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CASE REPORT

# Principles of design and manufacturing of zirconium dioxide infrastructures for fixed prosthetic restoration

**Iuliana Babiuc, Adrian Istoc, Viorel Stefan Perieanu, Mihai Burlibasa, Daniela Aurelia Pirvu, Mircea Popescu, Bogdan Alexandru Dimitriu**

"Carol Davila" University of Medicine and Pharmacy, Bucharest, Romania

## ABSTRACT

In dental practice, CAD-CAM digital technologies are used for zirconium dioxide processing. Thus, in recent years, zirconium oxide has determined an extraordinary development of digital CAD-CAM technologies, a fact that determined the presentation in this material of several extremely interesting aspects, regarding the technological process of designing and manufacturing structures made of this material.

**KEYWORDS:** zirconium dioxide, CAD-CAM, infrastructures, coping.

## INTRODUCTION

Zirconium was discovered by the German chemist Martin Heinrich Klaproth in 1789, but this "miracle material" was rediscovered and researched in much more detail only in the last 3 decades. The most well-known formula in current practice is zirconium dioxide, also known as zirconia. Chemically, zirconium dioxide has the chemical formula $ZrO_2$ and is composed of the rare element Zirconium (Zr) and Oxygen. The main element of this compound is Zirconium, which is located in Mendeleev's periodic table in group 4, period 5, block d, which places it in the group of metals. It has atomic number 40 and a hexagonal crystal structure of small dimensions (< 0.4μm)[1-3].

Zirconium dioxide is used in dental practice to replace metal structures (rods, dental implants, resistance infrastructures of prosthetic restorations, etc.), the biocompatibility and resistance of this material making it ideal for its use in other biomedical fields as well, such as: ENT (hearing prostheses), orthopedics (hip prostheses and making artificial limbs), etc.[1-3].

## GENERAL DATA

In general, zirconium dioxide is found in polymorphic forms: monoclinic, tetragonal, cubic. The monoclinic form is thermodynamically stable from room temperature up to 1170°C. The transformation from the monoclinic phase to the tetragonal phase takes place in the temperature range of 1100°C - 1200°C and is stable up to the temperature of 2370°C, and the cubic form appears from the temperature of 2370°C to the temperature of 2689°C. To prevent the appearance of microcracks during cooling, zirconium dioxide is stabilized with oxides, such as those of yttrium, calcium or magnesium[1-3].

In dental practice, CAD-CAM digital technologies are used for zirconium dioxide processing.

Thus, zirconium dioxide (in the specialized literature also known as zirconia) has determined in recent years an amazing development of CAD-CAM digital technologies, a fact that determined the presentation of several extremely important aspects in this interesting material, regarding the technological process of designing and manufacturing structures made of zirconia.

**Corresponding author:** Viorel Stefan Perieanu, MD, PhD, Lecturer, "Carol Davila" University of Medicine and Pharmacy, Bucharest, Romania
**Address:** 4 Eforie, District 5, Bucharest
**ORCID:** https://orcid.org/0000-0002-8411-3875
**e-mail:** viorelperieanu@yahoo.com
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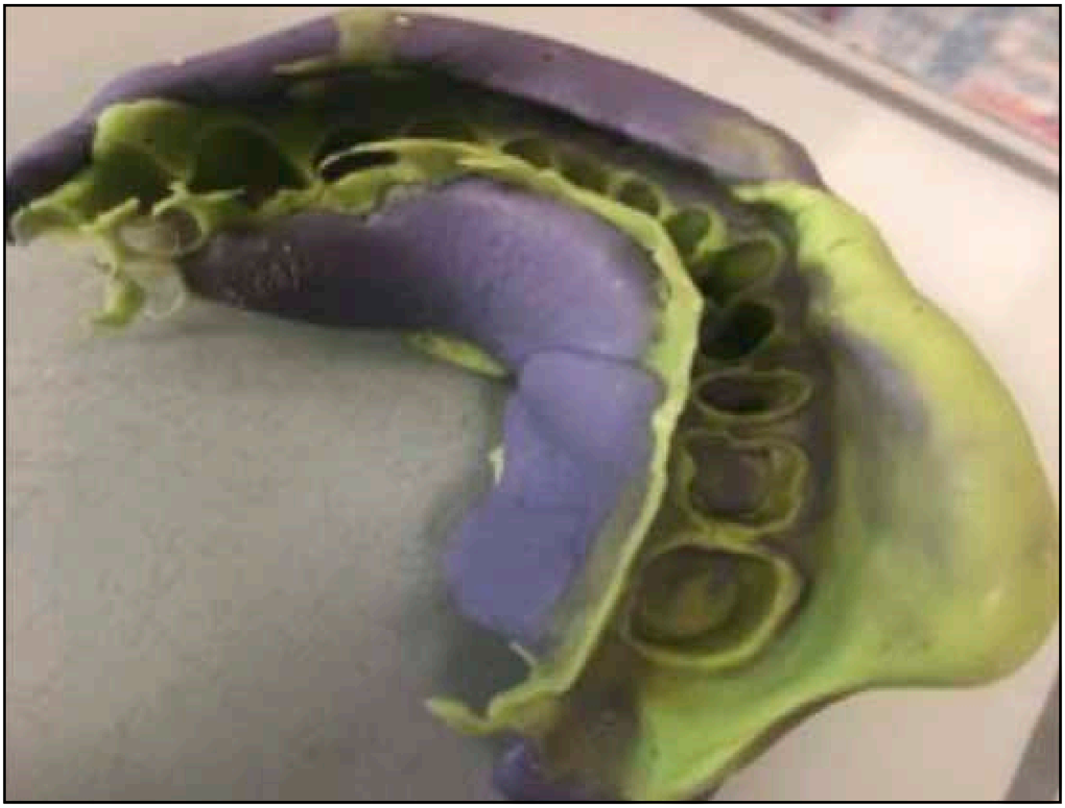

**Figure 1.** Mandibular functional impression, antagonists' impression and the occlusal relationship.

## CASE PRESENTATION

This case describes the fabrication of fixed prosthetic restorations from zirconium dioxide using CAD-CAM technology. In fact, it is about the fabrication of 3 zirconium dioxide copings for completely aesthetic single tooth prosthetic restorations, to be applied on 3 teeth with coronal destruction located on the lower arch: second premolar, first molar and second molar (3.5, 3.6, 3.7).

In the first stage, the dentist prepared dental abutments for teeth 3.5, 3.6 and 3.7 through endodontic treatments and the appropriate grinding. The impression of the two dental arches was made using silicone addition materials in double consistency: putty and light

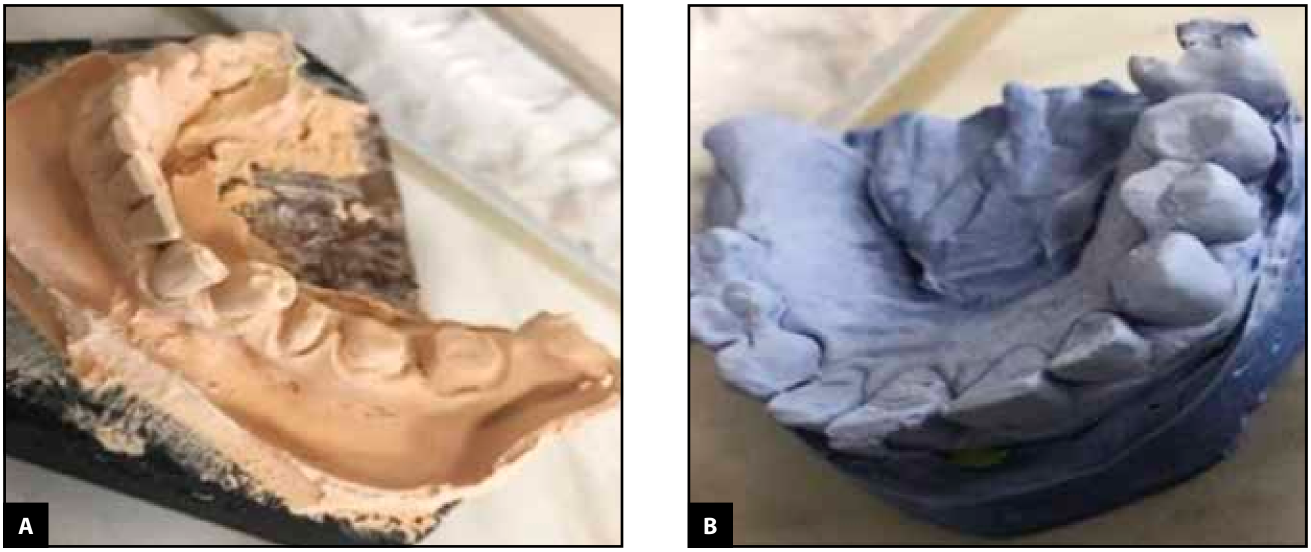

**Figure 2.** Mandibular working model **(A)** and maxillary model **(B)**.

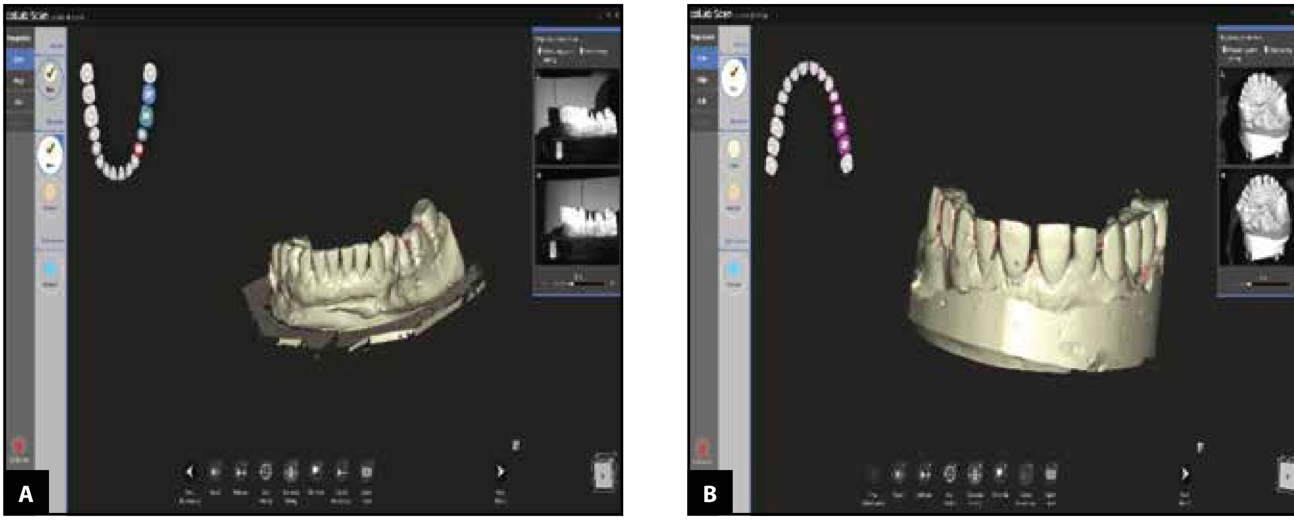


**Figure 3.** The virtual models: mandibular **(A)** and maxillary **(B)**.

body (Figure 1). The occlusal relationship was also recorded using the same impression. Afterwards, the impression was washed under tap water for 20 seconds, after which it was decontaminated by immersion in chemical substances with antimicrobial potential, following the instructions recommended by the manufacturers.

The functional mandibular model was cast using the Accu-Trac system, with a type IV dental stone. The antagonist model was cast by the classical method, with the help of the vibrating table, using a type III die stone. Later, based on the occlusal relationship previously determined by the dentist, the 2 models (mandibular functional model and maxillary antagonist model) were mounted in a simulator (Figure 2).

The dental technician will scan the 2 models (mandibular and maxillary) (Figure 3), the dental prosthetic abutments (Figure 4), as well as the occlusal relationship,

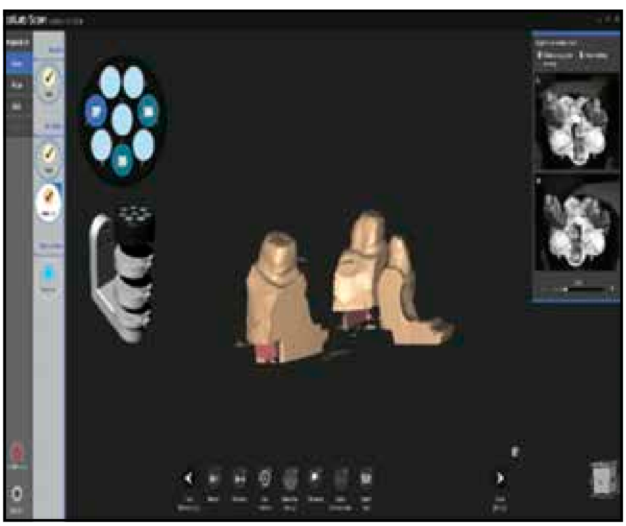

**Figure 4.** The 3D image of prosthetic abutments.

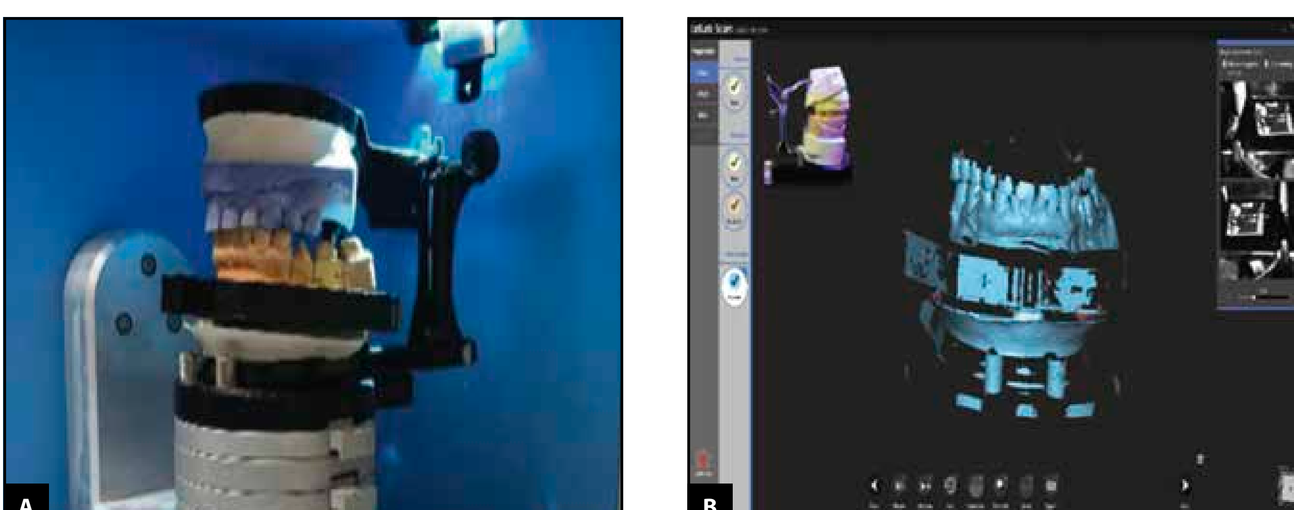


**Figure 5.** After mounting the models in an occlusal simulator, the hole system is placed on the support of the scanner **(A)**. The scanner converts the physical image in a 3D image of maxillary and mandibular models in occlusion **(B)**.

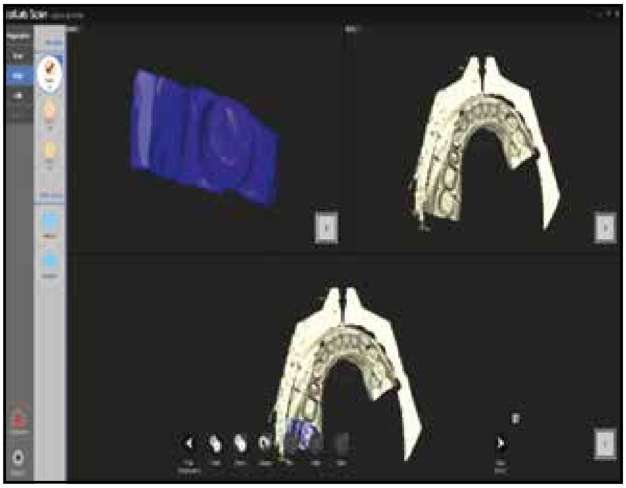

**Figure 6.** The appearance of the models after overlapping all the scanned elements.

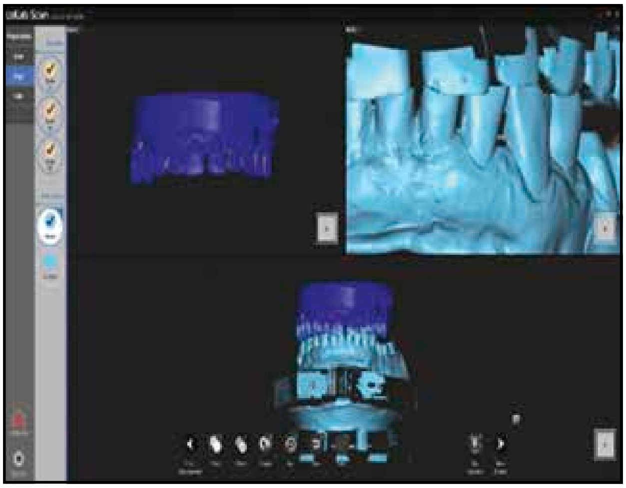

**Figure 7.** Superposition of the two models over the scanned occlusal relationship.

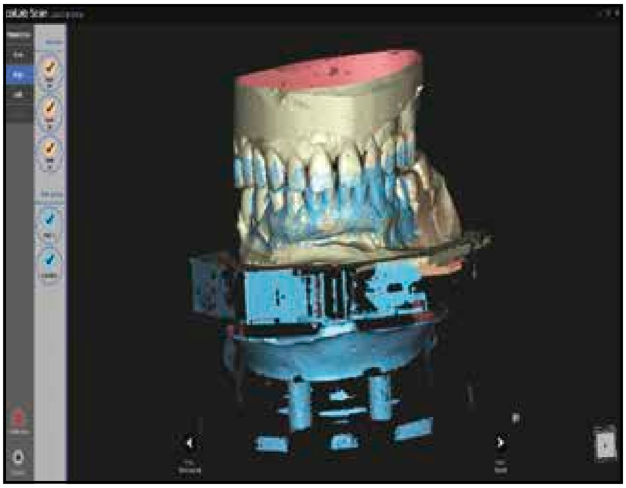

**Figure 8.** The virtual image of maxillary and mandibular models in occlusion.

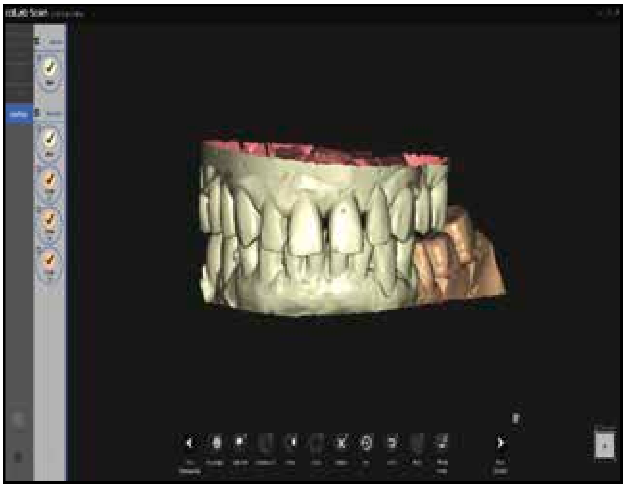

**Figure 9.** The final appearance of the virtual models in occlusion, after trimming.

**Figure 10.** The design of zirconia copings.

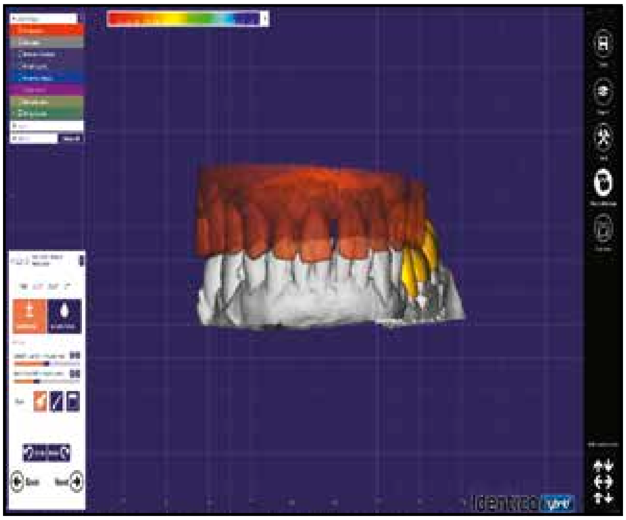

**Figure 11.** Checking the vertical space of designed copings by positioning the models in occlusion.

**Figure 12.** Computerized milling of copings in a zirconium dioxide disc.

using a laboratory scanner (Figure 5).

After the completion of the scanning operations, the dental technician will make the overlay of all scanned elements: dental abutments, maxillary and mandibular models (Figures 5 – 9).

In the next stage, the dental technician will draw the cervical on teeth 3.5, 3.6 and 3.7 to establish the limit of zirconia coping (Figure 10), the support structure for prosthetic restorations. Later, he will also establish the insertion axes for zirconia copings, as well as setting other specific parameters (space for luting material, friction etc.) (Figure 11).

The design of the copings will be made on the virtual model, and later, the virtual image will be transformed in zirconium dioxide.

After completing the design of the copings, the virtual image will be sent in a STL format to a computerized milling centre, where these copings will be obtained by milling from a prefabricated zirconium dioxide disc (Figure 12).

At the end of the computerized milling process, the copings are removed from the zirconium dioxide disc with the help of a turbine, and subsequently are processed in the pre-sintered phase, since this is much easier when the prosthetic structures are in the monoclinic form. Then follows the sintering process in a special furnace, respecting the time intervals recommended by the manufacturer.

After the copings have been removed from the sintering device and cooled, their fit on the dental prosthetic abutments is checked. If these zirconium dioxide infrastructures require small adjustments, they will be made with special burs. But before these zirconium dioxide copings are sent to the dental office for try-in, they will undergo cleaning, decontamination and sandblasting processes by the dental technician (Figure 13).

The try-in stage is the last clinical stage before applying the ceramic masses on the zirconia copings in order to complete the physiognomic aspect of the prosthetic restorations.

## DISCUSSIONS

Zirconia is used as a material for obtaining fixed prosthetic restorations both for its aesthetic advantages and for its physical properties[4-6].

The aesthetic advantages are based on the appearance of zirconium dioxide (zirconia), with a matte white colour that can be produced in several shades according to the VITA shade guides[7,8]. It eliminates the problem that most alloys used in porcelain fused to metal technology present, namely masking the ash-gray colour that the alloy has, a completely unaesthetic colour[5,9]. At the same time, this prevents the problem that appears over time, through the retraction of the gum and the exposure of the edge of the prosthetic work with a slightly dark blackish appearance given by the dental alloy used[10-12].

The use of zirconia in dental practice is possible due to the implementation and improvement of CAD/CAM technology[12]. The chemical stability of zirconium cannot be obtained by the usual procedures in the dental laboratory; therefore, it is necessary to manufacture it in a pre-sintered form industrially and later finalize it in the laboratory[13]. Milling in zirconia as well as sintering of milled parts are procedures that can be obtained individually in dental laboratories through a relatively simple technology and with affordable equipment.

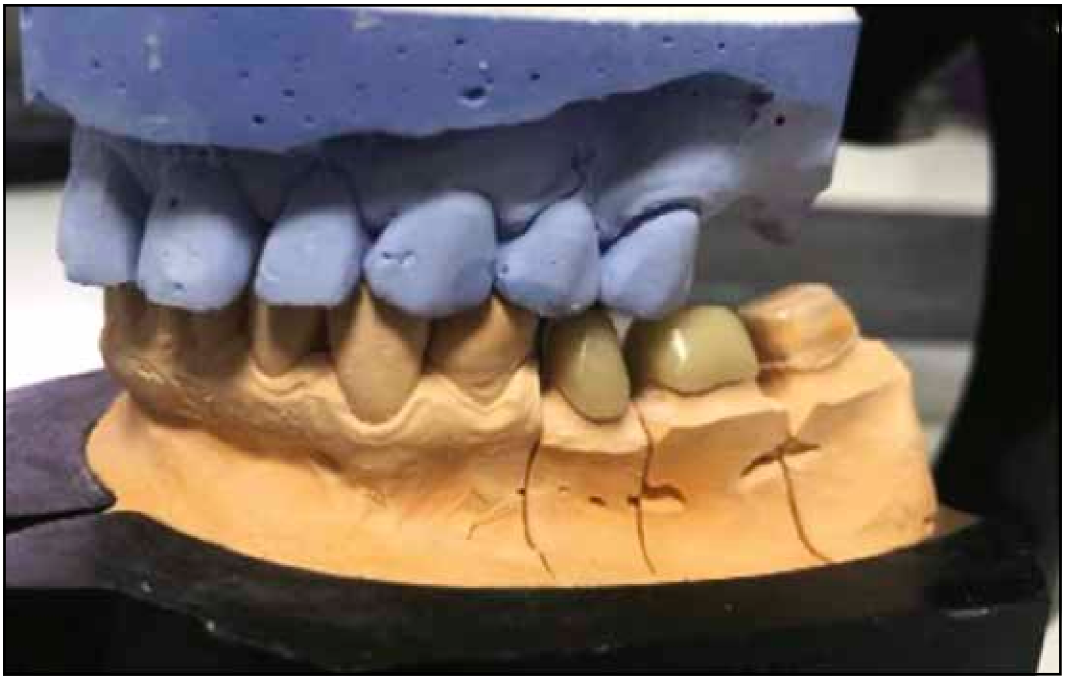

**Figure 13.** Zirconia copings on the functional model, before being sent to the dental office for try-in.

The results obtained are equivalent or even superior to prosthetic restorations obtained through classical procedures (from dental alloys)[14-16]. Abduo et al., in a study that focused on marginally accuracy, concluded that zirconia restorations made by digital technological flow have an increased accuracy compared to those made by hybrid flow[17]. This shows that the equipment used at the moment has reached a very good calibration level, which can ensure the obtaining of high-quality aesthetic and functional prosthetic restorations.

To improve the aesthetic appearance, the veneering or complete covering of the zirconia copings with ceramic materials are the most frequently used methods[18-20]. Thus, the matte appearance of zirconia is transformed into a natural, lively appearance by covering with ceramic masses in a combination of different shades, to obtain a personalized result for each individual patient[21-23].

## CONCLUSIONS

After going through this material, several aspects can be concluded, as follows:

CAD-CAM technology is considered a future-oriented technique, in continuous evolution, important both for the dental technician and the dentist.

In recent years, aesthetic prosthetic restorations are increasingly requested by patients, and the CAD-CAM technique ensures a fast, precise and predictable workflow.

Marginal fitting is one of the key elements of the success of prosthetic restorations. If the dental practitioner follows step-by-step the use of digital technologies with the help of CAD-CAM systems, the margins of prosthetic restorations can be adapted within the limits of 50 μm, these techniques being thus far superior to conventional manufacturing techniques of various prosthetic parts.

Most of the patients declared themselves very satisfied with the functionality offered by the prosthetic restorations made using CAD-CAM technology, these benefiting from a digitized modelling.

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**Authors' information:**

Iuliana Babiuc, MD, PhD, Lecturer, "Carol Davila" University of Medicine and Pharmacy, Bucharest, Romania. E-mail: dr.iuliana.babiuc@gmail.com.

Adrian Istoc, Dental Technician, "Carol Davila" University of Medicine and Pharmacy, Bucharest, Romania. E-mail: trili_poli@yahoo.com.

Viorel Stefan Perieanu, MD, PhD, Lecturer, "Carol Davila" University of Medicine and Pharmacy, Bucharest, Romania. E-mail: viorelperieanu@yahoo.com. ORCID: https://orcid.org/0000-0002-8411-3875.

Mihai Burlibasa, MD, PhD, Professor, "Carol Davila" University of Medicine and Pharmacy, Bucharest, Romania. E-mail: mburlibasa@gmail.com. ORCID: https://orcid.org/0000-0001-8672-5579.

Daniela Aurelia Pirvu, MD, PhD, Assistant Professor, “Carol Davila” University of Medicine and Pharmacy, Bucharest, Romania. E-mail: danielaa_pirvu@yahoo.com.

Mircea Popescu, PhD Student, “Carol Davila” University of Medicine and Pharmacy, Bucharest, Romania. E-mail: mircea.popescu@drd.umfcd.ro.

Bogdan Alexandru Dimitriu, MD, PhD, Professor, “Carol Davila” University of Medicine and Pharmacy, Bucharest, Romania. E-mail: bogdim@gmail.com. ORCID: https://orcid.org/0000-0003-3831-8543.

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