ZIRCONIA ESTHETIC RESTORATIONS CHARACTERISTICS. TECHNOLOGICAL ASPECTS

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ABSTRACT

Aim of the study The purpose of this work is to study the possibility of manufacturing zirconia restorations in accordance with the properties and characteristics of the materials, correlated with digital technologies. **Materials and methods** In order to reestablish the aesthetic aspect of a patient who came to our dental office, we had the option to fabricate using CAD-CAM technology, a fixed prosthetic restoration made from a zirconium oxide (ZrO_2) framework – Katana HTML Plus, covered with layered ceramic IPS e.max Ceram, consisting of 4 elements in the anterior area of the maxillary arch, for the incisors – 1.1, 1.2, 2.1, 2.2. **Results** CAD/CAM technology was used for both main steps – software CAD to analyse and elaborate the design of the Zirconia framework and then, for milling, the CAM machine milled the structure in zirconia disc, followed by sintering and each part of the restoration was covered with layers of ceramic for aesthetic aspect. **Conclusions** Evaluating and comparing the strength and translucency properties of zirconia allows the possibility to choose the most appropriate treatment option for the patient, for the anterior area of the dental arch, to restore aesthetic and functional aspects.

Key words: Zirconia properties, Zirconia framework, Aesthetic restoration

INTRODUCTION

Zirconia (ZrO2) is a white crystalline oxide of zirconium (that exists in several forms), a polycrystalline ceramic without a glassy phase. The name "zirconium" comes from the Persian word "Zar-Gun," meaning "golden-colored." Zirconia was discovered by the German chemist Martin Heinrich Klaproth in 1789 [1] and isolated in 1824 by the Swedish chemist Jöns Jacob Berzelius (Gautam et al., 2016; Nistico, 2021) [2].

Researches and studies on zirconia and its properties, the evolution and the development of materials and processing technologies have configured four main generations of zirconia and a new generation of multilayer zirconia:

1. The first generation 3Y-TZP 0.25Al2O3 - was introduced about two decades ago, where the zirconia crystals are partially stabilized with 3 mol% yttria (4.5-6 wt% Y2O3), and by the presence of alumina, it becomes opaque. At the time of introducing the zirconia in the green state, in the furnace, alumina is applied as a sintering aid to help prevent the formation of pores [3, 4].

2. Second generation 3Y-TZP 0.05 Al2O3 - introduced between 2012 and 2013, has a partially stabilized crystal structure with 3 mol% yttrium (Y2O3), but modified by providing a smaller volume of aluminum oxide (Al2O3) with smaller Al2O3 grain sizes and repositioned in the zirconia matrix. It has less

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alumina to stabilize the tetragonal phase, which causes a predisposition to degradation at low temperatures [5].

3. Third generation 5Y-TZP 0.05 Al_2O_3 - a new category of translucent zirconia materials was developed (2014 and 2015), also known as Early Zirconia, High Translucency Zirconia or Cubic Stabilized Zirconia (CSZ), to overcome the limitation of translucency. The translucency of these materials is determined by the increase in the yttrium content from 9 to 10% by weight, increasing the percentage of cubic phases at the expense of the tetragonal phase. Therefore, the substance becomes more porous, resulting in increased translucency [6]. The optical qualities of cubic zirconia materials are comparable to those of glass-ceramics, but the high translucency achieved by increasing the level of yttrium significantly reduces the intrinsic mechanical properties of the material. Therefore, cubic zirconia materials have a flexural strength of about half that of standard 3Y-TZP materials (about 600 MPa) [5, 6].

4. (4Y-TZP 0.05 Al_2O_3 fourth generation - 4Y-PSZ zirconia has translucency and mechanical properties that are intermediate between 3Y-PSZ zirconia and 5Y-PSZ zirconia, making it an attractive material for the aesthetic area [7].

5. Multilayer zirconia - the construction of zirconia blanks with multiple layers of different shades and the creation of polychromatic zirconia for full-contour zirconia restorations are much more aesthetic than conventional monochromatic zirconia, in the form of a multilayer graduated zirconia disk with two to seven or even more colour layers, simulating the appearance of layered porcelain in a full-contour monolithic restoration.

Zirconium oxide (ZrO_2) exhibits a polymorphic structure that is temperature dependent, thus zirconia can have, at ambient pressure, three crystallographic forms. The pure zirconia form is monoclinic (m) under normal conditions. At 1170°C, the substance transforms into a tetragonal crystal structure (t), and at 2370°C into a cubic crystal structure (c) and finally into a fluorite structure above 2370°C, melting at 2716°C. During heating and cooling cycles, zirconia ceramics undergo a hysteretic, martensitic t-m transformation, which is reversible at 950°C upon cooling [8, 9]. Fig. 1.

MATHERIALS AND METHODS

Main forms of zirconia restorations are either, monolithic zirconia frameworks (made entirely of zirconia, single or layered - superior resistance to fracture and wear, that make them ideal for the lateral areas of the dental arch), or Zirconia-supported ceramic frameworks (consist of a solid zirconia framework supporting a thin layer of ceramic. The zirconia support provides strength and stability, while the ceramic layer improves the aesthetic appearance, making them ideal for anterior restorations).

To reestablish the aesthetic aspect of the patient who came to our dental office, we had the option to fabricate using CAD-CAM technology, a fixed prosthetic restoration made on a zirconium oxide (ZrO_2) framework, covered with layered ceramic consisting of 4 elements in the anterior area of the maxillary arch, for the incisors – 1.1, 1.2, 2.1, 2.2.

After the clinical preparation of the abutment teeth, digital impressions were taken by intraoral scanning of the maxillary arch, mandibular arch and intermaxillary relationships. The data obtained were transmitted to the dental laboratory as digital files .STL, which were imported into a CAD software for the design of the prosthetic restoration. Based on the digital files, the technician created the virtual design in the Exocad software. After the design was completed, a 3D working model was printed in resin BlueCast Fast Dental Model, which was

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used to check the adaptation of the restoration and to control the proximal and occlusal contacts. Fig. 2.

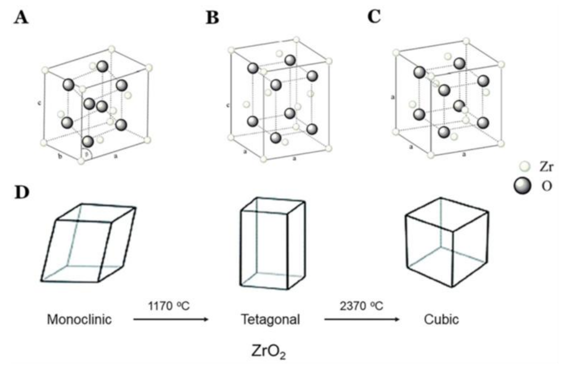


Figure 1. Crystallographic phases of zirconia and temperature hysteresis.

Figure 2. The cast (3D printing resin)

The dental technician then analyses the virtual cast, selects the type of work to be performed, namely a fixed bridge on a zirconia infrastructure, and identifies the abutment teeth involved in the restoration.

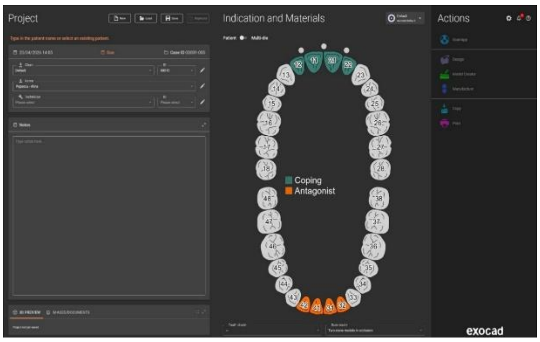


Figure 3. Selecting the job type/title

One of the most important steps is to identify and mark the contour line of the dental preparation. This represents the limit to which the prosthetic restoration will be adapted.

The contour line must be positioned with great precision to ensure: correct marginal adaptation; optimal sealing and protection of the periodontal tissues.

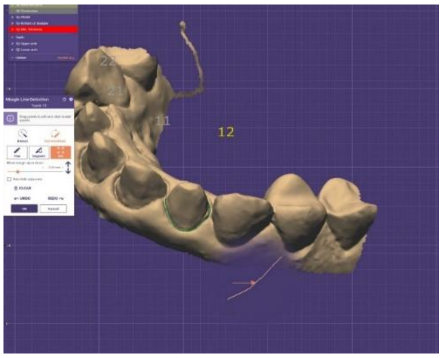
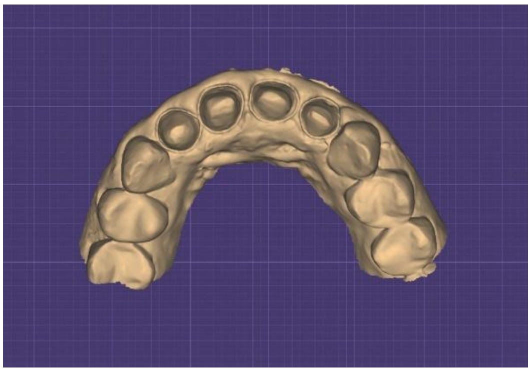


Figure 4. Delimitation of the cervical aspects of the future prosthetic work to perfect the marginal adaptation



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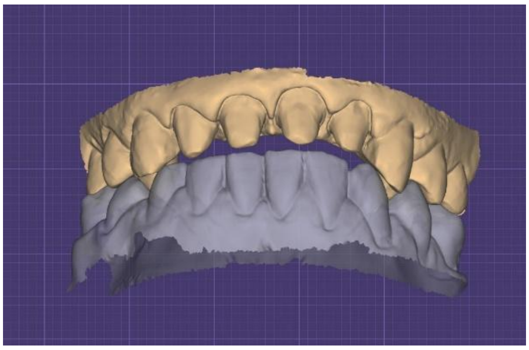


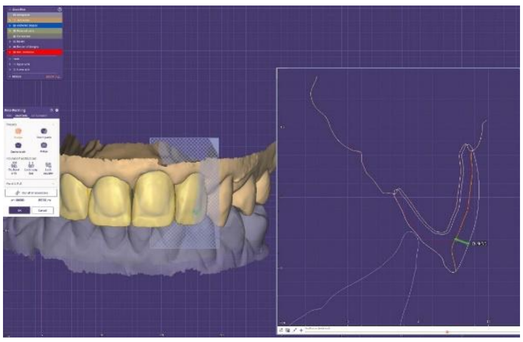
Figure 5 a and b. Zirconia infrastructure preparation

The software analyses the surfaces of the preparations and allows the choice of the common axis for insertion of the restoration.

At this stage, the following is checked: the existence of retentive areas; any undercuts; the parallelism of the abutments. If there are interferences, they are digitally signalled and can be corrected virtually.

Exocad automatically generates the shape of the restoration using the integrated dental libraries. The software then creates: the aggregation crowns; the bridge body; the initial occlusal anatomy. This is only a proposal work, that will be later personalized.

In the modelling and individualization stage of the restoration, the dental technician modifies the automatically generated shape to adapt to the particularities of the clinical case. The following elements are adjusted: embrasures; vestibular morphology; crown length and width; general aesthetic appearance.



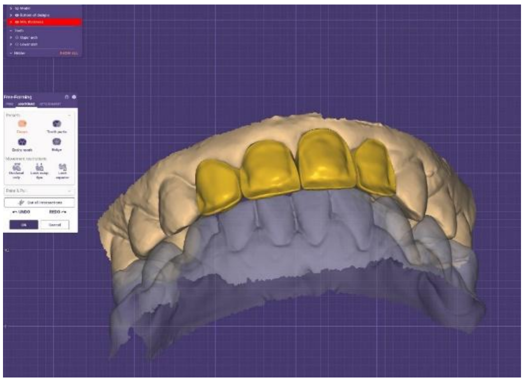


Figure 6 a and b. Zirconia infrastructure design

The digital file is transmitted to the CAM unit, where the infrastructure is milled from a pre-sintered zirconia disk Katana Zirconia HTML Plus (High Translucency Multi Layered).
The process is computer-controlled and accurately reproduces the design in Exocad.
the automatic processing of the zirconia disk.
The thickness of the zirconia in all areas of the restoration is analysed to avoid the appearance of thin areas that could compromise the functionality of the future restoration.

Figure 7. Milling the zirconia block

After milling, the framework is removed from the blank and processed when it is in the “chalk” phase, then placed in the sintering furnace. During this stage, the zirconia acquires its final mechanical properties and the strength characteristic of the material.

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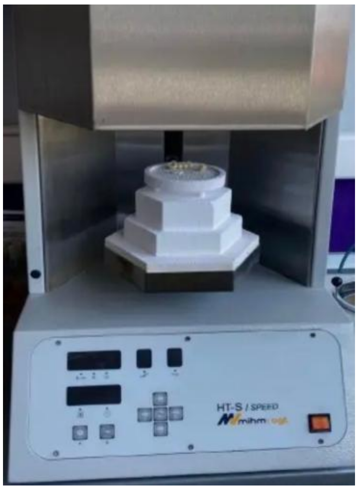

Figure 8. Sintering stage

The infrastructure is checked on the model and subsequently tried in the oral cavity to assess the marginal adaptation, insertion and occlusal relationships.

After confirmation of the adaptation, aesthetic individualization is achieved by layering the veneering ceramic, followed by successive sintering and glazing. The specific zirconia adhesive is applied to the infrastructure. Fig. 9.

Figure 9. Zir Liner

By layering the ceramic material, IPS e.max Ceram, Ivoclar, its shape is built:

a. First, the dentin layer (body) is applied which: provides volume and base colour, is applied in several layers and is compacted slightly to reduce porosities

b. The enamel layer - superficial translucent layer, reproduces the natural optical effect

Figure 10. Ceramic layering

Successive sintering must be done after each layer, in a ceramic specific device controlling the shrinkage of the ceramic. The glaze is applied to give shine and protection to the ceramic layers, and final mechanical polishing is very important. Colours are needed to create the makeup of the work, and to complete the work, there is necessary slow cooling to avoid thermal shocks.

RESULTS AND DISCUSSIONS

CAD/CAM systems have quickly been adopted by many dental laboratories, as they greatly increase work efficiency, eliminating a multitude of intermediate steps, generating additional costs and possible errors. Initially used to produce metal ceramic crowns, nowadays the subtractive method can realize most of the common materials in dentistry (ceramic, zirconia, plastic, resins, presintered zirconia, sintered zirconia, cobalt-chromium, titanium, and alumina) [10].

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CAD-CAM technology produces dental zirconia restorations using two different techniques: “soft machining” of pre-sintered blanks or “hard machining” of fully sintered blanks.[11]

Soft machining: The soft machining process, the most widely used manufacturing system for 3Y-TZP, is based on milling pre-sintered blanks which are then fully sintered in a final step. The crown/fixed bridge restoration wax models are scanned and then a virtual, enlarged structure is designed using special software - CAD. The CAM milling procedure processes a structure with precisely controlled, enlarged dimensions from the zirconia blank. The sintering of the structures takes place at an elevated temperature, during which the structure returns to its normal dimensions as it undergoes linear volume contraction.

Hard machining: Fully sintered 3Y-TZP blocks are used, which are prepared by pre-sintering at temperatures below 1500ºC to achieve a density of at least 95% of the theoretical density. By “hot isostatic pressing”, the blocks are machined at high temperatures of 1400-1500ºC, under high pressure in an inert gas atmosphere to produce very hard, dense (99% of the theoretical density) and homogeneous blocks of fully sintered zirconia. These blocks are machined using a specially designed milling system to shape the structure to the correct final shape and size. Due to the high hardness and low machinability of fully sintered Y-TZP, the milling system must be particularly robust. [11,12]

Zirconia has mechanical properties superior to those of other ceramics but similar to those of stainless steel. The fracture strength of zirconia is between 6 and 10 MPa m1/2, almost twice that of aluminum oxide ceramics, due to transformative hardening, which gives zirconia unique mechanical properties - flexural strength of 900–1200 MPa and compressive strength of 2000 MPa.

Full-contour zirconia restorations have superior aesthetics to monochromatic restorations and can be obtained immediately after sintering [13]. Multilayer technology uses only pigmentation to simulate the shade gradient of natural teeth, maintaining the same percentage of yttrium in the zirconia blank, resulting in a colour gradient without differences in flexural intensity between the enamel and dentin layers [14, 15]. Zhang investigated the remaining tetragonal phase and its role in 4Y- and 5Y-PSZ (mol% yttria partially stabilized zirconia). Both materials had similar basic properties.

However, 5Y-PSZ (mol% yttria partially stabilized zirconia) had a variation on the microstructure. When 5Y-PSZ was processed from an yttria co-precipitated powder, in which the 5 mol% Y2O3 stabilizer was already homogeneously distributed inside, the zirconia starting powder had a significantly higher translucency, biaxial strength, and aging stability, demonstrating that the cubic content and the microstructure of the remaining tetragonal grains had considerable influence on the properties of 4Y- and 5Y-PSZ (mol% yttria partially stabilized zirconia) [16, 17-20].

Studies in the specialized literature have highlighted and demonstrated the difference in properties between third and fourth generation zirconia materials - the third generation presents superior optical properties to fourth generation materials, but by compensation, fourth generation zirconia presents better resistance.

The important advantage of the zirconia structure is minimal tooth preparation, less enamel reduction and preservation of the natural tooth structures, maintaining the integrity and strength of the teeth. [21]

Zirconium-based prosthetic restorations represent a choice, due to the emphasis on aesthetics and their realization through modern technologies, thus being much more

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accurate. [22, 23]

Evaluating the characteristics of zirconia restorations regarding strength and translucency allows doctors and technicians to develop optimal aesthetic works by applying digital technologies with state-of-the-art materials - monolithic structures or on zirconia structures. Computer-aided design and manufacturing technology ensures precise fit and aesthetics, and advancements in zirconia materials have led to the development of high-quality, high-translucency zirconia options.

Conclusions

All-zirconia prosthetic constructions are some of the most recommended treatment options, as they are closest to the structure and properties of natural teeth, and will restore the integrity and functionality of the dental arch, and the aesthetic appearance, which is essential for the patient.

Zirconia prosthetic restorations require minimal preparation of the dental tissues, which respects the tendency towards minimally invasive dentistry.

Digital technology perfects the accuracy and precision of structural zirconia creations and allows for the correct size of restorations and close morphological modelling of natural teeth, with excellent marginal integrity.

Evaluating and comparing the strength and translucency properties of zirconia allows the possibility to choose the most appropriate treatment option for the patient, for the anterior or posterior area of the dental arch, to restore aesthetic and functional aspects.

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