International Journal Of

Recent Scientific Research

ISSN: 0976-3031

Volume: 7(3) March -2016

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THE OFFICIAL PUBLICATION OF
INTERNATIONAL JOURNAL OF RECENT SCIENTIFIC RESEARCH (IJRSR)
http://www.recentscientific.com/ recentscientific@gmail.com

ISSN: 0976-3031

Available Online at http://www.recentscientific.com

International Journal of Recent Scientific Research
Vol. 7, Issue, 3, pp. 9352-9361, March, 2016

International Journal of Recent Scientific Research

REVIEW ARTICLE

CAD-CAM CERAMICS - A LITRATUREREVIEW

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ARTICLE INFO

Article History:

Received 06th December, 2015
Received in revised form 14th January, 2016
Accepted 23rd February, 2016
Published online 28th March, 2016

Keywords:

CAD-CAM; Ceramics;

ABSTRACT

Dentists have searched for the ideal restorative material for more than a century. Although direct restorative materials such as amalgam, composites, and restorative cements have been used with reasonably good success during the past several decades, but they are not feasible for multiunit restorations. In this regard a restorative material should be biocompatible and durable, and it should maintain its surface quality and esthetic characteristics over an extended period of time, preferably for the lifetime of the patient. Dental ceramics consist of silicate glasses, porcelains, glass ceramics, or highly crystalline solids. They exhibit chemical, mechanical, physical, aesthetic and thermal properties that distinguish them from metals, acrylic resins, and resin-based composites. The use of all ceramic prosthesis in restorative treatments has become popular and many of these restorations can be fabricated by both traditional laboratory methods and CAD/CAM machination. The objective is to review the state of the arts of CAD/CAM all-ceramic biomaterials.

INTRODUCTION

The introduction of CAD/CAM systems in Late 1980s to restorative dentistry represents a major technological breakthrough. The traditional methods of ceramic fabrication have been described to be time-consuming, technique sensitive and unpredictable due to the many variables and CAD/CAM may be a good alternative for both the dentists and laboratories.[1,2]

Ceramics: - Compounds of one or more metals with a non-metallic element, usually oxygen. They are formed of chemical and biochemical stable substances that are strong, hard, brittle, and inert non-conductors of thermal and electrical energy.[3]

CAD-CAM: acronym for Computer Aided Design-Computer Aided Manufacturer (or Computer Assisted Machining)

CAD-CAM ceramic*:* - a machinable ceramic material formulated for the production of inlays, crowns etc through the use of a computer-aided design, computer-aided machining process.

Composition

Silica – Filler, Kaolin – Binder, Feldspar – Basic glass former, Alumina , Quartz, Boric acid, Leucite, Nepheline syenite, Glass modifiers, Oxides of Na, K ,Ca, Metallic pigments and Other oxides (Zro2, Sno2, Bao, Tio2 etc)

Silica

It is one of the most abundant elements on earth and can exists in 4 different forms:

1. Crystalline quartz
2. Crystalline Cristobalite
3. Crystalline Tridymite
4. Non-crystalline fused silica

Pure quartz crystals are used in dental porcelain. Act as a filler and strengthening agent. Because of its high melting point, it provides a high strength framework for the other ingredients during firing and helps to maintain a form of a freestanding object during firing. The quartz may be replaced by alumina (AI2O3), which is called aluminous porcelain. The alumina particles are much stronger than quartz and have an increased rigidity. Since the fracture of porcelain is caused by

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propagation of cracks through the structure, the alumina crystals tend to obstruct the path of the cracks.[1]

Kaolin

Kaolin is a hydrated aluminosilicate (Al2O3.2SiO2.2H2O) Acts as a binder, increasing the ability to mould the unfired porcelain. It gives porcelain its properties of opaqueness. When subjected to high heat, it adheres to the framework of quartz particles and also it improves workability.[1]

Feldspar

The feldspars are mixtures of potassium aluminosilicate and sodium aluminosilicate, also known as albite (Na2O.Al2O3.6SiO2).precursor of natural clay.

Types of feldspars- Albite (Na2Al2Si6O16), Orthoclase or microcline (K2Al2Si6O16)

Feldspars are naturally occurring substances, so the ratio between the potash (K2O) and the soda (Na2O) will vary.

Soda: - lower the fusion temperature and
Potash: - increases the viscosity of the molten glass
Potash Feldspar + Metal Oxides combined at 11500C – 15300C give rise to leucite formation and glass phase formation.[1]

Glass modifiers

Sintering temperature of crystalline silica is too high. Alkali metal ions such as Na, K & Ca lower the sintering temperature. The three dimensional silica network contains many linear chains of tetrahedral Silica that can move easily. This ease of movement increases fluidity

This ease of movement

Increases fluidity (decreases viscosity), Lower softening temperature, Increases thermal expansion.[1]

Leucite

Leucite is a potassium-aluminium-silicate mineral with a large co-efficient of thermal expansion (20-25ppm/0C) compared with feldspar glasses (10ppm/0C) The leucite forms a refactory skeleton and glass fills the spaces.

Functions

Raises coefficient of thermal expansion (CTE) and brings it closer to metal. substrate, consequently hardness & fusion temperature. Creates a high expansion porcelain to match thermal expansion of the alloys. Strengthening of porcelain in high strength ceramics.

CAD/CAM Ceramics

1. Feldspathic ceramics
2. Mica-based ceramics.
3. Leucite-reinforced ceramics
4. Lithium disilicate reinforced.
5. Glass infiltrated alumina and zirconia ceramics
6. Resin nanoceramic
7. Hybrid ceramic
8. Zirconia-silica ceramic in a resin matrix.

Feldspathic ceramic

Feldspathic ceramic is a silica-based ceramic available in sintered, pressed and milled forms.

Composition

Three main components: quartz, Feldspars and kaolin, with the basic component being silica dioxide. Feldspars are mainly comprised of silica dioxide (60% - 64%) and aluminum oxide (20% - 23%) and are modified in different techniques to create glass that can be used in dental restorations. Other essential components are oxides of sodium, potassium, calcium, aluminum, magnesium, zinc, iron, copper, titanium, nickel, manganese, cobalt, tin, zirconium.[5]

Properties

Feldspathic porcelain has low mechanical properties. Due to the high glass contents in this material they are much more susceptible to fracture under mechanical stress. These feldspathic ceramic materials have excellent aesthetic properties and have been recommended for use in fabricating veneers inlays/onlays and single anterior and posterior crowns.[6] The first CAD/CAM produced inlay was fabricated in 1985 using a ceramic block comprising fine grain feldspathic ceramic (Vita Mark I, Vita Zahnfabrik, Bad Sackingen, Germany). The clinical performance of these CAD/CAM inlays and onlays was evaluated in a 10-year prospective study and a success rate of 90.4% was achieved. However, a much higher breakage rate of up to 36% after 2 years was also reported.[7]

Vita Mark II (Vita Zahnfabrik, BadSackingen, Germany)

Introduced specifically for CEREC (Cerec – Siemens GmbH, Bensheim, Germany) in 1991, exhibited better mechanical properties with a reported flexural strength from about 100 MPa to 160 MPa when glazed. Vita Mark II blocks (Fig.5) are made of materials similar to the conventional feldspathic ceramic but produced in a different process known as extrusion moulding.[8]A plasticized ceramic mixture is pressed and extruded through a nozzle to give its form. The blocks are then dried over several days before sintering.

Fig.5 Vita Mark II blocks

Clinical studies of Vita Mark II inlays showed survival rates of 94.7% after 5 years, 90.6% after 8 years and 85.7–89% after 10 years.[9] An in vitro study of mandibular crown specimens machined out of Vita Mark II blocks using Cerec 3 (Sirona Dental Systems, Bensheim, Germany) showed that the marginal gap within the range of 53– 67 mm could be achieved.[10] Vita Mark II is monochromatic but available in multiple shades. The newer Vitablocs TriLuxe, Triluxe Forte and RealLife blocks (Vita Zahnfabrik, Bad Sackingen, Germany). Contain multi-shade layers and offer a gradient of colour and translucency.

Indication

They have been recommended for use in fabricating veneers, inlays/onlays and single anterior and posterior crowns.[7,10,12]

Contraindication

The material is not considered to be strong enough for posterior load bearing areas.[12,13]

CAD/CAM System compatibility

1. CEREC/in Lab (Sirona Dental GmbH)
2. Ceramill Motion II (Amann Girrbach AG)
3. KaVo ARCTICA/Everest (KaVo Dental GmbH).

Mica-based ceramics

The mica minerals are a group of sheet silicate (so-called phyllosilicate) minerals. Dicor is a mica based glass ceramic marketed for both laboratory ceramming and machining. Dicor has been discontinued because of low tensile strength.[14]

Composition

Silica, Sodium Pottasium, Calcium, Fluorine, Oxygen, Iron, Aluminium.

Dicor MGC is a higher quality product that is crystallized by the manufacturer and provided as CAD-CAM blanks or ingots. The CAD-CAM ceramic Dicor MGC contains 70% of tetra silicic fluoromica platelets, which are approximately 2 µm in diameter.[15] Its machinability is made possible by the presence of tetra silicic fluoromica crystals which are highly interlocked within the glassy matrix.[16] It has been shown that Dicor MGC and Vita Blocs were very similar in clinical performance but its cumulative breakage at 2 years was found to be higher than Vita Mark II.[17] Although both Dicor and Dicor MGC were very well studied, the materials are no longer in the market.

Leucite-reinforced ceramics

Glass-based systems are made from materials that contain mainly silicon dioxide (also known as silica or quartz), which contains various amounts of alumina. The leucite crystals $KAlSi_2O_6$ which have been formed in a controlled process, endow the material with an increased strength. The propagation of cracks is slow down or deflected by the leucite crystals. In the process, the crystalline phase absorbs fracture energy. As a result, the propagation of cracks is arrested or decelerated. The distribution and size of the leucite crystals also affects the esthetic properties of the restoration. Leucite crystals are formed by surface crystallization, i.e. the crystals grow slowly along the grain boundaries towards the centre of the grain. In a clinical study of partial crowns observed for 1–4 years, no fracture was reported with a survival rate of 100% after 2 years.[18]

ProCAD (Ivoclar-Vivadent, Schaan, Liechtenstein) was introduced in 1998 to be used with the CEREC inLAB (Sirona Dental Systems, Bensheim, Germany). IPS Empress CAD is the successor product of ProCAD. The IPS Empress CAD ingots exhibit a homogeneous distribution of leucite crystals. The leucite crystals are evenly and densely distributed. The diameter of the crystals is 1 – 5 µm, the crystal phase volume is 35–45 % by volume. The microstructure of IPS Empress CAD consists of a glassy matrix and leucite crystals. Leucite is the result of surface crystallization. Therefore, the leucite crystals are located along the grain boundaries. The small leucite crystals that are arranged like strings of beads show the former grain boundaries prior to tempering/sintering.[18]

Composition

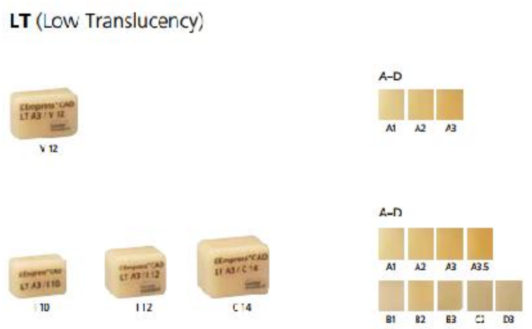
SiO_2 =60 – 65%, Al_2O_3=16 – 20%, K_2O=10 – 14%, Na_2O=3.5 - 6.5%, Other oxides 0.5 - 7.0 %, Pigments=0.2 – 1 %.

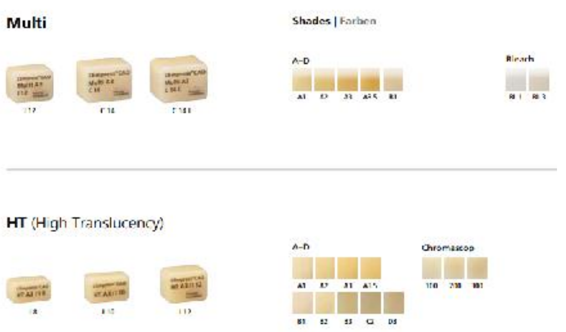
Properties

Flexural strength (biaxial) 160 MPa
Chemical solubility < 100 µg/cm2
Coefficient of thermal expansion (100 - 500 °C) 17.5 ± 0.5 µm/(m K)
Transformation temperature 625 ± 20 °C
Fracture toughness 1.3 MPa m1/2
Modulus of elasticity 62 GPa

Indication

The IPS Empress CAD HT blocks with high translucency are mainly used for the milling of smaller restorations (e.g. inlays, onlays, veneers). The blocks with lower translucency (LT) are ideally suitable for the fabrication of larger restorations (e.g. partial crowns, crowns, veneers). The polychromatic IPS Empress CAD Multi blocks are the highlight of the IPS Empress CAD range of products. (Partial crowns, crowns, veneers)[18]





Lithium disilicate reinforced ceramics

Lithium–disilicate ceramic (IPS Empress II, Ivoclar Vivadent, Schaan, Liechtenstein) using the lost-wax press technique was introduced in 1998 as an enhanced glass– ceramic system for single tooth and anterior three-unit FDP restorations.[19] Although this all-ceramic system was very successful in anterior and posterior crown indication, heterogeneous survival rates ranging from 50 % after 2 years to 70 % after 5 years were reported.

Therefore IPS e.max Press (Ivoclar Vivadent, Schaan, Liechtenstein) was released to the market in 2001 with significantly improved mechanical and optical properties. A promising survival rate of 87.9 % after 10 years has been reported for monolithic posterior three-unit FDP application.[20] Most recently, a CAD/CAM fabricated version of the lithium–disilicate glass–ceramic was designed. A lithium disilicate CAD/CAM ceramic IPS e.max CAD (Ivoclar-Vivadent) was introduced in 2006 and was a chair-side monolithic restorative material. Lithium disilicate (Li_2SiO_5) glasses have their flexure strength between 350 MPa and 450 MPa.[21] This is higher than that of leucite-reinforced dental ceramics. They are supplied in a pre-crystallized called blue state. The blue ceramic contains metasilicate and lithium disilicate nuclei and exhibits a flexural strength of 130 MPa. At this state, the block can be easily milled after which the restoration is re-crystallized in a chair-side ceramic oven at 850 DC in vacuum for 20–25 min. During this heat treatment, the metasilicates are dissolved, lithium disilicate crystallizes and the ceramic is glazed at the same time. The block also changes from blue to the chosen shade and translucency.[22]

Composition

SiO_2 57.0 – 80.0 %,Li_2O 11.0 –19.0%,K_2O 0.0 –13.0 %, ZrO_2 0.0 –8.0%,ZnO 0.0 –8.0%
Al_2O_3 0.0 –5.0%, MgO 0.0 –5.0%, Colouring oxides 0.0 – 8.0%.

Indication

Inlays, Onlays, Veneers, Anterior and Posterior crowns, Implant supported crowns.

Shades

IPS e.max CAD is available in three different degrees of translucency: MO, LT and HT. IPS e.max CAD MO is a tooth-coloured, esthetic framework material, which is veneered with IPS e.max Ceram. The IPS e.max CAD LT blocks demonstrate a low translucency. They are available in various A to D and Bleach shades. This glass-ceramic allows the fabrication of fully anatomical restorations due to its low translucency and large variety of shades. For highly esthetic results, the restorations can be partially reduced in the labial area and subsequently veneered using IPS e.max Ceram. The IPS e.max CAD HT blocks are an ideal ceramic for inlays and onlays due to its very high translucency. These ingots exhibit what is known as the chameleon effect, which means that the ceramic reflects the shade of the surrounding dentition.

IPS e.max CAD Abutment Solutions are designed for the fabrication of implant- supported hybrid structures for single teeth using CAD/CAM technology. The hybrid components are individually milled from lithium disilicate blocks (LS2) and bonded to a titanium base.IPS e.max CAD blocks A14 and A16 feature a special interface, e.g. for the Sirona Ti base. The blocks are used for the fabrication of hybrid abutments and hybrid abutment crowns. They are available in the MO and LT levels of translucency and in several shades. MO blocks are supplied in size A14, LT blocks in size A16 and now also in size A14.

IPS e.max CAD hybrid abutment and IPS e.max CAD crown, milled

IPS e.max CAD hybrid abutment and IPS e.max CAD crown, completed

Glass infiltrated alumina

Aluminous core porcelain is a typical example of strengthening by dispersion of a crystalline phase. Alumina has a high modulus of elasticity (350 GPa) and high fracture toughness (3.5 to 4 MPa). Its dispersion in a glassy matrix of similar thermal expansion coefficient leads to significant strengthening of the core.[23] The materials can also be fabricated by CAD/CAM machination since 1993.CAD/ CAM InCeram Alumina has been reported to yield survival rates of 91.7% to 100% after 5 years. The flexural strength for InCeram Alumina reported to be 450–600 Mpa. Another study using the same system reported the mean marginal gap for anterior, premolar and molar crowns of 66.8 mm which was considered clinically acceptable.[24]Polycrystalline ceramics, such as alumina and zirconia, have no intervening etchable glassy matrix and all the crystals are densely packed into regular arrays and then sintered. The dense crystal lattice reduces crack propagation resulting in excellent mechanical properties. Polycrystalline ceramic is relatively opaque by nature and is indicated for the fabrication of crown and bridge copings upon which a veneering ceramic is layered for the required aesthetic result.[25]Procera AllCeram (Nobel Biocare, Go¨ teborg, Sweden), the fully dense dental polycrystalline ceramic was introduced in 1993.[26] This core material contains more than 99.9% alumina and has a flexural strength of about 600 Mpa.[27] The cumulative survival rates of Procera All Ceram anterior and posterior crowns have been found to be about 97% after 5 years and 93.5% after 10 years.[28] Studies have reported a tendency for more failures in the posterior region and that crown failures were generally higher in molars than premolars. The marginal fit of ProceraTM AllCeram restorations have been tested to be consistently between 60 and 80 mm and within the range of clinical acceptance.[29]

Indication

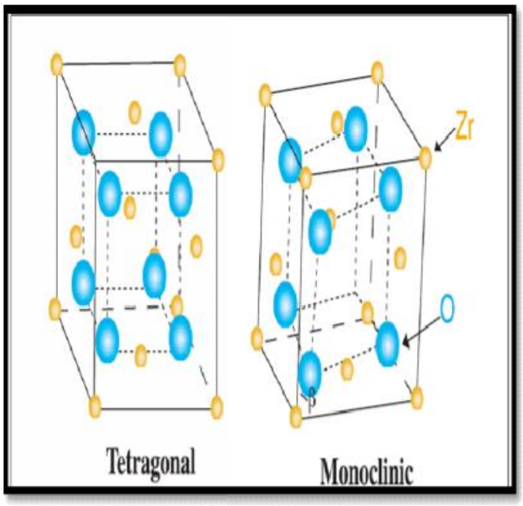
Single anterior and posterior crowns,
Anterior bridge substructures with no more than one pontic unit.[26,27]

Zirconia

Zirconium dioxide (Zro 2) identified by the German chemist Martin Heinrich Klaproth in 1789. It is fully biocompatible so there are no risks of allergic reactions.[30] Have superior mechanical properties, high flexuralstrength (>1 GPa) and fracture toughness (KIC = 9-10MN/m3/2) have been used increasingly for copings and frameworks of fixed restorations. The majority of zirconia frameworks have been made with yttria-stabilized, tetragonal zirconia polycrystal ceramics (Y-TZP).[31]

Chemical Structure

Zircon is a naturally occurring mineral from which zirconium can be obtained. Zirconium is a chemical element in the periodic table that has the symbol Zr and atomic number 40. Zirconium is obtained chiefly from zircon and is highly corrosion resistant. Zirconium is primarily used in nuclear reactors for a neutron absorber and to make corrosion-resistant alloys. Pure ZrO_2 has a monoclinic crystal structure at room temperature and transitions to tetragonal and cubic at increasing temperatures, they exists in three crystal phases at different temperatures.[32,33] At very high temperatures (>2370°C) the material has a cubic structure. At intermediate temperatures (1170 to 2370°C) it has a tetragonal structure. At low temperatures (below 1170°C) the material transforms to the monoclinic structure.[33]



Properties of Zirconia

Excellent biological compatibility: absolutely bio-inert,
Hardness (Vickers) 1200 HV,
Compressive Strength 2000 MPa,
Bending Strength 1000 MPa,
Modulus of Elasticity 210 GPa
Tensile Strength 7 Mpa.[31]

Tetragonal zirconia polycrystals (TZP)

The most recent core materials for all-ceramic FPDs are the yttrium tetragonal zirconia polycrystals (YTZP) based materials. Y-TZP–based materials were initially introduced for biomedical use in orthopedics for total hip replacement and were successful because of the material's excellent mechanical properties and biocompatibility. In dentistry, Y-TZP ceramics have been used for orthodontic brackets and endodontic posts since the early 1990s.[34] Dental CAD/CAM procedures have been developed to produce Y-TZP zirconia-based fixed restorations since the Late 1990s.The yttria (Y2O3) ceramic is present at only 2% to 3% mol. Yttrium oxide is a stabilizing oxide added to pure zirconia to stabilize it at room temperature and to generate a multiphase material known as partially stabilized zirconia.[35] The high initial strength and fracture toughness of Y-TZP result from the physical property of partially stabilized zirconia.

A valuable feature of this Y-TZP ceramic is its "transformation toughening" effect.[35] Tensile stresses acting at the crack tip induce a transformation of the metastable tetragonal zirconium oxide form into the monoclinic form. This transformation is associated with a local increase of 3% to 5% in volume. This increase in volume results in localize compressive stresses being generated around and at the tip of the crack which counteract the external tensile stresses acting on the fracture tip. This physical property is known as transformation toughening.[35] the long-term stability of ceramics is closely related to subcritical crack propagation and stress corrosion caused by water in the saliva reacting with the glass, resulting in decomposition of the glass structure and increased crack propagation in glass- containing systems. However, Y-TZP cores are glass free, and because they have a polycrystalline microstructure they do not exhibit this phenomenon. Therefore, long term stability of Y- TZP cores may be enhanced. The mechanical properties of 3Y-TZP strongly depend on its grain size.[36] In vitro studies of Y-TZP specimens demonstrated a flexural strength of 900 to 1200 MPa. Y-TZP-based materials have demonstrated a fracture toughness of 9-10 MPa/ m½, which is almost double the value demonstrated by alumina-based materials, and almost 3 times the value demonstrated by lithium disilicate–based materials.[37] An in vitro study evaluating Y-TZP FPDs under static load demonstrated fracture resistance of more than 2000 N.[38]

Soft Machining: Restorations produced by soft machining are sintered at a Late stage (i.e. following the forming steps), this process prevents the stress-induced transformation from tetragonal to monoclinic and leads to a final surface virtually free of monoclinic phase.

***Hard Machining**:* Restorations produced by hard machining of fully sintered 3Y-TZP blocks have been shown to contain a significant amount of monoclinic zirconia. This is usually associated with surface microcracking, higher susceptibility to low temperature degradation and lower reliability.

Currently available 3Y-TZP for soft machining of dental restorations utilize final sintering temperatures varying between 1350 and 1550 ◦C depending on the manufacturer. This fairly wide range of sintering temperatures is therefore likely to have an influence on the grain size and Late the phase stability.[35] Eg: DC Zirkon (DCS Precident, Schreuder & Co), Cercon (Dentsply Prosthetics) Lava (3M ESPE), In-Ceram YZ (Vita Zahnfabrik).

Zirconia toughened ceramics

Another approach to utilize the stress induced transformation capability of zirconia is to combine it with an alumina matrix, leading to a zirconia-toughened alumina (ZTA). One commercially available dental product, In Ceram Zirconia (Vident), was developed by adding 33 vol.% of 12mol% Ceria stabilized zirconia (12Ce-TZP) to In-Ceram Alumina. In-Ceram Zirconia can be processed Soft machining. Initial sintering takes place at 1100 ◦C for 2h, prior to this porous ceramic composite being glass-infiltrated. The glass phase represents approximately 23% of the final product.[35]

The microstructure of In-Ceram Zirconia: The zirconia grains appear brighter compared to the darker alumina grains. Large alumina grains (6um long, 2um wide) together with clusters of small zirconia grains (less than 1um in diameter). The amount of porosity is greater than that of sintered 3Y-TZP and comprises between 8 and 11%. This partially explains the generally lower mechanical properties of In-Ceram Zirconia when compared to 3Y-TZP dental ceramics. In terms of translucency, the In-Ceram Zirconia core is as opaque as a metal-alloy core. Therefore, In-Ceram Zirconia is not recommended for fabricating anterior all- ceramic FPDs, where the translucency of the all-ceramic core materials is a major factor in enhancing an esthetic result. In-ceram ceramics usually exhibit better thermal stability and resistance to low temperature degradation than Y-TZP under similar thermo-cycling or aging conditions.[38]

Partially stabilized zirconia (PSZ)

Although a considerable amount of research has been dedicated to magnesia partially stabilized zirconia (Mg-PSZ) for possible biomedical applications, this material has not been successful due mainly to the presence of porosity, associated with a large grain size (30–60um) that can induce wear. The microstructure consists of tetragonal precipitates within a cubic stabilized zirconia matrix. Dental example: Denzir-M (Dentronic AB) The amount of MgO usually ranges between 8 and 10mol%. Denzir-M (Dentronic AB) is available for hard machining of dental restorations. These materials are the most widely studied, commercially important, microstructurally complex, and in the case of Mg-doped some of the toughest of the transformation toughened ceramics.[38] The material is stabilized by magnesia but the difficulties in obtaining Mg-PSZ precursors free of impurities result in a decrease in stability in the tetragonal phase in a wet environment and lower mechanical properties when compared to 3Y-TZP after veneering. The material has not been widely used.[35]

Properties of Zirconia

Marginal and internal adaptation

The adaptation of most zirconia-based restorations fabricated with CAD/CAMtechnology is within the acceptable range for meeting clinical requirements. Some basic in vitro studies have evaluated the adaptation of single crown restorations in terms of clinical parameters for tooth preparation. Komine *et al*.[39] concluded that rounded shoulder or chamfer preparations were recommended for the finish line design of zirconia-based restorations, and favourable results were also reported by Comlekoglu *et al*.[40] The 90-degree shoulder preparation, which has a sharp axiogingival internal line angle, had a negative influence, since a scanning laser appeared not to completely irradiate the area of the axiogingival internal line angle. Increasing the convergence angles of the tooth abutments reportedly improved the internal and marginal adaptation of zirconia-based crowns.

Using CAD software, Iwai *et al*.[41] found that computer-fixed cement spaces with might influence the marginal adaptation of zirconia-based crowns. Att *et al*.[42] showed that milling of pre-sintered zirconia material yielded results superior to those for milling of fully sintered zirconia. Moreover, Komine *et al*.[43] reported that pre-sintered zirconia exhibited better marginal adaptation of four-unit FPDs than fully sintered zirconia.

Some studies have evaluated the influence of porcelain firing cycles on the distortion of zirconia-based FPDs. Vigolo *et al*.[44] found that porcelain firing and glaze cycles did not affect the marginal adaptation of zirconia-based four-unit FPDs.The Procera (Nobel Biocare) system exhibited better marginal adaptation than the Lava (3M ESPE) system.[45] Another study showed that Cerec inLab (Sirona) achieved better marginal adaptation that the Procera or DCS system.[46] These differences were probably attributable to variations in the FPD fabrication procedures, as well as the investigation designs.[47]Gonzalo *et al*.[45] found that marginal discrepancies for zirconia-based FPDs were significantly smaller than those for metal ceramics, and concluded that zirconia ceramic systems could be an alternative to metal ceramic systems.

Fracture resistance

In 2001, Tinschert *et al*.[48] reported that the fracture strengths of zirconia-based three- unit FPDs were significantly (almost three times) higher than those fabricated with the ceramic materials IPS Empress (Ivoclar-Vivadent) and In-Ceram Alumina (Vita). That study and others have indicated that zirconia-based FPDs have the potential to withstand physiological occlusal forces applied in the posterior region, and may be interesting alternatives to metal-ceramic restorations.

The most common fracture pattern of tested zirconia-based FPDs was at the loading point and through one or both connectors[49]. Therefore, the connector design appears to be crucial for the fracture resistance and longevity of zirconia-based FPDs. Pluengsombut *et al*.[50] demonstrated that the fracture was initiated from the gingival surface of the connector and propagated toward the pontic. Several in vitro studies have evaluated the fracture resistance of zirconia based FPDs with a connector dimension of 3 × 3 mm, and obtained favourable results.[51] A connector dimension of 4 × 4 mm has been recommended for zirconia based FPDs in a clinical study and an in vitro study. Clinically, the connector design should be determined according to material properties, anatomical limitations, hygiene considerationsand estheticexpectations.[49]

Therefore, the dimension of the connectors and the radius of curvature at the gingival embrasure should be taken into account when designing zirconia-based FPDs. Cantilever zirconia-based FPDs survived for three years.In another clinical study, the four-year survival rate was 92% for cantilever zirconia-based FPDs.[52] It was therefore concluded that the clinical performance of cantilever zirconia-based FPDs was promising. Some complications have been reported in clinical trials, such as veneering porcelain chipping, loss of retention, caries lesions, and loss of vitality. The most commonly reported complication is chipping or cracking limited to the porcelain veneer.

This chipping or cracking of zirconia-based FPDs is attributable to mechanical insufficiency of the veneering porcelain, inappropriate framework support for the veneer, and unfavourable shear forces between the zirconia framework and veneer material. Other contributing factors include a mismatch of the coefficient of thermal expansion, residual thermal stresses, and differences in the modulus of elasticity between the zirconia and the veneering material.[53]

Zirconia-based restorations can allow the use of traditional cementation procedures because of their high fracture resistance.[54] In clinical studies, zinc-phosphate cement, glass-ionomer cement, resin-modified glass-ionomer cement, and resinbased luting material have been used for placement of zirconia-based FPDs.[55] Most of them evaluated zirconia-based FPDs for posterior missing teeth while a few investigated zirconia based single crowns. Zirconia-based FPDs exhibited promising clinical results with a high survival rate (over 95%) in most of the studies.[56.57] It was found that posterior zirconia-based FPDs can be a reliable treatment modality. Moreover, since zirconia-based FPDs exhibited survival rates similar to those of metal-ceramic FPDs, the authors concluded that zirconia ceramics could be a valid alternative to metal frameworks.[57]

Resin nano ceramic (Lava Ultimate, 3M ESPE)

It consists of a highly cured resin matrix reinforced with approximately 80% by weight Nano ceramic particles.The combination of silica nanoparticles (20 nm diamètre), zirconia nanoparticles (4 to11nm diameter), and zirconia-silica nanoclusters (bound aggregates of nanoparticles) reduces the interstitial spacing of the filler particles, enabling high nanoceramic content.[58]

Hybrid ceramic

Glass ceramic in a resin interpenetrating matrix (eg, Enamic, Vita) This is typically composed of a dual network: a feldspathic ceramic network (86% by weight / 75% by volume) and a polymer network (14% by weight / 25% by volume). The polymer network is composed of urethane dimethacrylate (UDMA) and triethylene glycol dimethacrylate (TEGDMA). The manufacturer refers to this as a hybrid ceramic.[58]

The specific composition of the ceramic part is SiO_2 -58% to 63%, Al_2O_3- 20% to 23%, Na_2O- 9% to 11%, K_2O- 4% to 6%, B_2O_3- 0.5% to 2%, less than 1% of Zr_2O and CaO.

Indication

inlays, onlays, veneers and crowns for anterior and posterior applications. They can also be used for minimally-invasive restorations such as non-prepared veneers and for restorations in areas where space is limited.

Zirconia-silica ceramic in a resin matrix

Tailored with different organic matrices as well as variation in ceramic weight percentage.eg, silica powder, zirconium silicate, urethane dimethacrylate (UDMA) and triethylene glycol dimethacrylate (TEGDMA). Another example is the composite composed of 85% ultrafine zirconia-silica ceramic particles (spherical 0.6 µm) embedded in a polymer matrix of bisphenol A glycidyl methacrylate (bisGMA), TEGDMA, and a patented ternary initiator system (MZ100 Block, Paradigm MZ-100 Blocks, 3M ESPE).[58]

Paradigm™ MZ100 Blocks for CEREC,3M ESPE

Brand	Paradigm
CAD-CAM System	CEREC®
Digital Materials	Digital Chairside Restorative Materials
Material Type	Composite
Shades	A1, A2, A3, A3.5, B3, Enamel
Size	Size 10, Size 14

Indications for Use - Inlays, Onlays, Crowns, Veneers

CONCLUSION

Advances in CAD/CAM technology have catalyzed the developments of aesthetic all ceramic restorations with superior biomechanical properties. Although none of these materials exhibit ideal clinical properties for universal applications, intense research efforts are under way to promote the strength, aesthetics, accuracy and an ability to reliably bond to dental substrates. The field of CAD/CAM ceramics in dentistry is strongly evolving with evidence from materials development and from longer-term clinical studies

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How to cite this article:

Vidya Bhat *et al*.2016, Cad-Cam Ceramics - A Litrature Review. *Int J Recent Sci Res.* 7(3), pp. 9352-9361.

ISSN 0976-3031

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