

REVIEW ARTICLE

Recent Advances in Dental Ceramics: A Review Of Literature

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Introduction

Dental ceramics are inorganic, non-metallic, structures, primarily containing compounds of oxygen with one or more metallic or semi metallic elements (aluminium, calcium, lithium, magnesium, phosphorous, potassium, silicon, sodium, titanium and Zirconium). Dental ceramics are superior because of their biocompatibility, long term color stability, wear resistance, and their ability to be formed into precise shapes.

Methods

A comprehensive search of PubMed journals was conducted to retrieve clinical and experimental studies, case reports and review articles by using keywords. After studying a series of related articles and publications we have reviewed and compared the various properties, applications and advances in dental ceramics.

History

In approximately 700 B.C., the Etruscans made artificial teeth of ivory and bone, human teeth and animal teeth that were held in place by gold wires or flat bands and rivets (Fig.1). Animal bone and ivory from hippopotami and elephants were used for many years thereafter. ¹



Fig 1: Copy of Etruscan denture recovered from a tomb in Etruria, Italy, circa 700 B.C. Gold bands of this type held human or animal teeth that were fastened by means of gold rivets.

The Journey From Metal Ceramics To All Ceramic Prosthesis

Metal Ceramics Restorations

Weinstein et al. first described the production of metal ceramic restoration by using porcelain powders containing 11% to 15% K_2O frit.

Metal Reinforced Systems (Captek System)

The Captek System: In the Captek system the coping is produced from two metal impregnated wax sheets that are adapted to a die and fired. The first sheet forms a porous gold platinum palladium layer that is impregnated with 97% gold when the second is fired. Advantages of the system include excellent esthetics and marginal adaptation. ²

Aluminous Porcelain Crowns

The porcelain jacket restoration has been in use since Land introduced it in 1903. Seghi et al found strength of the core to be up to four times greater than other ceramics materials. ³

Castable And Machinable Glass Ceramics (Dicor And Dicor MGC)

Dicor 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. ⁴

Pressable Glass Ceramics

IPS Empress, a new addition to the metal free ceramic restorations uses a wax-up lost wax technique (Fig.2). The ceramic is leucite reinforced and comes in precerammed cylinders (Fig.3) in various shades. ³



Fig 2: IPS Empress furnace, Fig 3: Empress pellets

Cerestore: A Shrink Free Ceramic Crown

Sozio and Riley in 1903 ³ introduced the Cerestore system. It employs a heat stable epoxy die and an aluminous core porcelain which is injection molded.

Ceromers

Ceromers are more viscous than typical composite resin, have greater filler components and different handling characteristics.

Ormocers

Acronym: - Organically modified ceramic.

It is composed of inorganic-organic hybrid prepolymerized matrix with chemically attached polymerizable group. It contains multifunctional Urethane and Thioether (meth) acrylate alkoxy silane sol-gel precursors.

Computer Assisted Restorations

Today's world is not a mere electronic or computer world but it is a world of automation. CAD-CAM is the one of the important milestone in the world of automation.

Tuntiprawon M. and Wilson P.R. (1995) ⁵ stated that long term success of all ceramic crowms and fixed partial dentures depends on accuracy of fit between restoration and prepared tooth structure which can influence the strength of restoration.

According to Tinscert J. et al. (2000) ⁶ advantages of using CAD/CAM are:

- Room temperature milling of ceramic materials processed under high quality processes will yield homogenous materials where voids, cracks and flaws are reduced to minimum.
- This technology is able to produce highly accurate restorations.
- It yields restorations with higher strength, accuracy and marginal fit.

Systems Of CAD-CAM

Some popular systems that are in current use to accomplish CAD-CAM restorations:

a) The CEREC system manufactured by Siemens Dental Corp. This compact chairsided system consists of an optical data aquisition camera, CAD CAM software and micromilling machine.

b) The DUX or Titan system consists of a miniature contact digitizer, a central computer and a milling machine.

c) The DURET system is produced by Sopha. It consists of three discrete units: a camera module for data acquisition, the CAD module used to design the restoration and the milling module.

d) The CELAY system is a very small unit consisting of contact digitizer that "reads" the shape of an acrylic inlay and directly transfers the shapes to a miniature milling machine.

e) The PROCERA system is a coping and fabrication system using a pantograph and an electric discharge machining. The shape of the die and the wax pattern of the restorations transmits these

shapes to a milling machine to produce electrodes in these shapes. These electrodes are used to produce a restoration.

f) The DENTI-CAD system consists of miniature robot arm digitizer, CAD-CAM software with an export for fully automated design and a milling machine. It is completely automated. ⁷

The CEREC System

The CEREC 3 (Fig.4) all ceramic, chair side computer aided design/computer aided machining restorations system was introduced in January of 2000. Chair-side fabrication of ceramic inlays, veneers partial and full posterior crown and anterior full crown was simplified and accelerated (Fig.5).

The newest model known as CEREC AC (powered by BlueCam) also has the ability to take half-arch or full arch impressions and create crowns, veneers and bridges. The entire tooth preparation scanned is coated with a layer of titanium dioxide powder, which makes translucent areas of teeth opaque and permits the camera to register all of the tissues. ⁸



FIG 4: CEREC 3 with monitor, Fig 5: CEREC milling unit

DCS Precident CAD/CAM System:

The DCS (Digitizing Computer System) Precident system, called the DUX or Titan system in the United States, was developed in 1988 and introduced to the market in 1990.

J.Tinschert et al. (2001)⁹ studied marginal fit of alumina and zirconia based fixed partial dentures produced by DSC precident system. It was concluded from the results of the study that the level of accuracy found for investigated All-ceramic Fixed partial dentures meet the clinical requirements.

The Procera All-Ceramic System

Application of the Procera system for manufacturing individual crowns made of aluminum oxide ceramics for the first time joins computer-controlled technology with the increasing demands for improved esthetics (Fig.6).



Fig 6: PROCERA CAD CAM System

CAD/CAM Glass Ceramics

CAD/CAM-compatible feldspathic ceramics

The conventional dental porcelain is based on feldspar, comprises a tectosilicate mineral feldspar, quartz, or kaolin and have excellent aesthetic properties and have been recommended for use in fabricating veneers, inlays/onlays and single anterior and posterior crowns. 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 (Otto T, et al. 2002).¹⁰ However, a much higher breakage rate of up to 36% after 2 years was also reported.

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 (Pallesan U, et al.2000).¹¹

CAD/CAM with leucite-reinforced ceramics

ProCAD was introduced in 1998 to be used with the CEREC. It is a leucite reinforced ceramic, similar in structure to the heat pressed ceramic Empress.

CAD/CAM milling lithium disilicate reinforced ceramics

Lithium disilicate glasses have their flexure strength between 350 MPa and 450 MPa. This is higher than that of leucite-reinforced dental ceramics. Lithium disilicate CAD/CAM ceramic IPS E.max CAD was introduced in 2006 and is a chair-side monolithic restorative material. They are available in A–D and Bleach shades as well as in 3 translucencies and are supplied in a pre-crystallized so-called blue state.

CAD/CAM and glass infiltrated alumina and zirconia ceramics

The Vita In-Ceram Classic group of ceramics are slip cast, glass infiltrated ceramics that have at least two interpenetrating phases intertwined throughout the material. Acid etchants have no appreciative effects on aluminium trioxide and conventional cements such as glass ionomer cement has been suggested for luting. Air particle abrasion with 50 mm aluminium trioxide with the use of tribochemical silica- coating for bonding to a silane coupling agent have also been suggested to be effective CAD/CAM.¹⁰

Recent Advances In Dental Ceramic Materials

The evolution of computerized systems for the production of dental restorations associated to the development of novel microstructures for ceramic materials has caused an important change in the clinical workflow for dentists and technicians, as well as in the treatment options offered to patients.¹²

Monolithic Zirconia restorations

The better translucency of the new zirconia materials has been achieved by means of microstructural modifications, like decrease in alumina content, increase in density, decrease in grain size, addition of cubic zirconia and decrease in the amount of impurities and structural defects.^{13,14} Laboratory studies have shown that monolithic zirconia usually causes a rather comparable wear of the antagonists in comparison to other restorative ceramics, and this wear rate is within the physiological range reported in the literature. Some of these studies^{15,16} compared different surface finishing techniques for monolithic zirconia restorations, such as polishing versus glazing, and found that polished surfaces resulted in less enamel wear of the antagonist.

New Glass Ceramics

These new glass-ceramics were designed to contain lithium silicate as the main crystalline phase in a vitreous matrix reinforced with zirconium dioxide crystals.¹⁷ Suprinity and Celtra duo are two new glass ceramics containing smaller and finer crystalline phase occurs due to the presence of zirconia particles in the material, which acts as an additive influencing the crystallization by hindering crystal growth.¹⁸ The main advantage of these materials is their time saving ability for the production of dental restorations, since they are faster to be milled in CAD-CAM machines than lithium disilicate glass-ceramics¹⁹ and are already offered in their fully crystallized state (CELTRA Duo) or need a very short crystallization cycle (Suprinity).

Polymer infiltrated ceramic networks (PICNs)

Recently, a new material has been developed by Vita which is marketed as a polymer infiltrated in a porous ceramic, generating an interpenetrating network (polymer infiltrated ceramic network, PICN). This new material was developed based on the glass infiltrated ceramic technology, which was originally released by Vita in the 90's.¹⁹ This PICN is based on initial sintering of a porcelain powder to approximately 70% of its full density, followed by infiltration with a monomer mixture.

²⁰ A study evaluated the damage tolerance of different dental materials and showed that the damage tolerance of PICN was higher when compared to other ceramics for CAD-CAM, like veneering ceramics. ²¹

Recent Advances In Processing Technologies

Addition to CAD-CAM systems, the following techniques have stood out recently:

Selective Laser Sintering or Melting

SLS was invented by Deckard and Beaman at the University of Texas at Austin, with the very first patent filed in 1986. In this technique, the laser beam sinters thin layers of a ceramic from a container filled with powder to create a single coping or framework, in which each layer represents a cross section of the CAD model²². An additional advantage is that these materials are also more tolerant to temperature gradients. Like its counterparts, ceramic SLS has also become increasingly popular in biomedical applications, particularly in the fabrication of customized complex and highly cellular biocompatible scaffolds for tissue engineering.

Direct 3D Printing

Direct 3D printing (Fig.7) is similar to a traditional inkjet printer, performing the direct printing of a ceramic suspension, allowing the generation of dense green bodies with high resolution, and producing complex shapes²³. In 2009, using a modified inkjet printer, a zirconia crown was manufactured with sufficient mechanical properties to be used in the oral cavity²⁴. The impression of the posterior dental crown was performed using a cartridge filled with a 27 vol% solid content of zirconia-based ceramic suspension. Slurry-based ceramic 3D printing technologies generally involve liquid or semi-liquid systems dispersed with fine ceramic particles as feedstock, either in the form of inks or pastes, depending on the solid loading and viscosity of the system. The slurry content can be 3D printed by either photopolymerisation, inkjet printing or extrusion. Advances in materials science have also made it possible to photopolymerise pre-ceramic polymers (PCPs) for transformation into polymer-derived ceramic (PDC) components via heat treatment²⁵.



Fig 7: 3-D Printing technology

Stereolithography

Stereolithography is frequently used nowadays, and has already evolved enough to allow production of more complex ceramic pieces, whereas the previously mentioned techniques are in the early development stage for dental applications. It is a process in which a light source of a certain wavelength (usually in the ultraviolet range) is used to selectively cure a liquid surface in a vat containing mainly photopolymerisable monomer along with other additives in very small amounts, particularly photoinitiators²⁶. The light-activated polymerization process (i.e. liquid monomer turns into solid resin) generally proceeds point-to-line, line-to-layer, and then layer-by-layer, along with the light scans on the liquid surface. When polymerisation is finished for one layer, the vat or platform supporting the part being produced is lifted or lowered by the thickness of a layer, depending on whether the building process is being operated in a top-down or bottom-up mode.

Conclusion

Dental ceramics and processing technologies have evolved significantly in the past years, with most of the evolution being related to new microstructures and CAD-CAM methods. Also, a trend towards the use of monolithic restorations has changed the way clinicians produce all-ceramic dental prostheses, since the more aesthetic multi-layered restorations unfortunately are more prone to chipping or delamination. These new generations of all ceramic materials present interesting

options, both in terms of material selection and fabrication techniques. The various materials have different properties that specify their use in specific clinical situations.

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