Review of the Current Status of All-Ceramic Restorations

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Overview

Metal ceramic restorations have been available for more than three decades.¹ This type of restoration has gained popularity from its predictable performance and reasonable esthetics.² Despite its success, the demand for improved esthetics and the concerns regarding the biocompatibility of the metal has lead to the introduction of all-ceramic restorations.³

Historical perspectives of ceramics:

Ceramics are not considered new materials as they were in use more than 10,000 years ago during the Stone Age.⁴ In 1723, Pierre Fauchard described the enameling of metal denture bases.¹ De Chemant, a French dentist, introduced the first porcelain denture tooth in 1789.⁴ In 1808, in Paris, Fonzi introduced “tetro-metallic incorruptibles” which are porcelain teeth with embedded platinum pins. The first ceramic crown was introduced in 1903 by Dr. Charles Land.⁴

Indications for all ceramic restorations:

Esthetics: ceramics are considered the best in mimicking the natural tooth appearance.⁵ The optical behavior of ceramic materials differ from system to system and this should be taken into consideration during the selection of which system to be used.⁶

Contraindications of all ceramic restorations:

- Limited interocclusal distance: in cases of short clinical crowns, deep overbite, or with a super erupted opposing tooth.⁷
- Heavy occlusal forces: Due to the brittle nature of the material and its abrasive potential, ceramic restorations should be avoided in patients with parafunctional habits such as bruxism.⁸
- **Inability to maintain a dry field**: ceramic restorations require good moisture control at the time of their cementation to ensure positive outcomes.\(^8\)

- **Deep subgingival preparations**: this is not considered an absolute contraindication, although supragingival preparations are desirable to produce a more accurate recording during impression taking.\(^8\)

### Advantages:

- **Esthetics**: is considered the primary advantage.\(^9\)

- **Wear resistance**: ceramics are more wear resistant than direct restorative materials.\(^8\)

- **Precise contour and contacts**: indirect fabrication of all ceramic restorations provides more precise contour and contacts than directly placed restorations.

- **Biocompatibility**: The allergic reaction by some to metal alloys is a weak point against metal ceramic restorations which increased the demand on the more biocompatible all ceramic restorations. However, the degree of cytotoxicity of the metal alloys largely depends on the type of the dental alloy used in the fabrication of the metal ceramic restoration.\(^10\)

### Disadvantages:

- **Cost and time**: all ceramic restorations are fabricated indirectly and require at least two appointments to be delivered. The additional laboratory fees make this type of restoration more expensive than other direct restorations.\(^5\)

- **Brittleness of the ceramics**: adequate thickness of ceramic should be provided to avoid the fracture of the restoration.\(^8\)
- **Wear of apposing dentition and restorations**: ceramics can cause wear of opposing restorations and/or dentition. This problem has been considered during the improvement of ceramic restorations.\(^{11}\)

- **Low repair potential**: If fracture occurs, repair is not considered a definitive treatment.\(^8\)

- **Difficult intraoral polishing**: ceramic restorations are difficult to polish once they are cemented because of access problems and lack of proper instruments to perform this task.\(^8\)

**Classification of dental ceramic restorations**: \(^4\)

Dental ceramics can be classified in many different ways according to their:

1. Indication or use.
2. Composition.
3. Processing method.
4. Firing temperature.
5. Microstructure.
6. Translucency.
7. Fracture resistance.
8. Abrasiveness.
Simplifying concepts in understanding dental ceramics:

Two concepts help in simplifying the understanding of dental ceramics.

First, ceramics fall into three main composition categories

- Predominantly glass
- Particle–filled glass
- Polycrystalline

Second, 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.

- **Predominantly glass:** have a high content of glass making this type of dental ceramic highly esthetic. This type is 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:** This type of ceramic contains no glass. Atoms are packed into regular crystalline arrangement making it tougher and less susceptible to crack propagation.

It is important to understand the fact that highly esthetic ceramics are predominately glass, and ceramics that exhibit high strength are generally crystalline.
Organizational chart of dental ceramics for all-ceramic systems according to matrix material, filler or dopant (atomic-level filler) and fabrication process.\textsuperscript{12}
Similar composition of ceramics could be fabricated in different ways.  

**Focus will be on classification according to method of fabrication:**

1. **Powder condensation:**

   This is considered the traditional way for fabrication of an all-ceramic restoration. This technique involves applying moist porcelain using a special brush, then compacting the porcelain by removing the excess moist. The porcelain is then fired under vacuum allowing further compaction.

   Ceramics fabricated by this technique have a great amount of translucency and are highly esthetic, and are used mainly as veneering layers.

   Examples of systems utilizing this technique:

   - Duceram LFC (Dentsply)
   - Finesse low fusing (Dentsply)
   - IPS e.max Ceram (Ivoclar-Vivadent)
   - IPS Eris (Ivoclar-Vivadent)
   - Lava Ceram (3M ESPE)
   - Vita D (Vita Zahnfabrik)
   - Vitadur Alpha (Vita Zahnfabrik)
   - Vita N (Vita Zahnfabrik)
Powder condensation utilizes feldspathic porcelain.

**Feldspathic porcelain:**

Potassium and sodium feldspars are naturally occurring elements composed mainly of potash (K₂O) and soda (Na₂O), they also contain alumina (Al₂O₃) and soda (Na₂O). Leucite and a glass phase are formed when potassium feldspar is fired to high temperatures. This glass phase softens during firing allowing coalescence of the porcelain powder particles. This process is called *liquid phase sintering*. This process occurs at a relatively high temperature allowing the formation of a dense solid. Since leucite has a large coefficient of thermal expansion, it is added to some glasses to control their thermal expansion.

Feldspathic porcelain is composed mainly of oxide components including:

- SiO₂ (52-62 wt %)
- Al₂O₃ (11-16 wt %)
- Na₂O (5-7 wt %)
- Li₂O and B₂O as additives

2. **Slip casting:**

This technique involves forming a mold of the desired framework geometry and pouring a slip into the formed mold. Gypsum is usually utilized to form the mold due to its ability of extracting some of the water from the slip. The slip then becomes compacted against the mold forming a framework. The framework is then removed from the mold by partial sintering. The resulting
ceramic is very weak and porous and must be infiltrated with glass or fully sintered before application of the veneering porcelain.5

Materials processed by this technique tend to have fewer defects from processing, and exhibit higher toughness than the conventional feldspathic porcelain.14

The use of this technique in dentistry has been limited to one of three products.5 This limitation might be due the complicated steps, which makes achieving an accurate fit difficult.13, 15, 16

In-Ceram Alumina® (Vita Zahnfabrik)

This material was first introduced in 1989, and was the first all-ceramic system available for single unit restorations and 3-unit anterior FPDs.17

A slurry of Al2O is applied on a refractory die and sintered for 10 hours at 1120°C.18, 19 This produces a porous framework of alumina particles which is infiltrated with lanthum glass during a second firing for 4 hours at 1100°C. This procedure is done to remove porosities, increase strength, and limit crack propagation sites.19 Then feldspathic porcelain is used to veneer the produced coping.20

In-Ceram Alumina is considered to be a strong material having a mean biaxial flexure strength of 600 MPa.21 The material should not be used in esthetic zones because it does not fully allow light transmission.2 In-Ceram Alumina is recommended for anterior and posterior crowns and anterior FPDs.4
In-Ceram Spinell ® (Vita Zahnfabrik)

In-Ceram Spinell was introduced in 1994 to overcome the opacity of In-Ceram Alumina. The framework contains a mixture of magnesia and alumina (MgAl2O4) to improve the translucency of the material.\textsuperscript{2,22}

The basic principles of fabrication are the same as those for In-Ceram Alumina. It has a flexural strength of 250 Mpa which is lower than that for In-Ceram Alumina.\textsuperscript{4} In Ceram Spinell is indicated for anterior crowns because of its low flexural strength.\textsuperscript{23}

In-Ceram Zirconia® (Vita Zahnfabrik)

In Ceram Zirconia is considered a modification of In-Ceram Alumina system with the addition of 35% of partially stabilized zirconia oxide to the slip to increase the strength of the ceramic.\textsuperscript{24} The ceramic is fabricated using the traditional slip-casting technique.\textsuperscript{7} In-Ceram Zirconia is considered the strongest of three cores of the slip-casting technique having a flexural strength of 700 MPa.\textsuperscript{4} The material is considered opaque and has poor translucency limiting its use for posterior crowns and posterior FPDs.\textsuperscript{24,25}

3. **Hot pressing**

Molds for pressable dental ceramics are formed utilizing the lost wax technique. Pressable ceramics are available as glass-ceramic ingots which are supplied from manufacturers. The ingots have a similar composition of powder porcelains, however; they have less porosity and more crystalline content. The ingots are heated to a high temperature where they become a highly viscous liquid, and then pressed slowly into the formed mold. The advantage of this
technique is that it utilizes the experience that the lab technician already has in lost wax method with metal alloys.\textsuperscript{15, 16}

IPS Empress\textsuperscript{®} and IPS Empress 2\textsuperscript{®} (Ivoclar Vivadent) are representatives of materials utilizing hot pressing technique for fabrication.

**IPS Empress\textsuperscript{®} (Ivoclar Vivadent)**

IPS Empress is a leucite-reinforced glass ceramic (SiO\textsubscript{2}-Al\textsubscript{2}O\textsubscript{3}).\textsuperscript{26} IPS Empress has a low flexural strength of 112±10 MPa limiting its use to single unit complete-coverage restorations in the anterior region.\textsuperscript{4, 26}

**IPS Empress 2\textsuperscript{®} (Ivoclar Vivadent)**

IPS Empress 2 is a lithium-disilicate glass ceramic (SiO\textsubscript{2}-Li\textsubscript{2}O).\textsuperscript{7} IPS Empress 2 has a flexural strength of 400±40 MPa which is much higher than that of IPS Empress.\textsuperscript{4, 26} Its increased flexural strength makes it suitable for the usage for fabrication of 3-unit FPDs in the anterior region, and can extend to the second premolar.\textsuperscript{27, 28}

Both IPS Empress and IPS Empress 2 are recommended in situations where average to high translucency is needed.\textsuperscript{2} They are considered as monochromatic restorations which can be surface characterized to the desired shade and produce comparable esthetics to the layering techniques.\textsuperscript{29}

Another example is the **IPS e.max Press\textsuperscript{®} (Ivoclar Vivadent)**, which was introduced in 2005. It is considered as an enhanced press-ceramic material when compared to IPS Empress 2. It has better physical properties and improved esthetics.\textsuperscript{30}
4. **Computer-aided design/computer-aided manufacturing**

Machinable ceramics are available as prefabricated glass-ceramic ingots. They are cut by tools that are controlled by the computer. After the tooth is prepared, an optical impression is taken for the preparation by a special scanner. The image is then transferred to the system’s software. Then the software designs the restoration and sends the data to the computer-controlled milling machine that grinds the ceramic block according to the desired shape.31

**Examples of materials available for the CAD/CAM technology:**32

(a) Silica based ceramics

(b) Infiltration ceramics

(c) Oxide high performance ceramics

(a) **Silica based ceramics**

Several CAD/CAM systems offer silica based ceramic blocks for the fabrication of inlays, onlays, veneers, partial crowns and full crowns. Blanks with multicolored layers [Vitablocs TriLuxe (Vita), IPS Empress CAD Multi (Ivoclar Vivadent)] are available in addition to the monochromatic blocks for the fabrication of posterior crowns.

**Lithium disilicate ceramic blocks** have high stability values (360 MPa) making them suitable for fabrication of posterior crowns and 3-unit FPDs.33-36 An example of a lithium disilicate ceramic block is the **IPS e.max® CAD** which is used frequently because of its superior esthetics, excellent color stability, and its high resistance to wear. 37

**Glass ceramics** are highly esthetic even without veneering, and can be etched with hydrofluoric acid for adhesive bonding.38, 39
(b) Infiltration ceramics

Blocks of infiltrated ceramics for CAD/CAM systems originate from the Vita In-Ceram system. They have the same composition and clinical indications of the three previously mentioned Vita In-Ceram products.32

(c) Oxide high performance ceramics

Blocks of aluminum oxide and zirconium oxide are currently available for the CAD/CAD technology.32

*Alumina Oxide (Al₂O₃)*

It is considered as a high performance ceramic. It is ground then sintered at a temperature of 1520°C. It is clinically indicated in cases of crown copings in the anterior and posterior area, and 3-unit FPDs in the anterior region.

**In-Ceram AL Block (Vita)** and **inCoris Al (Sirona)** are examples of aluminum oxide blocks that are available in the market.32

*Yttrium stabilized zirconium oxide (ZrO₂ Y-TZP)*

Zirconium dioxide ceramics have excellent mechanical properties. They have high flexural strength (750–>1000 MPa) when compared to other dental ceramics.32, 37 Yttrium-oxide is added to zirconia in order to stabilize the tetragonal phase at room temperature, which as a result can prevent crack propagation in the ceramic (Transformation strengthening).7, 40, 41 Zirconium oxide ceramics are indicated for the fabrication of crowns, FPDs and individual implant abutments.32 The cores have high radiopacity which is very useful in evaluation of marginal integrity.42 Zirconia has a color similar to teeth but if translucency is needed then other ceramic materials should be considered.43
Examples of Zirconium oxide blocks:  
- Lava Frame® (3M ESPE)
- Cercon Smart Ceramics® (DeduDent)
- Everest ZS und ZH® (KaVo)
- inCoris ZR® (Sirona)
- In-Ceram YZ® (Vita)

Systems available for the machining of the ceramic blocks:  
- DCS Precident® (1989)
- Procera ® (1993)
- CEREC inLAB® (2001)
- Cercon® (2001)
- Everest® (2002)
- Lava ®(2002)
- CEREC 3D® (2003)
- TurboDent® (2005)
- E4D Dentist® (2008)

Marginal integrity of CAD/CAM restorations

Software limitations as well as accuracy of milling devices may affect the fit of CAD/CAM restorations. Most clinicians agreed that marginal gap should not be greater than 100 µm. It has been reported in the literature that restorations produced by CAD/CAM systems can have marginal gaps of 10-50 µm which is considered to be within the acceptable range.
**Cementation of all-ceramic restorations:**

The protocol used for cementation of all-ceramic restorations can be essential for success.\(^9\) Clinicians can effectively etch silica-based all-ceramics for adhesive bonding.\(^{51}\) The clinical life span of such all-ceramic restorations significantly increased when this protocol is used.\(^{52, 53}\) Zirconia and alumina-based all ceramic materials cannot be etched and bonded.\(^{54}\)

**Survival of all-ceramic restorations:**

It is very important to consider the available survival data for all-ceramic materials when selecting a treatment strategy. This could be very challenging due to the numerous all-ceramic systems available and the definition of failure that varies in the literature. It has been reported that survival rates of all-ceramic restorations range from 88 to 100\% after service for 2-5 years, and up to 97\% after 5-15 years.\(^{7, 20, 33, 55-61, 62}\)

Long-term survival was related to the fabrication method of all-ceramic restorations. Restorations fabricated using the hot pressing technique had the highest long-term survival. CAD/CAM ceramics had the next highest long-term survival. The lowest long-term survival was for restorations fabricated by powder condensation.\(^5\)

**Preference of the profession:**\(^{63}\)

THE DENTAL ADVISOR has selected some products for special recognition. The products awards are given to products that have exceeded their standard of performance and quality. The products were selected based on the clinical experience of their Editorial Board and Consulting Team.
2009 Product Awards:

Top All-ceramic Bridge Material: 3M ESPE Lava Crowns and Bridges (3M ESPE)

Top Anterior Ceramic: IPS Empress (Ivoclar Vivadent)

Top Posterior Ceramic: IPS e.max (Ivoclar Vivadent)

**Conclusion**

All-ceramic materials and systems will continue to improve. The dental practitioner should be aware of this development. Selection of a material should be based on esthetic needs and strength required.


63. www.dentaladvisor.com; 2009.