 3-unit FDPs in the anterior region. Apatite glass ceramics are recommended for veneering.

Pressable veneering materials, such as IPS e.max ZirPress (Ivoclar-Vivadent) are available.

D) Glass ceramic:

Is a ceramic consisting of a glass matrix phase and at least one crystal phase that is produced by the controlled crystallization of the glass.

DICOR is a castable polycrystalline fluoride containing tetrasilic mica glass ceramic material, initially cast by lost wax technique and subsequently heat treated.

Advantages:

- Increased strength and toughness
- Increased resistance to abrasion,
- Thermal shock resistance,
- Chemical durability,
- Decreased translucency

Composition

- SiO_2-45-70%
- K_2O- 20%
- MgO- 13-30%
- 55% vol of tetrasilicic flourmica crystals

Supplied as –

- DICOR castable ceramic cartridges
- Special DICOR casting crucibles each contain a 4.1 gm DICOR ingot
- and DICOR shading porcelain kit.

Equipment required –

1. DICOR Casting machine
2. DICOR Ceramming furnace with ceramming Trays.

Method – Transparent casting is embedded in castable ceramic embedment material (gypsum-based) and placed in a Ceramming tray in the DICOR Ceramming furnace.

Ceramming cycle – 650^0C-1075^0C for 1.5 hrs and sustained upto 6 hours.

Advantages:

- Uniformity and purity of the material,
- Minimal processing shrinkage,
- Good fit,
- Moderately high flexural strength(152 mpa).

Disadvantages:

- Opaque due to the presence of mica,
- Low tensile strength,
- Inability to be colored internally ,
- Labour intensive,
- High cost.

Indications:

Inlays, Onlays, Partial Tooth Coverage

Hydroxyapatite Based Castable Glass Ceramics : Cerapearl

The cast material has an amorphous microstructure when reheated at 870^0C forms crystalline Hydroxyapatite.

Advantages:

- Biocompatible,
- Crystalline structure similar to enamel.

Modulus of rupture: 150 Mpa.

E) Machined ceramics

Computer Aided Design/Computer Aided Design (CAD/CAM) technology was introduced in dentistry by Diuret in the early 70's. The technology was originally intended for fully sintered ceramic blocs (hard machining), it has now been expanded to partially sintered ceramics (soft machining), that are later fully heat treated to ensure adequate sintering.

Hard machining

Currently, fully sintered ceramic materials include Feldspar-Based (VITABLOCS MARK II), Leucite-Based (IPS EMPRESS CAD) And Lithium Disilicate-Based Ceramics (IPS E.Max CAD).

Soft machining

Soft-machining of partially sintered zirconia ceramic blocs by CAD/CAM technology, to produce dental restorations was proposed in 2001 after intensive research work. The design compensates for the volume shrinkage that will later occur during sintering of the zirconia blocs (about 25%).

The partially sintered blocs are easy to mill, which leads to substantial savings in time and tool wear. The type of zirconia used in this technology is biomedical grade tetragonal zirconia stabilized with 3 mol % yttria (3Y-TZP)

Partially stabilized tetragonal zirconia exhibits phase transformation toughening, which involves the transformation from tetragonal to monoclinic phase at the crack tip, associated with a volume increase, thereby creating compressive stresses. This mechanism is efficient in preventing further crack propagation.

Examples:

- CERCON (Dentsply Friadent, Mannheim, Germany),
- LAVA (3M ESPE, Seefeld,Germany),
- Procera (Nobel Biocare, Gothenburg, Sweden and

- Cerec (Sirona, Bensheim, Germany).

CAD/CAM TECHNOLOGIES:

Advances in dental ceramic materials and processing techniques; sply. CAD/CAM and milling technology have facilitated the development and application of superior dental ceramics.CAD/CAM allows the use of materials that cannot be used by conventional processing techniques[4].

Advantages:

- Increased microstructural uniformity,
- Higher density,
- Lower porosity,
- Decreased residual stresses.

The CAD/ CAM process:

A CAD/CAM system utilizes a process chain consisting of scanning, designing and milling phases. The scanning device converts the shape of the prepared teeth into three dimensional (3-D) units of information (voxels). The computer translates this information into a 3-Dmap (point could). The operator designs a restoration shape using the computer which generates a tool path, which is used by the milling device to create the shape from a restorative material[5].

DIFFERENT CAD/CAM SYSTEMS ARE:

1) Cerec : An acronym for chair side economic reconstruction of esthetic ceramic Cerec introduced in 1980s, improved cerec 2 introduced in 1996 and the advanced 3-D Cerec 3 in 2000[8].

With Cerec 1 and 2, an optical scanner is used to scan the prepared tooth or impression and a 3-D image is generated on monitor. A milling unit is used to prepare the restoration.

With newer Cerec 3-D, the operator records multiple images within seconds, enabling clinician to prepare multiple teeth in same quadrant and create a virtual cast for the entire quadrant. Designed restoration is transmitted to a remote milling unit for fabrication.

Cerec in-lab is a lab system in which dies are laser scanned and image displayed on screen. After designing VITA In-cream blocks are used for milling. The coping is glass infiltrated and veneer porcelain added.

Examples:

In-Ceram Alumina, In-Ceram Spinell and In-Ceram Zirconia-700 MPa.

At least three materials can be used with Cerec 1:

- **Dicor MGC**
  - ✓ Flexural strength of less than 100 mpa.
  - ✓ Indications: Inlays, Onlays And Veneers
- **CEREC VITABLOCS MARK 2**
  - ✓ Flexural strength of 150 Mpa.
  - ✓ Indications: Inlays, Onlays ,Veneers and anterior crowns.
  - ✓ Have Finer Particle Size Than CEREC VITABLOCS MARK 1
- **IPS ProCAD(Leucite reinforced)**
  - ✓ Flexural strength of 150 Mpa.
  - ✓ Indications: Inlays, Onlays ,Veneers and anterior crowns.

2) Copy milling, CELAY SYSTEM

In this system, the pattern was made with a wax like modeling material (oracrylic). Then pattern is used in a copy milling machine. As the outline of the pattern is traced on one side, a ceramic block is milled simultaneously to duplicate the wax pattern, in a process analogous to key duplication. Milling is done by a diamond-tipped milling wheel. The marginal accuracy is better than cerec system, it is in a range of 80-100µm. It is not a single visit procedure, extra visit is required for impression and wax pattern.

3) Cercon: commonly referred to as a CAM system, it does not have a CAD component. The system scans the wax pattern and mills a zirconia bridge coping from presintered zirconia blanks, which is sintered at 1,3500^{0}C for 6-8 hrs. Veneering is done with a low fusing, leucite free cercon Ceram to provide esthetic contour.

4) Procera All Ceram System: Introduced in 1994, it is the first system which provided outsourced fabrication using a network connection. Once the master die is scanned the 3-D images is transferred through an internet link to processing center where an enlarged die is milled by a computer controlled milling machines. This enlargement compensates for sintering shrinkage. Aluminum oxide powder is compacted on the die and coping is milled by a computer controlled milling machines. This enlargement compensates for sintering shrinkage. The coping is sent back to the lab for porcelain veneering.

According to research data average marginal gap for Procera all Ceram restoration ranges from 54 µm to 64 µm .

Flexural strength: 600 MPa

Indications: Single unit crowns, anterior bridges

5) Lava CAD/CAM System: Introduced in 2002, used for fabrication of zirconia framework for all ceramic restorations. This system uses yttria stabilized tetragonal zirconia poly crystals (Y-TZP) 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. CAM produces an enlarged framework to compensate shrinkage. A partially sintered ziroconia block is selected for milling. Milled framework undergoes sintering to attain final dimensions, density and strength. Studies on marginal adaptation of Y-TZP bridges processed with Lava system for 2 milling times (75 mins Vs 56 mins) did not affect the marginal adaptation (61 ±25 µm Vs 59± 21 µm) .

Flexural strength: 900-1200 MPa

Indications: single unit anterior and posterior crowns, anterior and posterior bridges, implant abutments.

6) Monolithic glass ceramics:

Traditionally, high strength core material made of either a cast-metal framework or an oxide based ceramic(such as alumina or zirconia). In today's dentistry, **Monolithic glass cermic structures** provide exceptional esthetics without requiring a veneering ceramic. Greater structural integrity can be achieved by eliminating veneered ceramic and its requisite bond interface.

This has two disadvantages:

- ➢ May not be esthetically pleasing
- ➢ The layering ceramic with which it is veneered exhibits a much lower flexural strength and fracture toughness.

EXAMPLES:

1) IPS e.max CAD(lithium disilicate based glass ceramic): IPS e max CAD**, Blue block** is based on two- stage crystallization and is obtained with 70% crystal volume that refracts light very naturally. Flexural strength(360MPa to 400MPa).

2**) BruxZir® Solid Zirconia** is a monolithic zirconia crown, bridge, alternative to posterior metal occlusal PFMs or cast gold restorations for demanding situations like bruxers, implant restorations and areas with limited occlusal space.

Flexural strength: 900-1200 Mpa

Rationale for Material Selection

Treatment planning with ceramic materials should follow a very systematic process, and use several specific guidelines[11]. There are four broad categories, or types of ceramic systems, from which to choose:

Category 1 (Powder/Liquid Feldspathic Porcelains**)**—are the most esthetic, especially in thin sections and thus can be used the most conservatively with low flexure and stress risk assessment, but are the weakest.

Indication:

Anterior teeth; Occasional bicuspid use.

Category 2 (Pressed Or Machined Glass-Ceramics**)** also can be very translucent but requires slightly thicker dimensions for workability and esthetics than Category 1. It has higher fracture resistance.

Indication:

For thicker veneers, anterior crowns, and posterior inlays and onlays.

Category 3: High-strength ceramics (specifically zirconia) are more opaque and, therefore, require additional tooth reduction that produces a less conservative alternative.

Indication:

- when significant tooth structure is missing,
- an unfavorable risk for flexure and stress distribution is present, and
- it is impossible to obtain and maintain the bond and seal (eg, most posterior full-crown situations with subgingival margins).

Category 4: Metal-ceramics are indicated in all full-crown situations, especially when all risk factors are high.

CONCLUSION

In the last two decades, exciting new developments in dental materials and computer technology have led to the success of dental computer aided design/computer aided manufacturing (CAD/CAM) technology. CAD/CAM systems offer automation of fabrication procedures with standardized quality in a shorter period of time. They have the potential to minimize inaccuracies in technique and reduce hazards of infectious cross contamination. It allows application of newer high strength materials with outstanding biocompatibility combined with adequate mechanical strength, provisions for esthetic designs, excellent precision of fit and longetivity. However, these advantages must be balanced against the high initial cost of CAD/CAM systems and the need for additional training. Patient's expectations, financial constrain, operator's preference, as well as availability of CAD/CAM systems will dictate the suitability of this type of restorations on an individual basis in the future.

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