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RECENT ADANCES IN CERAMICS-A REVIEW

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ABSTRACT

Ceramics now-a-days plays an important role in dentistry especially in cosmetic dentistry. Modern dentistry gave birth to many materials and techniques where ceramics had major impact on development. Zirconium, a type of ceramics was known as the strongest dental material. Custom made zirconium crowns were made using CAD/CAM technology. This article gives an overview of recent advances in ceramics today.

KEYWORDS: Ceramics, Zirconium, Monolithic, glass ceramics, CAD/CAM Technology

INTRODUCTION

It is quite common in dentistry to adopt a material from engineers and apply it in clinical conditions. Example of such an instance is dental ceramics. Ceramics are refered to as non-metallic, inorganic structures primarily containing compounds of oxygen with one or more metallic or semi metallic elements.[1] Dental ceramics are the most suitable tooth colored restorative material and the most durable of the aesthetic materials, impervious to oral fluids and biologically compatible. Ceramics are chemically indestructible in oral environment. Apart from the materials that used in dentistry to restore the natural dentition, ceramics have the best optical properties to minimic the tooth structure in appearance, translucency, and light transmission which gives dental ceramics, a highly desirable aesthetic properties.[2] This article is a review of major advances in dental ceramics with respect to its chemistry and new techniques that has been evolved.

Development of Dental Ceramics: Dental ceramics consist of an amorphous part and crystals. The mechanical properties are determined by the amount and size of the crystals. The amorphous part consist of SiO_2, which gives ceramics aesthetically pleasant and natural looking appearance. Esthetics is the major advantage of porcelain and brittleness is its weakest point for load bearing. Ceramics are widely used for fabrication of framework in dental restorations. They are basically classified according to the crystalline phase, fabrication technique, and core/veneering ceramic systems. Goal of the ceramic development is to achieve adequate strength and toughness without affecting the aesthetics. Ceramics are used more often in the restoration of inlays, onlays, crowns and bridges. Obtaining a very good aesthetics and mechanical properties in a single restoration between the porcelain veneer and a metal sub structure is termed as metal ceramic restorations. In 1903 first all-ceramic crowns were introduced.[3] The all-ceramic restorations are composed of feldspathic porcelain, glass ceramics and alumina core systems.

Classification of Dental Ceramics

Based on the Application

- Metal ceramic: crowns, fixed partial prostheses.
- All-ceramic: crowns, inlays, onlays, veneers, and fixed partial prosthesis.
- Additionally ceramic orthodontic brackets, dental implant abutments and ceramic denture teeth.

Based on the Fabrication Method

- **Sintered porcelain:** leucite, alumina, fluorapetite
- **Cast porcelain:** alumina, spinel
- **Machined porcelain:** zirconia, alumina, spinel

Based on the Crystalline Phase

- Glassy phase.
- Crystalline phase.

Based on the Processing Method

- Casting.
- Sintering.

- Partial Sintering.
- Glass Infiltration.
- Slip-casting and sintering.
- Hot-isostatic pressing.
- CAD/CAM milling and copy milling.

Based on Firing Temperature

- Ultralow fusing.
- Low fusing.
- Medium fusing.
- High fusing.

A brief description for these materials are described below: The consolidation process of ceramic powder particles through heating at high temperatures resulting in atomic motion is referred to as SINTERING**.** It promotes physical and chemical reactions that are responsible for the final properties of ceramics. Using alumina and magnesia, ceramics are reinforced by a mechanism known as "dispersion strengthening".[4] Due to their good optical properties leucite reinforced ceramics are indicated to fabricate veneers. The commercially available leucite reinforced feldspathic porcelain is the OPTEC HSP. The strongest and hardest oxide that can be reinforced using "dispersion strengthening" is the alumina-based porcelain. The core material of magnesia-based porcelain is responsible for strengthening of ceramics which is made by reacting magnesia with a silica glass with 1100-1155$^{\mathbf{0}}$c temperature resulting in precipitation of forsterite crystals.

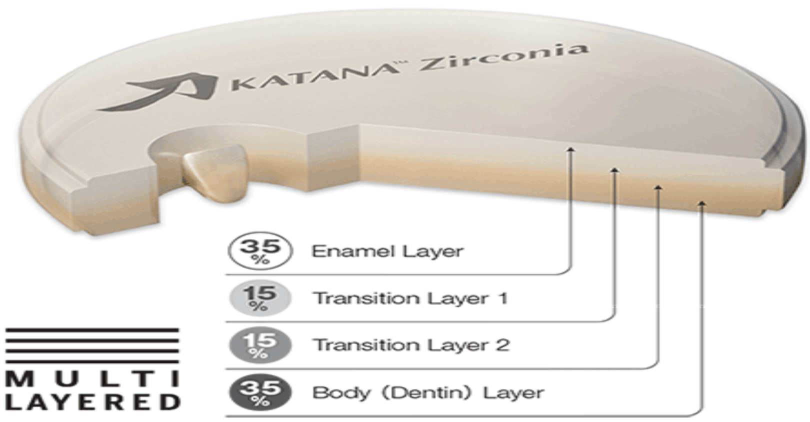
Zirconia: Zirconium crown was first introduced in 1970s. It is a polycrystalline material reinforced into conventional feldspathic porcelain to strengthen them by a mechanism known as "transformation toughening". It is made up of zirconium oxide or zirconia. Zirconium crowns are one of the most important and most recommended types of ceramic crowns used in recent times. The flexural strength of zirconia is 1900-1200 Mpa and hardness is about 1200 HV.[5] In nature, zirconia has monoclinic crystalline structure which can be converted into tetragonal phase by heating at 1170^{o} c and it transforms into cubic phase on heating at 2370^{0}c. It is a white powdered material which has the ability to be radiopaque in x-rays. Zirconium crowns are known for its natural look, which makes it a favorite crown to dental patients and to the dental technicians. Life span of zirconium crown is greater when compared to other regular crowns.Due to the mechanical properties of zirconia, it used in posterior FPDs and permit substantial reduction in core thickness[6]. Various fluids and foods consumed over years leads to the corrosion of the dental crowns, but zirconium crowns do not undergo corrosion. Latest dental technologies can be successfully used in the production of zirconium. Base material of zirconia is developed as semitransparent which can replicate the natural color of tooth. Abrasive nature of zirconia to opposite dentition is now shown in clinical studies.

Chipping or fracture of veneering ceramics is the main problem of zirconium-dioxide restorations in clinical practice. Eventhough, minor chipping does not affect the aesthetics and functions of restorations,it can be corrected by composite restorations whereas major chipping may expose the underlying core material. However, the most important factor in the chipping phenomenon is the residual stress which is incorporated during the fabrication stage of zirconia restorations especially by thermal methods. Furthermore, repeated occlusal loading also adds to the risk of crack propagation which by means of tensile stress gets aggravated eventually leading to chipping.

To overcome this problem, zirconium framework is veneered with glass ceramics, instead of feldspathic ceramics. In addition to this “over-pressing” technique is introduced, in which the whole veneer is over-pressed to zirconium framework at once. Apart from this application and veneering ceramics, anatomically designed framework and veneer/framework thickness ratio, with lower ratio decreases chipping. CAD/CAM production of whole veneer from lithium-disilicate ceramics shows better mechanical properties when compared to layered or over-pressed zirconium restorations. Production of high-translucency (HT) zirconium-dioxide in recent times allows full-contoured monolithic restorations that reduces the risk of chipping.

Monolithic Zirconia Restorations: To overcome problems related to chipping of porcelain layers applied over zirconia, yttria stabilized tetragonal zirconia polycrystal (Y-TZP) for monolithic restorations has been developed. Y-TZP has high strength level of more than 1000Mpa and fracture toughness of 4 to 5 Mpa.m$^{0.5}$. The three different crystallographic forms of zirconia are cubic, tetragonal and monoclinic phases. Translucency ofthis type of material is achieved by microstructural modifications such as decrease in alumina content, increase in density, decrease in grain size, addition of cubic zirconia and decrease in amount of impurities and structural defects. Though zirconia microstructure have higher translucency, the final restoration color remains a limited whitish shade. This can be altered by adding coloring pigments to monolithic zirconia which does not affects its flexural strength and translucency. Long-term success rate of this material in addition to mechanical and optical properties is the wear of antagonist enamel and the marginal adaptation. Marginal adaptation of Y-TZP monolithic restorations has improved by the evolution of CAD/CAM systems. Monolithic zirconia restorations are considered as a promising alternative because of their simple processing method and less time consuming when compared to other multilayered restorations.[7]

Multilayered Dental Prostheses: The lower biocompatibility and lower translucency of metals are the factors responsible for the use of ceramics as infrastructure materials in multilayered restorations. Alumina-based zirconia reinforced glass infiltrated ceramic, polycrystalline alumina and Y-TZP are the examples for such materials.Because of its excellent mechanical properties Y-TZP has gained remarkable popularity among those ceramic materials. The fracture of veneering layer applied over Y-TZP has been associated with a) design of the Y-TZP infrastructure b) thickness of the restoration layers c) thermal residual stresses and d) mechanical properties of the veneering ceramic. To gain a proper restoration Y-TZP framework has the application of a mixture containing veneering ceramic powder and the modeling liquid with the use of brush. This reduces the fracture of restoration during chewing. Similar to Y-TZP, Zirconia- toughened alumina (ZTA) is toughened by stress-induced transformation mechanism. The properties of ZTA are 85% alumina/15% zirconia. Press-on method is the another technique used for the application of veneering layer, in which the material is applied on the ceramic infrastructure by lost-wax with hot-pressing technique resulting in better mechanical behavior and less pores. Multilayered restorations made using CAD/CAM blocks showed higher fracture strength values when compared to crowns made layering and press-on techniques.[7]



Glass Ceramics: Also known as castable glass ceramics is processed by using lost-wax pattern casting procedure. DICOR is the first commercially available castable ceramic material.Glass ceramics are used commonly in prosthetic dentistry because of their improvement in mechanical properties associated with better microstructures and new processing methods. A non-crystalline phase of glass ceramic prosthesis were converted into crystalline phase controlled devitrification process using heat treatment called ceramming. This procedure increases strength and fracture toughness of glass ceramics by interrupting the crack propagation under masticatory forces. The first lithium disilicate glass ceramics was produced by melting a glass, which was ground to make powder that was used to make so called "blue "blocks or ingot. Depending on the type of production it was decided whether it was "blue" block or ingot for hot-pressed technique. Glass ceramics were designed to contain lithium silicate as the main crystalline phase which is reinforced with zirconium dioxide crystals. Two examples of lithium silicateglass ceramics are a) suprinity, material that requires an additional thermal cycle in a furnace b) CELTRA Duo a material that is already in final stage these material show similar composition. Time saving ability of these materials are the main advantage in production of dental restorations since they are faster to be milled in CAD-ACM ceramics.[7] The good aesthetic quality is the major factor that attracts the clinicians to prefer glass ceramics.

Slip-Cast Ceramics: Pouring of an aqueous porcelain slip on a refractory die is referred as slip-casting. It consist of two 3-dimensional phases like core framework made up of alumina or zirconia or spinell and infiltrated glass that is usually lanthanum aluminosilicte glass with sodium and calcium. Slip-cast ceramic materials are classified into Inceram-alumina, Inceram-spinel and Inceram-zirconia based on their type of core material. The porosity in the refractory die helps in condensation by absorbing the water from the slip through capillary action. At high temperature the die shrinks and helps in easy separation. Since the resulting ceramic is very porous it is infiltrated with molten glass or fully sintered before the application of veneers. Ceramic undergone this technique has reduced porosity and higher toughness.

Pressable Ceramics: Application of external pressure at elevated temperature to obtain sintering is the fabrication of pressable ceramics. It is known as "hot-pressed" or "heat-pressed" ceramics. It includes first generation phase as 35 to 45 % volleucite reinforced crystalline phase which has flexural strength and second generation as 65 vol% of lithium disilcate based. The highly interlocked lithium disilicate crystals and layered crystals contributes strengthening in final microstructure.Along with its superior mechanical properties, this technique also prevents porosity and increases density. Recently developed ceramics are IPS e.max-press and IPS e.max, in which IPS e.max-press is processed in the laboratory with pressing technique that provides very high accuracy of the restoration fit.

Injection Molded Technique was introduced in 1970 with "shrink-free" cerec system. This technique was used to fabricate flexible denture base resin prosthesis such as Rpds, Nesbit bridges, complete dentures, maxillofacial prosthesis, space maintainers, Tmj splints, gum veneers and night guard. Application of rapid and firm pressure is important for success of this technique. Recently denture manufacturing companies have introduced this technique in which fluid resins flow into the mould cavity through sprues formed by sprue formers, which can also be used in relining and rebasing. Alceram is the commercially available material that contains magnesium spinel as the major crystalline phase. It has excellent marginal fit to the restorations.

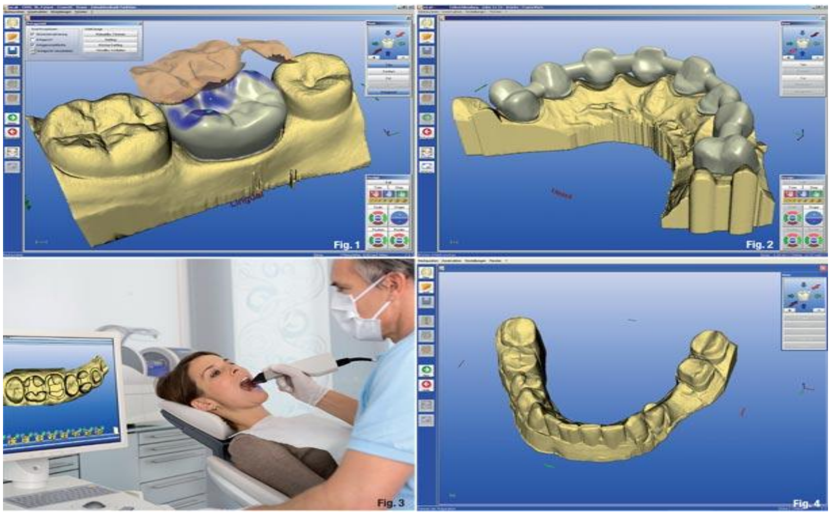
Polymer Infiltrated Ceramic Networks (Picns): Based on the glass infiltrated ceramic technology, polymer infiltrated ceramics are the newly developed material, generating an interpenetrating network. PICNs is an elastic modulus which can be repaired by composite resins. They are easy to mill and adjust. This material is composed of dominant ceramic and polymer. Recent article shows the polymer present is composed of urethane dimethacrylate and triethylene glycol dimethacrylate cross linked polymers. The strength of PICN is 135 MPa with polymeric part below 30 MPa and ceramic part around 135 MPa. PICNs is more suitable for posterior region than the anterior due to its inferior optical properties.

CAD/CAM Technology: CAD/CAM application in dentistry is the process in which dental restoration is done through milling process of ready ceramic blocks. CAD/CAM is an acronym of COMPUTER AIDED DESIGN/COMPUTER AIDED MANUFACTURE for the manufacture of inlays, onlays, crowns and bridges.CAD/CAM isfirst introduced in the year 1985. The development of technology consists of copy milling machine to computer controlled system that leads to the production of crowns and bridges. This method has greater use in producing fixed restorations. Materials that cannot be used by conventional processing techniques are used in CAD/CAM technology.[8]

CAD/CAM technology in dentistry consists of three components; 1) Digitalization tool/scanner that transforms geometry into digital data that are processed by computer. 2) Software that processes data and 3) a production technology that forms the basic shape that produces the dental restorations. Forming a 3D image of teeth, it helps the dentist to create an appropriate anatomical design of missing tooth substance. The resulting 3D model provides a basic for restoration design. CAD/CAM machine undergoes further milling process with finished ceramic block that produces the final dental restorations with the replica of 3D drawings. Depending on the location of the components, three different production concepts are available, a) chair side production b) laboratory production c) centralized fabrication in a production center.

Optical scanners and mechanical scanners are the two possible scanners in CAD/CAM technology. Optical scanner consists of three-dimensional structures called triangular procedure.The source of light and the receptor unit are in different angle with alaser beam that serves as a source of illumination. Examples are Lava scan ST, Everest scan and es1 (etkon, laser beam) whereas Mechanical scanner consist of master card that is read mechanically line-by-line with a rubber ball and the three dimensional structure measured. Procera scanner from nobelbiocare is the only example.The materials used in CAD/CAM processing are metals, resin materials, silica based ceramics, infiltration ceramics and oxide high performance ceramics.[9]

Dental restorations can be fabricated in chairside without a laboratory procedure. Conventional impression is replaced by a digitalization instrument with an intra oral camera, so this saves time and offers patients indirectly fabricated restorations in one appointment. Now this procedure is in its third product generation. A very exact three-dimensional reconstruction of occlusal surface is produced with this procedure which is a major benefit of this system.



Metal free restorations were made using CAD/CAM technology where more precise than conventional process of producing metal-ceramic crowns and bridges. Dentist diagnose and recommend several options based on the indications and status of the tooth, by explaining the pros and cons depending on the indications. Preparation begins by grinding the teeth depending on the types of ceramics to be used. After taking the tooth imprint casting of model is done. Modeling of teeth is carried out by CAD/CAM software based on the entered requirements. Hence the procedure ends with cementation.

Optical method of spatial digitalization consist of intraoral and extraoral methods. Intraoral method occurs in dental office whereas extraoral is related to laboratory work. In intraoral method, the technique is done using light rays in the form of line that is projected on the preparation. The most commonly used method is Cerec system. Extraoral method is carried out by laser triangular procedure. Cerec scan is commonly used in this technique. The advantages of using CAD/CAM in dentistry are: a) a simplified procedure b) increased productivity c) multiple restorations can be done d) patient comfort.[10]

CONCLUSION

The technological advancements in dental ceramics are fast growing in dental research and development. The introduction of new technologies has improved the services in the field of dentistry. Due to its aesthetic appearance dental ceramics are preferable. The ability of the clinicians to select the appropriate material to match intraoral conditions and aesthetic demands are the factors responsible for the success rate of ceramic restorations. Hence the introduction of these technologies will have a greater impact in future dentistry.

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