Review Article

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Recent Advancements in Porcelain Material: A Peek into Esthetic Manoeuvre…

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ABSTRACT

Background: Day by day the dentistry is getting advanced with the help of newer researches, new inventions following the same the silver colored restorative material now have been changed to tooth color restorative materials and porcelain material is one of them, current article is focused on the recent advancements in porcelain materials to update dental practitioner's knowledge about esthetic restorations.

Keywords: Porcelain Material, Esthetic restoration, Ceramic.

INTRODUCTION

Aesthetics in contemporary dentistry is partly defined by the patient's desires for neutrality. However, it is among the tasks of the dentist to translate the patient's wishes to reality providing the ideal restoration and one such restoration can be ceramic restoration. The word "CERAMIC" is derived from Greek word "KERAMOS" which means "BURNT STUFF". Ceramic is an earthen material usually of silicate nature.[1] Modern techniques in restorative dentistry include the use of ceramic materials for jacket crowns, laminates, inlays and onlays. These restorations not only look natural but also have a very good periodontal response when placed properly. Considering the above factors, let us go into details of ceramics.

History:

Ceramics were probably the first material, to be significantly made by human beings. The Greek word 'Keramos'. Pottery or burnt stuff of fire has been known to man for about 4000 years. At the same time during this period the 1st burnt stuff would have been accidentally produced. Early fabrication of ceramic articles has been found and dated as far back as 3,000 years. The earliest glassing technique was a Sumerian invention made famous about 4,000 B.C. Historically 3 basic type of ceramic materials was developed.

Earthen ware:

It fired at low temperature and is relatively porous.

Stone ware:

This appeared in China in about 100 B.C. and is fired at a higher temperature than earthern ware, which results in both higher strength and renders the material impervious to water.

Porcelain:

This was obtained by fluxing white China clay with "China stone" to produce a white translucent stone ware. This was developed in King-te-tehing in China in about 1,000 A.D. This material was strongest than the stone ware and earthen ware.

The development of the art and science of dental ceramic in many way parallels the historical development of industrial revolution.

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Pioneer Workers:

Year	Works done
1774	A French apothecary named **Alexis Duchateau** noticed that ceramic utensils that he used every day for mixing and grinding his various chemicals resisted staining with the relatively non-porous surface and were also resistant to abrasion. It would appear that these were the circumstances which gave birth to the idea of using porcelain as a dental restorative material.[2]
1800	**Nicholas Diu – Chemant** of Paris in collaboration with Alexis improved the method of fabrication and wedge wood supplied the paste for porcelain.[3] He succeded in making the first partial denture.
1803	**Foucous** reported and highlighted the shortcomings in color and translucency of early porcelain materials.
1806	**Fonzi** an Italian dentist produced the first “terro metallic teeth” i.e. porcelain with metal.[4] He also developed teeth with platinum brackets, backed into porcelain and were subsequently soldered with gold to patient denture bases. Porcelain was the parian chinar type with extreme translucency – 2 types: Matt, Cmooth – Dentistry. This has feldspar as its principal constituent under proper firing control can develop a self-glazing surface without loss of detail.
1838	**Elias Wildman** formulated a much more translucent and attached to teeth by fusing the porcelain to the patient post.[5]
1886-1890	The first porcelain inlay was produced in Philadelphia PC in 1900 the development of the small electric furnace added impetus to the making of these inlays. 1886: Porcelain J C – Land of Detroit.[6]
1889	**Dr. Charley Holand** of Detroit filed the first patient for the construction of PJC. Mechanic props. Published
1918	Chemical analysis of porcelain.
1923	First casting of dental porcelain.
1940	Vacuum firing of dental porcelain
1942	Fluoroscent porcelains.
1956	Porcelain fused to gold systems to improve strength.
1962	Development of much improved gold alloys as a porcelain fused to metal system.
1965	Development of dental aluminous porcelain by **McLean and Hugh**.[7]
1967	Restriction of uranium to 1% by Wt.
1968:	First use of a glass ceramic by **McCulloch**.[8]
1970	Development of porcelain fused to base metals.

1974	Porcelain fused to noble metals.
1980	Development of "non-shrink" aluminous direct moulding core for crowns.
1983	Development of high expansion core material by O'Brien (DCNA).
1984	Introduction of glass-ceramic system. First international standard published.
1984 1985	Dental ceramic powders by Corning Glass Company. ISO 6872-1984 (E). Organic liquid binder instead of H_2O was developed by Sanderson.
1991	Repair of porcelain by Ralph using hydrofluoric acid etching silane.
1993	Monsenego Burdaicon studied the effect of fluorescence in ceramics and showed the effect of cementing media on fluorescence of ceramics.

DEVELOPMENTS OF DENTAL PORCELAINS

A) PAST DEVELOPMENTS

1. ***Air firing:*** prior to early 1960s, porcelain powders used had large particles size, to avoid opacity but resulted in porosities (internal). But aesthetic of these materials was excellent (Mclean 1979).[13]

2. ***Vacuum firing***: The introduction of vacuum fired porcelains reduced the internal porosities and further increased the aesthetics.

3. ***Porcelain fused to metal***: Since the introduction of the first successful porcelain-fused to metal systems in early 1960s there has been increasing demands for ceramic restorative materials.

Porcelain was fused to metal substrate to increase its resistance to fracture which occurred due to:

i. Relatively low tensile strength.

ii. Brittleness of porcelain.

Disadvantages of porcelain fused-to-metal:

1. Metal base can affect the aesthetic of porcelain by reducing light transmission through the porcelain by creating metal ion discoloration.

2. Patients might have allergic reaction or sensitivity to metal.

3. Material and labor costs for its fabrication.

These drawbacks of PFM have prompted the development of new all-ceramic restorations.

4. ***Aluminous porcelains***: Aluminous porcelain used in PJC's is composed of a similar composition as that of feldspathic dental porcelain with increased amounts of aluminium oxide (Al_2O_3) by 50 wt%.

- Ceramics employed in conventional porcelain jacket crown are "high fusing feldspathic porcelain".

- Due to relatively low strength of this type of porcelain "Mclean and Hughes in 1965"[7] developed alumina reinforced porcelain core material for fabrication of PJC's.

Manufacture:

The alumina reinforced porcelain described above are produced by prefitting the crystalline component with the glassy matrix.

These can be used as cores to replace the substructure used in ceramo-metal constructions. They are veneered with conventional feldspathic porcelain to reproduce contour and shade of a natural tooth.

Advantages:

1) Improved aesthetics.
2) Increased flexural strength (because of higher crystalline content).
3) Enhanced fracture toughness.

Disadvantages:

1) Low translucency (due to presence of second phase in glassy matrix).
2) Increased sintering shrinkage.
3) Strength is inadequate for use in posterior teeth.
4) Fit is poor as compared to PFM.
5) High clinical fracture.
6) Technique sensitive

Indications:

For restoration of anterior crown when aesthetic is prime concern.

Examples: Hi-ceram.

Magnesia core:

- A high thermal expansion core porcelain has been described by O'Brien in 1985.[14,15]

- Magnesia crystals were used to reinforce a high expansion coefficient glass, resulting in core porcelain with a modulus of elasticity same as alumina – reinforced porcelain-131 Mpa.

Indications:

1. Used with body porcelain normally used to veneer metallo-ceramic restorations → Magnesia reinforced material is thermally compatible with body porcelain because of its high thermal expansion coefficient.

Advantages:

1. Improved shade matching when used with veneers.

2. Flexural strength is doubled – this is due to treating of surface of magnesia core porcelain with a suitable glass.

Two mechanisms were suggested for improved strength:

a) The glaze was thought to penetrate the open pores, effectively reducing the number of surface flaws.

b) Glaze may have replaced the surface layer in compression.

Disadvantages:

Due to high expansion magnesia core porcelain is more liable to thermal shock on cooling.

Bonded platinum foil coping:

This technique uses bonding of porcelain to metal by use of tin oxide coatings on platinum foil.

Objective:

1) Improves aesthetic by replacing thicker metal coping with a thin platinum foil thus providing more space for porcelain.

Procedure: Aluminous porcelain is bonded to pt foil copings, attachment of porcelain in secured by electroplating the foil with a thin layer of tin and then it is oxidized in a furnace to provide a continuous film of tin oxide for porcelain bonding.

Rationale:

Bonded foil acts as an inner skin on the fit surfaces to reduce subsurface porosity and formation of microcracks in the porcelain thus increasing its fracture resistance of the unit.

B. Recent Porcelains:

All Ceramic System: The evolution of porcelain materials has been a battle for the ideal strength-aesthetic combinations.

Due to the inherent drawbacks related to PFM, as stated earlier, all ceramic crowns were introduced into dentistry.

The first all-ceramic crowns were introduced by 'LAND' in 1903.[3]

These materials were:

a) Relatively weak.

b) Had limited clinical use.

Thus, in 1965, Mclean and Hughes[7] formulated aluminous porcelains compositions which form the basic composition of these All-ceramic crowns.

- These aluminous porcelains had increased rate of fracture.

- More recently, newer types of all-ceramic restoration have been developed that may prove to have a lower incidence of clinical fracture:

This may be due to:

a) All-ceramic restorations today consist of stronger materials and involve better fabricating techniques.

b) These restorations can be etched and bonded to the underlying tooth structure with the new dentin adhesives.

c) With greater tooth reduction than what was previously used for PJC's, clinicians now provide lab technicians with enough room to create thicker and stronger restoration.

FIVE CATEGORIES OF ALL-CERAMIC SYSTEM INCLUDE:

1) Conventional (powder-slurry) ceramics.
2) Castable ceramics.
3) Pressable ceramics.
4) Infiltrated ceramics.
5) Machinable ceramics.

I] Conventional Powder slurry ceramics:

These are supplied as powder which the technician adds water to produce a slurry, which is built up in layers on die material to form the contours of the restorations.

Powders:

- Available in various shades and translucencies.

- Supplied with characterizing stains and glazes.

This system includes:

a) Optec HSP (Jeneric Pentron).

b) Duceram LFC.

a) Optec HSP: (Also known as leucite-reinforced porcelain):[16]

Optec HSP is a leucite-reinforced feldspathic porcelain that is condensed and sintered like aluminous porcelain and traditional feldspathic porcelain. Leucite – a reaction product of potassium feldspar and glass.

Advantages:

1. Lack of metal or opaque substructure.
2. Good translucency (uniform).
3. Moderate flexural strength – 146Mpa.
4. Special lab equipments not required.

Disadvantages:

1. Potential marginal inaccuracy caused by porcelain sintering shrinkage.
2. Potential to fracture in posterior teeth.
3. Fit of crowns not as good as that of PFM crowns with metal margins.
4. Increased leucite content increases in vitro wear of opposing teeth.

Indications:

- Inlays.
- Onlays.
- Low stress crown and veneers.

Features:

1) More translucent than alumina core crown / glass infiltrated alumina core crowns because has only a moderately opaque core.

2) Strength of optec HSP is increased than feldspathic porcelain used for porcelain fused to metal because of its leucite crystals.

- The shrinkage on condensation and sintering occurs when fired because of volumetric reduction caused by sintering.
- Only body and incisal porcelain are used because the opacity provided by the leucite crystals does not require the use of core porcelain.
  b) Sandblasting recommended achieving bonding with resin cement.

b) Duceram LFC (Degussa)[17]

This is a relatively new category of restorative material, referred to as hydrothermal low-fusing ceramics.

Composed of an amorphous glass containing hydroxyl ions.

Indications:

1. Inlays.
2. Veneers.
3. Full contour crowns.

Advantages:

1. Greater density.
2. Higher flexural strength (110Mpa)..
3. Greater fracture resistant.
4. Lower hardness (than feldspathic porcelain).
5. No special equipment required for fabrication.

- Higher flexural strength is due to an ion-exchange mechanism of hydroxyl ions.
- Lower hardness is due to absence of leucite crystals in this material.

Difference between LFC and OPTEC HSP:

LFC	Optec
1) Contains OH^- ion in matrix.	- Contain leucite crystals in matrix.
2) Uses a metal Duceram ceramic as a core.	- No core material.
3) Less abrasion of opposing tooth.	- More abrasion of opposing tooth.

The restoration is made in two layers:

i. Base layer: is a Duceram metal ceramic (a leucite containing porcelain). This is placed on a refractory die using standard powder-slurry technique and then baked at 930°C.

ii. Duceram LFC – This is applied over the base layer using a powder slurry technique and baked at a relatively low temperature of 660°C.

The material is supplied in a variety of shades and can be surface-characterized with compatible stains and modifier.

II] Castable Ceramic Systems

These products are supplied as solid ceramic ingots, which are used for fabrication of cores or full contour restoration using a lost wax and centrifugal casting technique.

Also referred to as “Glass ceramic crown”.

- Introduced in dentistry by Mac Culloch in 1968.[8]
- Previously used a glass molding process to produce denture teeth.
- Later crowns and inlays were fabricated using centrifugal casting of molten glass.

Definition:

A glass ceramic is a material that is formed into a desired shape as a glass, then subjected to a heat treatment to induce partial divetrification (i.e. loss of glassy structure by crystallization of glass).

FIRST COMMERCIALLY AVAILABLE CASTABLE CERAMIC MATERIAL WAS DICOR (developed by corning glass works marketed by DENTSPLY)

Dicor: This is a polycrystalline glass, ceramic material initially formed as a glass and subsequently heat treated under controlled crystallization conditions to produce a glass-ceramic material.

Indications:

a) Inlays.
b) Veneers.
c) Full crowns.

Procedure:

A full-contour transparent glass crown is cast at 1350°C then is heat treated at 1075°C for 10 hours. This heat treatment causes microscopic plate like crystals of mica to grow within the glass matrix. he crystal nucleation and crystal growth process is known as “CERAMMING”.

These crystals:

1) Create a relatively opaque material.
2) Increase the fracture resistance.
3) Increases the strength.
4) Also they are less abrase to opposing tooth structure.

After this glass is fitted on a die and coated with veneered porcelain to match the shape and appearance of adjacent tooth. To achieve the shade, the colored stains are baked on the surface of glass ceramic material.

Advantages:

1. High flexural strength – 152MPa.
2. Abrasiveness same as that of tooth.
3. Accurate fit of crown.

Disadvantages:

4. Special investment and casting equipment required.
5. Surface stains may be lost due to abrasion, routine oral prophylaxis or application of acidulated fluoride gels.

To overcome these problems DENTSPLY introduced another glass ceramic material:

- Dicor plus – this is a shaded feldspathic porcelain veneer applied to Dicor substrate.

- Dicor plus is more abrasive than dicor to the teeth.

- These are more resistant to dissolution.

III] Machinable Ceramics:

These products are supplied as ceramic ingots in various shades and are used in computer-aided design, Computer-aided manufacturing or CAD-CAM procedures.

The machined restoration can be stained and glazed to obtain the desired characterization.

The ingots used do not require further high temperature processing. They are placed in machining apparatus to produce the desired contours.

The internal surfaces of restoration are ground with diamond disks or other instruments to the dimensions obtained from a scanned image of the preparation. This is followed by occlusal adjustment, polishing, etching and bonding the restoration to the prepared tooth.

Early pioneers of CAD-CAM system: Bruce Altschuler[18]

- Originated in 1940s in United States.

Advantages:

1. Negligible porosity.
2. Impression not required.
3. Reduce assistant time associated with impression procedures.
4. Single appointment procedure.
5. Good patients acceptance.

Disadvantages:

1. Need for expensive equipment.
2. Lack of computer controlled processing support for occlusal adjustment.
3. Technique sensitive nature of surface imaging required for the prepared tooth.

The different types of ceramic ingots used in the process are:

a) Cerec vitablocks mark I[19,20]

This is the feldspathic porcelain which was the first composition used with the cerec systems.

- Similar to feldspathic porcelain in composition, strength, wear properties.
- Flexural strength – 93MPa.
- Milling of a ceramic ingot is done from a digitized optical scan.

b) Cerec vitablocks mark II

This is a feldspathic porcelain of:

- Increased strength has finer grain size than the mark I compositions.
- Flexural strength → 152 MPa.
- This is less abrasive than cerec Mark I and is similar to that of enamel.
- Ingot is milled in a digitized optical scan.

c) Dicor MGC (Dentsply):

Composition:

65% fluorosilicic mica crystals in 35% glass matrix.

Features:

1) Improved flexural strength than castable Dicor – 216MPa.
2) Softer than conventional feldspathic porcelain.
3) Produces less abrasive wear of opposing tooth structures than cerec Mark I but more than CMK II.
4) Formed by milling process.

d) Celay:

This can be used for CAD-CAM produced restoration or in copy milling technique:

- It is a fine grained feldspathic porcelain that reduces the wear of antagonist tooth structure.

Manufactures claim that composition of celay is same as cerec vitablock mark II thus properties are also same.

Other characteristics of CAD-CAM system:

1) All these ceramic ingots can be characterized with surface stains which may be lost by abrasion.

2) The gap between tooth and the restoration is wider in CAD-CAM produced inlay than other all-ceramic restoration. Wear of cement in this gap may be of clinical significance.

3) They are etchable for bonding to tooth structure.

IV] PRESSABLE CERAMICS

Also known as injection molded glass ceramics.

- Supplied as ceramic ingots.
- These products are melted at high temperature and injected under pressure and high temperature into the mold created by using lost-wax technique.
- The processed form can be made to full contour or can be used as a substrate.

The two systems under this category are:

a) IPS Empress.
b) Optec pressable ceramic.

IPS EMPRESS[21]

- It contains increased concentration of leucite crystals that increase the resistance to crack propagation.
- Material is injection molded over a 45 minute period at high temperature to produce ceramic substructure.
- The crown forms can either by stained or glazed or build up using a conventional layering technique.

Advantages:

1) Lack of metal / opaque ceramic core.
2) Moderate flexural strength –126MPa initially after heat treatment → 160-182.
3) Excellent fit.
4) Excellent esthetics.

Disadvantages:

1) Potential to fracture in posterior areas.
2) Need for special laboratory equipment.

Optec Pressable Ceramic (OPC):[22]

- OPC is a type of feldspathic porcelain with increased leucite content processed by molding under pressure and heat.

Indications:

1) Inlay.
2) Veneer.
3) Full crowns.
4) Core material for feldspathic porcelain.

High abrasiveness than tooth structure.

Flexural strength – 165MPa.

Both Optec and IPS Empress produce strong, translucent, dense and etchable ceramic restorations.

V] INFILTRATED CERAMIC (glass infiltrated alumina core ceramic C).

These products are supplied as two components:

Powder – Al_2O_3 / spinel – (porous substrate).
Glass – Infiltrated into porous substrate at high temperature.

It is veneered using conventional feldspathic technique.
Commercially available as IN-CERAM (VIDENT).[23,24]
Advantages:

1) Lack of metal.
2) Increased flexural strength (450MPa).
3) Excellent fit because of less shrinkage.

Disadvantages:

1. Opacity of the core.
2. Unsuitability for conventional acid etching.
3. Need for specialized equipment.

Indications:

1) Single anterior and posterior crown.
2) Anterior three unit bridge.

Steps for fabricating in-ceram prosthesis:

1) Prepare teeth with heavy circumferential chamfer (> 1mm).
2) Make impression and pour two dies or duplicate on die in refractory die material.
3) Apply Al_2O_3 on duplicate die using the slip cast method.
4) Sinter coping for 10 hours at 1100°C.
5) Apply slurry of glass infiltration material.
6) Fire for 3-5 hours at 1120°C to allow infiltration of glass.
7) Trim excess glass from coping with diamond burs.
8) Build up core with enamel and dentine porcelain (vitadur alpha).
9) Fire in the oven, grind in anatomy and occlusion finish and glaze before delivery.

Slip cast method:

This involves the placement of a low-viscosity slurry of the powder onto a porous refractory die that draws water from the slurry, thus depositing a layer of solid Al_2O_3 on the die. The capillary action of die continues as other layers are added. Heat the die and material at 120°C for 2 hours to dry the Al_2O_3.

Formation of in-ceram:

The slightly sintered aluminous porcelain core is infiltrated with glass at 1100°C for 4 hours to eliminate porosity and strengthen the slip cast core. This initial sintering process causes minimal volume decrease because temperature and time are sufficient only to cause bonding between particles. This increased marginal fit because of decreased shrinkage.

Recently an alternative to in-ceram, a more translucent ceramic called in-ceram spinell is introduced.

- Decreased flexural strength.
- Increased translucency – increased aesthetics where adjacent teeth or restoration are more translucent.
- Core of in-ceram spinell is $MgAl_2O_4$ infiltrated with glass.

CERAMIC VENEERS:

Used since 1981 due to acid etching of porcelain.

Advantages:

1. More conservative approach than PJC.
2. Excellent aesthetics.

Disadvantages:

1. Technique sensitive – as a conventional acid-base / resin based luting cements play a role in appearance.
2. Resin bonded veneers have been reported with recurrent caries.
3. Expensive.
4. Might abrade opposing tooth structure if not polished.
5. Acid used hydrofluoric acid (for etching).

Indications:

1. Stained / hypoplastic anterior teeth.

Shrink free ceramics:

Due to ill fit of aluminous PJC's Sozio and Riley 1983[5,25] described the use of shrink free ceramic coping which is formed on epoxy die by a transfer moulding process.

Composition:
Alumina.
Magnesia.
Aluminosilicate glass frit.
Wax.

Silicone resin plasticizer.

The moulded core is subjected to a lengthy heat treatment during which time some of the alumina reacts with magnesium oxide to form magnesium aluminate spinel crystals. The reaction is accompanied with increase in volume which offsets the sintering shrinkage.

The so-called crestore coping is veneered with aesthetic porcelains.

Flexural strength for cevestore core – 145MPa.

- Compressive strength same as conventional alumina reinforced material.
- Fracture toughness is also same.
- Marginal fit not accurate.
- Due to limitations of cresetore systems a new shrink free ceramic was developed ALCERAM.

Castable Apatite crowns:

Synthetic hydroxyapatite may be used for replacement of lost tooth structure.

- This cannot be fabricated directly.

- An indirect technique involves conversion of calcium phosphate glass to a partially crystalline apatite glass ceramic. This is known as CERAPEARL.

- The procedure for its production is similar to that of Dicor glass ceramic system.

- The calcium phosphate based glass is transformed to a partially crystalline body by a controlled heat treatment is then tinted by the application of coloured glazes.

Characteristics:

- Tensile strength is increased 3 fold.
- Refractive index, density, hardness, thermal expansion, thermal conductivity similar to natural enamel.

Renaissance crown:

The Renaissance ceraphatin or ceplater crown is similar to the platinum bonded type of restoration in that a thin metal substructure is used to protect the fit surface of crown.

- Described by Schossow 1984.[26]

- The technique utilizes a gold-coated foil matrix which is folded like an umbrella which is burnished onto the die and heated.

Foil consists of four layers:

- Outer most layer – pure Au.
- Next layer – Alloy of Au, Pt, Pd.
- Third layer – 100% Pd.
- Inner most layer – Au, Pt, Pd.

The gold coating melts and acts as a solder which secures the folds in a place, thus creating a stable coping. The crown is then build up with metal bonding porcelain.

- Compressive strength is inferior to conventional aluminium PJC.
- Fit was accurate.

HYBRID CERAMICS: (ESTENIA):

Combination of ceramic and composite material.

Has 92 wt% filler loading.
Particle size 0.02µm-2µm.

Indications - Jacket crown.

- Inlay.
- Onlay.
- Crown and bridge.

Physical properties are much higher the conventional porcelain.

Advantages:

- Excellent aesthetics.
- Durability.
- Ease of use.

CONCLUSION

Although, the all-ceramic restorations being more precise, tedious, time consuming and require an elaborate equipmentation, it gives a better aesthetics and better marginal fit. Furthermore studies are going on to rollout the minor disadvantages and to improve aesthetic characteristics of this material. In future dentistry will be more equipped with advanced Porcelain

Materials to fulfil the requirements of aesthetic restorations.

CONFLICT OF INTEREST

No potential conflict of interest relevant to this article was reported.

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