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# Dental Ceramics: Considerations for New Materials and Processing Methods

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## Abstract

The development of advanced systems for the synthesis of dental restorations related to the development of new microstructures for ceramic materials has triggered a significant change in the clinical workflow and publications for dentists and dental technicians, along with the treatment options accessible to patients. Additionally, new microstructures have been developed by the industry to offer ceramic and composite materials with improved properties, such as enhanced mechanical properties, adequate wear resistance and satisfactory aesthetic characteristics. The purpose of this literature review is to analyze the main improvements of new ceramic restoration systems as well as their processing methods. CAD-CAM methods and microstructures have been developed attributing to the evolvement of dental ceramics and their processing technologies. Furthermore, the use of monolithic restorations has changed the way clinical dentists compose all-ceramic dental prostheses, as the more aesthetically pleasing multilevel restorations are, the more prone to breakage or detachment. CAD-CAM composite composites are now an appealing choice, as they exhibit intermediate properties between ceramic and polymeric materials, smoothing and polishing them more easily.

***Keywords:*** *Dental Ceramics; Computer-Aided Design; Zirconia, Dental Materials; Restorative Dentistry; Prosthetic Dental Technology*

## Introduction

In the restorative dentistry, ceramics are promoted more and more, due to their high-strength materials for dental prostheses. With the arrival of digital-age chairside milling, in conjunction with the novel technology of rapid sintering, dental restorations' production is becoming more automated, time effective, and accurate. The main purpose of the materials is the development of ceramics with superior aesthetics with long-term endurance. Prosthetic dentistry is an expansive and profitable health business, so improvements in technologies of materials and manufacture may have important economic outcomes for the dentists, dental technicians as well as the patient [1].

Ceramics were introduced in dentistry in 18th century by Alexis Duchateau, a pharmacist from Paris, when he successfully replaced his dentures from ivory with porcelain. Ceramics in dentistry are becoming more and more popular, as replacement materials due to their aesthetics, consistency and biocompatibility.

The aim of this review is to discuss the main advantages and disadvantages of novel ceramic systems and processing methods. Clinical and laboratory studies are discussed in detail in order to assist dentists and dental technicians in using these new technologies. Firstly, new ceramic systems are described, monolithic zirconia restorations, multi-layered dental prostheses, new glass-ceramics, polymer infiltrated ceramics and then the novel processing technologies.

## New materials

### Monolithic zirconia restorations

One of the most important changes due to the evolvement of systems, was the introduction of monolithic restorations, that are produced by high-strength ceramics, such as zirconia. Ceramic materials are used for a long period of time in order to produce monolithic restorations. However, an increase of monolithic restorations has been noticed, when the production of dental crowns covered from zirconia has been started, leading to dentists and dental technicians to be more confident, pointing to it as a ceramic construction material for crowns and bridges on the posterior teeth.

The most recent type of polycrystalline ceramics is yttria stabilized tetragonal zirconia polycrystal (Y-TZP) for monolithic (full-contour) restorations and can overcome problems related to chipping of porcelain layers applied over zirconia [2,3]. Zirconia has three different crystallographic forms, named tetragonal, cubic and monoclinic phase. The yttria stabilized tetragonal zirconia polycrystal, has strength level more than 1000MPa, which is the highest performance among the dental ceramics and superior fracture strength from 4 to 5 MPa. The high strength of zirconia is a result of transformation of grains from tetragonal to monoclinic phase, causing compression stresses.

The best transparency of the new materials made of zirconia, was accomplished through alterations of their microstructure, such as reduction of alumina content, addition of cubic zirconia, decrease in grain size, increase in density, and decrease in the amount of impurities and structural defects [4,5]. The size of crystalline grain is the microstructural characteristic that is related to the efficiency of the transparency of polycrystalline ceramics. For yttria stabilized tetragonal zirconia polycrystal, it has been proved that larger grains are more harmful for the mechanical properties but also for the stability of its tetragonal phase. Thus, zirconia's transparency cannot be accomplished via increasing its grain size.

A different approach for production of semi-transparent zirconia is the reduction of its grain size, until it reached a critical value, which results in the birefringence phenomenon [5]. Birefringence phenomenon in zirconia, appears due to the high volume of tetragonal crystal phase, > 90%. At this stage zirconia is a crystal with multiple refractive indexes, in relation to its crystallographic orientation in the microstructure. The scattering effects can also be erased with the use of cubic zirconia, which increased the transparency allowing optical isotropic behaviour [6].

Monolithic zirconia restorations are a very promising alternative for clinical dentists and dental technicians, as the processing methods are simple and less time consuming compared to the traditional multi-layered restorations. Monolithic restorations with zirconia allow dentists to perform invasive restorations, due to its high mechanical properties, particularly when compared with veneering porcelains. Specifically, significant mechanisms in the microstructure of the material, for instance its transformation toughening, allowing the construction of thinner formations, while maintaining as much as possible the integrity of tooth tissues.

Even though the new microstructures of zirconia have better transparency, the colour of the final restoration is limited to sub white shade. For this reason, one important technological evolvement for these materials is the colour process which allows a greater range of aesthetic potential [7]. Research studies demonstrated that addition of pigments in the monolithic zirconia does not affect its strength and transparency, though these results are related to specific colouring methods and are not related to other occasions [8,9]. Different techniques can also be used to add colour to restorations of zirconia. One of these is soaking of the material when it is pre-sintered state in solution that contains different pigment types. One disadvantage of this method is the inhomogeneous final shade, due to the fact that the pigment can only penetrate up to certain depth [10]. A different colouring technique makes available the production of pre-coloured zirconia blocks with more homogenous shade. These pre-coloured zirconia blocks are manufactured from a powder mixed or synthesized with pigments [7].

On the other hand, research studies have showed that monolithic zirconia has disadvantages, since it causes damage to the antagonistic teeth, when compared to other ceramic materials of restoration, with the pace of the material's damage being within the normal range, according to the literature. Some of these studies compared different finishing techniques of the surfaces for monolithic zirconia restorations and concluded that smooth surfaces had as a result less damage of enamel wear of the antagonist tooth [13-16].

The high surface zirconia's hardness has a significant effect on the antagonist tooth wear and the final polish of every zirconia's restoration is very important. Researchers used monolithic zirconia crowns placed on premolars and molars to test the surface wear of teeth. At the beginning of the trial, impressions were taken of the restorations and then after 24 months. Then, qualitative and quantitative analysis was performed with electronic scanning and optical profilometry, respective after the production of epoxy copies. This study demonstrated that after two years, monolithic zirconia showed an acceptable rate of wear on the surface of the antagonist tooth [17]. Thus, monolithic restorations of yttria square crystalline stabilized zirconia with smooth surfaces are unlikely to wear significantly the antagonist tooth. Monitoring though these restorations remains crucial due to the possibility of the smooth's surface change, which will eventually lead to increased wear potential.

The evolution of CAD-CAM systems improved the marginal adaptation of monolithic restorations of yttria square crystalline stabilized zirconia over the years. Specifically, some of these systems were evaluated according to their adaptation. Some examples are: CZ, Ceramill Zolid White (Amann Girrbach, Koblach, Austria), BZ, Bruxzir Solid Zirconia (Glidewell, Gais, Germany), TZI, TZ Incoris (Dentsply-Sirona, Bensheim, Germany), PZ, Prettau Zirconia (Zirkonzahn) and ZZ, Zenostar Zirconia (Wieland, Pforzheim, Germany). All of the above, showed an acceptable 'n' marginal deviation in adaptation, with the most advanced five-axis grinding systems having the best values [18].

The use of monolithic zirconia for dental restorations involves also the phenomenon of aging as a critical issue, as these restorations have direct contact with the oral environment and are constantly loaded with tendencies and forces. The formation of the monoclinic crystalline phase has been evaluated by research studies along with the flexural strength of various monolithic zirconia as the material ages. This study indicated that some species are not prone to aging, whereas others are more susceptible to square phase transformation [19,20]. Up to date there is no scientific, clinical evidence relating the clinical failure of dental monolithic zirconia to this type of aging, therefore more studies are needed to assess this aging phenomenon.

As monolithic zirconia is transparent, it may be used for aesthetic restorations, but special care should be taken before applying this type of restoration, as the number of follow-up clinical studies evaluating this type of crowns is not very great. For example, in one of these studies, 82 monolithic zirconia crowns placed in 1 patients, out of which only 6 developed complications after 3 years, a percentage of 7.3%. The study revealed that the problems related to this type of restoration are mainly linked to loss of endodontic complications (4.9%) and crown stability (2.4%). Therefore, this type of restoration is encouraging, although longer follow-up clinical trials would help to record more accurate results [21].

By recapitulating the above, we come to the conclusion that clinical dentists can overcome issues that are related to the multi-layered restorations with the use of monolithic restorations, which could be the fracture of the low-strength coating layer, usually made of a dental ceramic material (Figure 1A and 1B). Nevertheless, with the use of monolithic zirconia restoration, some other clinical issues may show up, such as damage and wear of the opposite (antagonistic) teeth and deterioration of aesthetics [22].

***Figure 1:*** *Aesthetic prosthetic restoration of upper jaw with monolithic zirconia restorations (A: initial condition, B: final condition).*

## Multilayered dental prostheses

According to studies, fixed prostheses with metal framing and ceramic coating typically have an annual failure rate of about 1% and survival rate of 94% as showed after clinical follow-up within 5 years [23]. These ceramic structures are typically considered standard, though many studies have been performed to accomplish the same level of performance using all-ceramic systems.

The low fracture strength of ceramic materials, led to the development of a series of ceramic materials with high crystalline content, resisting the mechanical stresses produced during the use of chewing forces. Some of these materials, are yttria square crystalline-stabilized zirconia, polycrystalline alumina and alumina-based glass-reinforced zinc-reinforced ceramics [22], out of which yttria square crystalline-stabilized zirconia is increasingly popular due to its outstanding mechanical properties [25]. Nevertheless, the more satisfactory aesthetic result will be accomplished by adding a coating layer made of compatible porcelain to materials with a high crystalline content (Figure 2).

***Figure 2:*** *Multilayered zirconia crowns (CAD-CAM).*

In the case of all-ceramic restorations, clinical observations have described little or no damage to the rectangular zirconia-fixed crystalline recovery structure in the course of clinical use, yet, ceramic coating layer fractures are often demonstrated [26]. In this way, the quality of the restoration is reduced functionally and aesthetically, resulting in the need for greater replacement of the dental tissue in the area of the lesion. The layer coating applied on a yttria square crystalline stabilized zirconia has been linked to numerous factors, as the design of the infrastructure of this material, which should support the coating layer, the relationship between the thickness of the ceramic infrastructure, coating and anatomical design and the properties of the ceramic coating layer [27-29].

In application of the coating layer, there are several methods, all designed to optimize the resistance of this layer and in some circumstances to downregulate the production of residual thermal stresses. The manufacturer proposes a ceramic powder and a liquid in the traditional processing technique. Specifically, the frame of the square crystalline stabilized zirconia for the restoration is achieved by applying a combination of the ceramic coating powder and the liquid using a brush. The desired anatomy of the tooth can be acquired only when several layers are applied. In this way, the coating layers that are created are sensitive to processing due to the risk of developing pores and a number of deficiencies, including areas of stress concentration, preferring the restoration fracture during chewing operation.

Compression method is an alternative technique to apply the coating layer, where hot technical pressure is used on the ceramic substructure (made of yttria square crystalline stabilized zirconia), producing a coating layer with less pores and improved mechanical behaviour compared to a coating layer synthesized by the traditional technique. Ceramic pellets are used in this case for the cladding ceramic, injected into a refractory mold including the previously fused frame of the yttria square crystalline-stabilized zirconia [30,31].

Using the traditional technique and crowns were produced with the CAD-on system, a study in 2012 compared the capacity of ceramic crowns composed of a fixed crystalline zirconia coating [32]. The results showed that the breaking limit was significantly increased from 1,575 N on the crowns produced by the CAD-on system to 1,166 N for the crowns with coating layer with the traditional technique.

The fracture strength of all-ceramic crowns on first molars with yttria square crystalline zirconia-stabilized infrastructures lined with different techniques was studied by another *in vitro* study [33]:

- Coating (VM9; Vita, Bad Sachingen, Germany),
- Compression (IPS e.max ZirPress; Ivoclar vivadent, Schaan, Liechtenstein),
- And milling from CAD-CAM blocks (LavaTM DVS; 3M, Seefield, Germany) by welding the posterior teeth using fiberglass fusion.

The fracture strength values were significantly increased to CAD-CAM blocks made multilayered restorations made compared to crowns synthesized by coating and compression techniques (6,242 N, 4,264 N, 5,071 N, respectively).

### New glass ceramics

Currently, glass ceramics are widely used in prosthetic dentistry because of the continuous advances of their mechanical properties combined with improved microstructures and novel processing methods. These materials have satisfactory mechanical properties and offer long life time of such dental restorations [34]. One more factor that contributes to the popularity of glass ceramics use from dentists, is the high-quality aesthetic [35-37].

Many materials with varied compositions have been developed since the beginning of glass ceramics use in dentistry. Nevertheless, this material's category advanced more after the introduction of lithium in 1998. In association with glass ceramics with leucite, the materials based on lithium disilicate appear to have significant mechanical properties (Table 1), a fact that contributes to their use in the production of all-ceramic prosthetic restorations [38-43].

| Material | Flexural strength (MPa) | Fracture toughness ($MPa.m^{1/2}$) | Hardness (GPa) |
|---|---|---|---|
| Leucite glass ceramic | 164 | 1.03 | 6.5 |
| Glass ceramic with lithium disilicate | 365 | 2.80 | 5.3 |

***Table 1:*** *Mechanical properties for the traditional glass ceramics [40-43].*

The first glass-ceramic with lithium silicate, based on the $Li_2O$ system: $2SiO_2$), was formed by melting a glass, and then designed accordingly to produce a powder, named "blue" blocks with a composition shown in table 2 [44]. Depending on the type of piece generated, the crystallization technique of this glass ceramic varied, though the crystallization process was analogous in all conditions.

| Constituent | Content % |
|---|---|
| $SiO_2$ | 57 - 80 |
| $Al_2O_3$ | 0 - 5 |
| $La_2O_3$ | 0.1 - 6 |
| MgO | 0 - 5 |
| ZnO | 0 - 8 |
| $Li_2O$ | 11 - 19 |
| Additives | ~8 |

***Table 2:*** *Composition of the glass-ceramic lithium disilicate [22].*

In summary, the crystallization of lithium silicate is monitored by a heating cycle, in which the lithium metasilicate ($Li_2SiO_3$) reacts with the glassy phase ($SiO_2$) to generate lithium silicate ($Li_2Si_2O_5$) [45]. Then, some changes occur on lithium silicate glass ceramics, which lead to better mechanical properties, primarily because of the decrease of the size of the microcrystals (length ranging from 2.0 to 3.0 μm) and the rise of the interconnection between them [46,47].

In spite of, the widespread use acceptance and widespread lithium silicate glass ceramics, the progression of dental materials has attempted to overcome the potential drawbacks of this ceramic system through the growth of glass ceramic materials covered with polycrystalline ceramics. This type of new glass ceramics contained lithium silicate as the major crystalline phase in a glass layer reinforced with zirconia crystals, about 10% [48]. The average size of lithium silicate crystals is 0.5 to 1 μm, when this material undergoes the crystallization process. This size is up to 6 times smaller than that observed for the lithium silicate crystals present in glass ceramics of lithium silicate [49]. The presence of zirconia fragments in the materials inhibit the growth of crystals and lead to the development of a smaller and thinner crystalline phase [50]. A microstructure containing smaller crystals guarantees in this material mechanical properties similar to those observed for lithium silicate ceramics. In addition, CAD-CAM systems support the formation of these new zirconia-reinforced lithium silicate materials, which can retain good optical properties and achieve a smooth surface as observed in traditional glass ceramics [51].

The existing commercial formulations of glass ceramics with lithium silicate have similar composition, as shown in table 3 [52].

| Constituent | Content % |
|---|---|
| $SiO_2$ | 56 - 64 |
| $Al_2O_3$ | 1 - 4 |
| $CeO_2$ | 0 - 4 |
| $ZrO_2$ | 8 - 12 |
| $K_2O$ | 1 - 4 |
| $Li_2O$ | 15 - 21 |
| $P_2O_5$ | 3 - 8 |

***Table 3:*** *Composition of glass-based ceramics based on lithium silicate in Suprinity (Vita Zahnfabrik, Bad Sachingen, Germany) [22].*

Zirconia-reinforced lithium silicate ceramics exhibit high-quality mechanical properties combined with outstanding aesthetic quality, therefore being an alternative to prosthetic restorations with high aesthetic requirement. The major benefit of these materials is their ability to save time, when producing dental restorations, since they are formed faster in CAD-CAM systems than glass-ceramic with lithium silicate. These materials are either already offered in their fully crystallized state or need very short crystallization cycle. A unique advantage of lithium silicate ceramics is their superior polishing capacity as a result of the smaller crystal sizes in their microstructure.

## Polymer infiltrated ceramic networks (PICNs)

CAD-CAM systems have been developed and used mostly the past years, particularly due to the trend towards high quality, aesthetics and productivity [54,55]. The main purpose of CAD-CAM systems when they developed was the production of ceramics, but pre-polymerized resin composites blocks have also been created with these systems. Paradigm™ (3M™, St Paul, USA), was the first resin block that has been established via CAD-CAM and was an alternative for the use of ceramics regarding the wear resistance. On the other hand, difficulties usually associated with composite resin systems still need to be addressed, for instance diminished mechanical properties and low wear resistance.

In recent years, Vita (Zahnfabrik, Bad Säckingen, Germany) designed and established a new material, which is advertised as a polymer filtered in porous ceramic, forming a permeability network, the so-called polymer infiltrated ceramic network, PICN. The development of this new material is based on ceramic glass filtration technology, originally distributed by Vita in the 90's (In-Ceram System, Vita, Bad Sachingen, Germany). When resin is filtered over a porous ceramic matrix, the final shrinkage of the polymer is about 5%, whereas the shrinkage of the filter glass is 1% [56].

PICNs have about 50% less elasticity than conventional ceramics and as such, are more similar to dentin. Moreover, they are more easily modified and can be repaired with repair resins. Unlike other ceramic materials such as porcelains, PICN has been shown to present greater damage tolerance and a lower modulus of elasticity [57]. One PICN product that is used for dental restorations, named Enamic, was introduced in 2013, by Vita, (Bad Sachingen, Germany), is built on the initial sintering of porcelain powder at about 70% of its full density, and then filtration with a mixture of monomers [58,59]. Enamic is a resin-ceramic composite, containing a ceramic and a polymer network. Several studies have shown that the polymer portion of this material consists of urethane dimethacrylate (UDMA) and triethylene glycol dimethacrylate (TEGDMA) [1,54-57]. Ceramic composition analysis revealed ceramic portion, consisting of $SiO_2$ ($Al_2$) 23%), $Na_2O$ (9 - 11%), $K_2O$ (4 - 6%), $B_2O_3$ (0.5 - 2%), CaO (< 1%) and $TiO_2$ (< 1%). Amorphous glass is also present in the inorganic matrix of this material.

Enamic has been shown to have elastic modulus values identical to those reported by the manufacturer (approximately 30 GPa), the values of fracture toughness though were lower than those mentioned by the manufacturer (0.86 MPa.m1/2, compared to 1,5 MPa.m1/2) and similar to the ceramic used for this study [1,54,57] Thus, the presence of a polymer network is not able to create treating mechanisms in material's microstructure. In addition, this study showed that PICN had increased sensitivity compared to a pure ceramic. Thus, the question arose as to whether the added polymer is sensitive to water absorption.

PICNs have advantages due to both ceramics and composite resins, with a significant balance between elasticity and resilience, indicated for single crowns, inserts, inlays and onlays. The strength of the polymeric part is about 30 MPa and 11 MPa for the ceramic part and the total PICN has a strength of 135 MPa. PICNs have properties between ceramics and resins [1,54,57].

Additionally, a range of 30 GPa is reported for the elasticity of these materials, which is closer to the range reported for the dentin and half of the veneering ceramics, while typical ceramic materials have higher range [1,54-59]. The hardness of enamel (3.43 ± 0.16 GPa) is similar to PICN (3.31 ± 0.11 GPa) and higher than that of composite resin (0.73 GPa to 1.1 GPa), and lower than the hardness of lithium silicate ceramics (10.0 GPa to 11.31 GPa) and zirconia (13.94 GPa). Furthermore, Enamic's flexural strength is lower than that of a glass-ceramic silicate 130 MPa and 342 MPa, respectively [54]. Finally, the resistance to breakage by grinding through diamonds of PICN is higher resistance to breakage compared to other pressed and CAD/CAM materials, such as ceramic veneers [1,59].

In terms of optical properties, the shrinkage of the resin leads to surface imperfections that appear on the ceramic frame and the polymer followed by micro-detachment and the creation of greater opacity due to the gaps that are developed. Enamic has been shown to be less translucent than IPS e. max or from Lava Ultimate (3M ESPE, St Paul, USA) [58,59]. However, the pigment resistance of PICN was lower than that reported for IPS e.max and higher than that measured for Lava Ultimate [1,58,59].

Finally, clinical studies demonstrate many encouraging long-term results for PICN. For example, a five-year chewing simulation showed that none of the Enamic crowns was unsuccessful, although six rims with IPS e.max CAD had minor cracks and twelve Vita Mark II restorations showed significant fractures. Enamic responded just like a glass-ceramic with filtered lithium in a 500,000-cycle cycling fatigue experiment [56]. It is understood that Enamic is particularly suitable for prosthetic restorations on implants due to its reduced elastic modulus. However, PICN is proposed to be applied more for posterior restorations and less for restorations in the anterior block area as a result of the lower optical properties.

### Novel processing methods

CAD-CAM construction systems include: one computer system used for the design and construction of a dental restoration. Specifically, CAD technology is based on a software that defines the restoration's dimensions and shape, whereas CAM technology transfers the designed model to a technology machine of computer numeric control (CNC), in order to create the restoration. The restoration is mostly made of a dental material block (subtractive manufacturing).

Nowadays, the use of CAD-CAM systems is essential for the production of restorations without metal, applying polycrystalline ceramic infrastructures, such as yttria-stabilized tetragonal zirconia polycrystal. The use of CAD-CAM systems to produce restorations with these polycrystalline ceramics set aside their use on prosthetic restorations with high liability, as the only available manufacturing technique was slip-casting. However, slip-casting produced restorations with an increased number of cracks and defects in the microstructure [49-53].

CAD-CAM systems are used for more than 30 years in dentistry, but in this period several machines have been added, due to the continuous evolvement of these systems to produce high-quality restorations with the most effective adaptation [46,47,49,59]. Additionally, the production of restorations with materials like veneering ceramics, metal alloys, and resin composites increased due to the advancement of CAD-CAM systems.

Two types of restoration techniques are available with CAD-CAM dental systems. Specifically, the first procedure involves the treatment of prosthetic restorations, made from, whereas the second refers to a partially concentrated block, which will be then sinterized in a particular furnace. Dentistry uses both techniques, each with its own advantages and disadvantages.

The treatment of a block of concentrated material offers the restoration with better accuracy of its borders and shape, less clinical time, as the restoration does not necessitate additional heat treatment. Nevertheless, when processing high-strength material such as polycrystalline ceramics, the wear of the machining tools as well as the machining time are quite high. Additionally, the treatment of brittle materials such as ceramics can result in the formation of small cracks and surface deficiencies [47,48]. Alternatively, the use of partially sintered block for restoration techniques, has the advantage of treating the microcracks as a result of the advancement of material during the subsequent sintering process [50,52,53]. This technique is likely to have a shorter processing time for a less dense material, although it is essential to understand that the final sintering will trigger dimensional changes owing to shrinkage, which may lead to imperfections of the prosthetic restoration.

A significant disadvantage of the CAD-CAM systems already described is associated with the high consumption of material during processing, although these systems are already well established in the dental market. The remnants of these dental restorations cannot be used again, and the waste is about 90% of the prefabricated block for a standard restoration [51]. Hence, new technologies are needed to address this problem, including systems to produce restoration of dental ceramics by adding layers in place of grinding prefabricated blocks. Furthermore, there are other CAD-CAM systems, named "free form" systems, continue to be the focus of research and advance for ceramic materials with three distinct techniques: a) selective laser melting, b) direct 3D printing and c) stereolithography [48].

In detail, selective laser melting is an already recognized technique for metal alloys, although is still in progress for polycrystalline ceramics (BEGO Medifacturing® System, BEGO Medical GmbH, Bremen, Germany). Selective laser technique, entails the laser beam, which steams thin layers of a ceramic from a container covered with powder to generate a single matrix, where each layer characterizes a cross section of the CAD model. On the other hand, 3D printing is analogous to a traditional inkjet printer, ultimately creating intricate shapes. Finally, stereolithography is mostly used currently, and has already been developed adequate, to make available the creation of more complicated ceramic materials, while the other aforementioned techniques are on early stages of progress when used for dental techniques. All of these techniques, allow little or no waste material, although the rough surface and poor marginal application of the restoration account as a significant disadvantage [22].

Taking into account the aforementioned methods, direct 3D printing is the most effective technique, since the equipment is rather affordable and a dense body ready for sintering is produced. A zirconia crown with adequate mechanical properties for use in the oral cavity was manufactured in 2009, applying a modified inkjet printer [60]. This frame was made using a cartridge loaded with 27 vol% solid zirconia based ceramic content. Robocasting is a variation of direct 3D printing, has been studied and is similar to it, but the ceramic mass is deposited with the Robocasting technique with the use of extruded fibers, whereas ejected droplets are used with 3D printing for the object's production.

## Conclusion

Dental ceramics and processing methods have advanced substantially the past ten years, with new microstructures and CAD-CAM methods being the significant part of the evolvement. Moreover, the dentists tend to use of monolithic restorations and the way that clinical dentists design all-ceramic dental restorations has changed, as the more aesthetic restorations are more susceptible to fractures or detachments. Complex materials that have been processed via CAD-CAM methods are an exciting option, since they have transitional properties between polymers and ceramics and can be milled and polished easier.

## Conflicts of Interest

The authors declare no conflict of interest.

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