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Study on the Use of Digital Technology in the Realization of Prosthetic Restorations

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Abstract: *The use of digital technology has become a useful and also a preferred process in the realization of dental prosthetic restorations, because through it, superior quality dental prostheses are obtained in terms of aesthetics, accuracy of execution and durability. CAD/CAM technology is changing all aspects of dentistry, making dental restoration processes much easier and more efficient for dentists, patients and dental technicians. The materials that can be used to manufacture dental restorations designed using Exocad software depend on the type of restoration (crowns, bridges, veneers, etc.) and the manufacturing method (milling with a 3-, 4-, or 5-axis CAM device); available materials include: PMMA (polymethyl methacrylate) and zirconia. Using digital technology, in this study we performed 6 fixed prosthetic restorations, of which 5 unidental restorations (5 dental crowns) and 1 pluridental restoration (a 4-element dental bridge); of the 6 prosthetic restorations, 3 restorations will be fixed by cementing on dental abutments, and 3 restorations will be fixed by screwing on implants. Digital technology allows the use of higher quality materials, resulting in more resistant and more aesthetic prosthetic restorations; helps reduce the occurrence of errors; obtaining a better marginal adaptation and a perfect adaptation to the anatomical structures of the patient`s teeth.*

Keywords*: digital technology, Exocad, prosthetic restorations*

1. Introduction

1.1. Digital technology in dentistry: generalities, advantages and limitations

Digital technology has permeated all fields of activity, including the medical field, as reliable prostheses can be made more easily than through the traditional method, prostheses being devices intended to replace an organ in its entirety or a segment of the human body that has been damaged, destroyed or which was absent from birth (congenital), to take over its functionality [1].

The use of digital technology has become a useful and also a preferred process in the realization of dental prosthetic restorations, because through it, superior quality dental prostheses are obtained in terms of aesthetics, accuracy of execution and durability. Using this technology, the treatment time is shortened, the number of workflow steps is reduced, the communication between dentist - patient - dental technician is improved.

CAD/CAM technology is changing all apects of dentistry, makind dental restoration processes much easier and more efficient for dentists, patients and dental technicians, in order to achieve aesthetic and durable prostheses [2]. “Dental medicine addresses an area with wide aesthetic implications, dental restorations; regardless of the area in which they are found, they must comply with the perfect integration in the entire dento-maxillary apparatus in terms of functionality” [3].

In dentistry, CAD/CAM systems are used for indirect dental restorations through *Computer Aided Design* - CAD and *Computer Aided Manufacturing* - CAM [4, 5].

Several CAD softwares are known; among these is the Exocad software for dental laboratories, which was created in Germany by the Exocad Company, which was founded in 2010 as a company of the Fraunhofer Organization [6].

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In the realization of fixed unidental and pluridental prostheses, it is important to take care to obtain an occlusal relief according to the antagonists, so that there are no prematurities in the static occlusion, respectively interferences in the mandibular dynamics [7, 8].

To prevent the premature contacts and the interferences, when digitally designing prosthetic restorations, it is necessary to use a virtual articulator [9], which is also available in the Exocad software. In terms of therapeutic, one of the criteria that ensures success in prosthetic rehabilitation treatments is obtaining correct dental occlusal contacts.

Among *the advantages* of using CAD/CAM technology in the dental field are:

-making the activity more efficient by shortening the working time and reducing the physical effort;

-improving the quality of the final dental restoration through the immediate control provided by the software;

-by replacing the conventional impression with the intraoral impression, the discomfort for the patient is reduced;

-the introduction of new dental materials, harder, denser and of a higher aesthetic level;

-reducing the consumption of materials;

-increasing productivity;

-the latest innovation in CAD/CAM systems allow visualisation and development of the occlusion in dynamic state [4, 5, 10].

Among *the limits* of the use of CAD/CAM technology in the dental field are the high costs on the several levels: the equipment, the periodic updates (these systems are in permanent development), the training of specialists (the cost of the training programs and the physical time in which the trained person does not produce profit), the cost of purchasing restoration systems and materials (the cost may be higher when the system or material cannot be purchased from its own country) [4, 10].

1.2. Properties of some dental materials used for prosthetic restorations designed using Exocad software

In recent times, the realization of dental prosthetic restorations with high aesthetics represents a real challenge for specialists in prosthodontics. New technologies and new materials contribute to obtaining fixed prosthetic restorations without metal support, thus contributing to obtaining dental aesthetics. Patients, increasingly better informed, request dental treatments with materials that give an appearance as close as possible to natural teeth [11].

The materials that can be used to manufacture dental restorations designed using Exocad software depend on the type of restoration (crowns, bridges, veneers, etc.) and the manufacturing method (milling with a 3-, 4-, or 5-axis CAM device). Available materials include: PMMA (polymethyl methacrylate) and zirconia [12].

Polymethyl methacrylate (PMMA) is a thermoplastic material, stable in the envirnment, with the chemical formula $(C_5O_2H_8)n$. PMMA has a high chemical inertia, being very stable in the mouth [13]. PMMA is the most popular material used for manufacturing dental restorations using digital technology, especially for provisional restorations, its advantages include: good aesthetic properties, low water absorption and solubility, good compatibility with human tissues, good marginal adaptation and with good transverse strength, resulting in a durable restoration, but limited by its resistance to abrasion, which is low. Because the traditional PMMA resin has low mechanical properties, improved polymers and technologies have emerged, obtaining finished materials with better physical and chemical properties than conventional ones, thus showing reduced porosity, color stability, increased strength, better adaptation, but the resistance at fracturing remains low. Nowadays, innovative technologies and new materials, such as high-density polymers, offer the possibility of obtaining long-term intermediate restorations in the field of implantology through progressive bone loading. Many manufacturers offer PMMA-based high-density polymers for CAD/CAM manufacturing, industrially manufactured resin blocks or discs with superior mechanical properties and with better optical properties than conventional ones. Because longer-term temporary prosthetic restorations must provide extensive functional loading,

the material used for the provisional restoration must have good mechanical properties, color stability, and act as a guide for soft tissue healing. In a study, it was found that using high-density polymers in the long-term temporary restoration by CAD/CAM technology, there were no fractures of the prosthetic restoration or bleeding of the soft tissues around the dental implants; anatomical configuration, physiognomic appearance, marginal adaptation, as well as surface texture being well preserved for 6 months. Thus, it is confirmed that the use of high-density polymer materials through CAD/CAM technology for the realization of provisional prosthetic restorations is a highly predictable technique [14, 15].

Another study concluded that the use of PMMA resin enhanced with graphene oxide (GO) is a suitable option for prosthetic rehabilitation, even for the definitive prosthesis. The final prosthetic restoration designed using Exocad software was subsequently made of PMMA resin reinforced with graphene oxide, by milling. Follow-up evaluations at 1 week and then 1, 3, and 8 months after placement of the definitive prosthetic restoration reported no mechanical, aesthetic, or biological complications, and the soft tissues showed good health and stability [16].

Zirconium oxide (ZrO_2), also called *zirconia*, is a ceramic oxide material with multiple uses in dentistry: crowns, bridges, abutments, implants. This is due to some special properties that this material has: it is a chemically inert material, being very well tolerated by the body; it has a very good biocompatibility with the human body; it doesn`t trigger allergies, it doesn`t corrode; it is a very good thermal insulator and thus thermal variations do not get transmitted to the dental pulp; it has special mechanical properties (hardness, resistance to abrasion and bending), thus being able to replace classic dental alloys; it offers a high degree of transparency to the dental restorations made of this material, obtaining restorations that closely resemble natural teeth, the absence of the metal support causing the light to be reflected by a zirconia crown just like a natural tooth, thus zirconia has the best aesthetic effect, an important fact if the new crowns are located in the frontal region and especially if they are adjacent to the natural teeth [17].

Zirconia abutments were introduced as an alternative to metal abutments, due to the biocompatibility, color and mechanical properties of zirconia. Bacterial adhesion to peri-implant soft tissue has been reported to be low, which is important in the maintenance of zirconia restorations [18]; there is also a minimal risk of corrosion between the restorative components on implant and the dental implant [19]. Zirconia abutments have some advantages compared to titanium abutments: they offer improved aesthetics, natural translucency, allow the attachment of epithelial cells [19, 20]. Two-piece (hybrid) zirconia abutments have been found to have greater resistance than single-piece abutments; therefore, hybrid abutments can be used in high-load areas such as the premolar and molar regions [21].

Monolithic zirconia is a material that can be used through CAD/CAM technology for the fabrication of provisional restorations. Thus, an article presented the case of a temporary aesthetic restoration (a Maryland bridge) supported on an implant, to replace a central incisor, the restoration being made of monolithic zirconia (a second-generation multicolored zirconia material), but it could also be made of PMMA [22].

In digital implantology, artificial abutments and final prosthetic restorations (such as definitive prosthetic crowns) can be manufactured from zirconia; intermediate prostheses (temporary prosthetic crowns) can be manufactured from PMMA. In a study, it was found that the use of digital technology (for the design part using Exocad software) was preferred by patients over the traditional technology for making the restorations (the digital workflow involved individual zirconia abutment on a titanium base, the provisional PMMA crown, the final monolithic zirconia crown; and traditionally, the titanium abutment, the temporary acrylic resin crown, and the final metal-ceramic crown). Digital procedures had a lower cost than conventional ones, and the working time was reduced when digital technology was used, both in the case of making provisional and final restorations [23]. In another study in which the same materials were used for restorations on implants (zirconia on a titanium base was used for the individualized prosthetic abutment, PMMA was used for the provisional crown, and monolithic zirconia was used for the final crown; the design being made with Exocad software) it was found that the marginal

adaptation, the quality of the interproximal and occlusal contacts and the aesthetic integration were very good; the success rate of monolithic zirconia crowns and three-year cumulative survival were 91.3% and 99.0%, respectively [24].

2. Materials and methods

We performed a study on 4 patients, between March and May 2021, the laboratory phases being carried out at the *Arno Milling Center* dental laboratory in Bucharest.

Patients selection. We selected 4 patients, who required fixed unidental and/or pluridental prosthetic restorations, made through an integral digital workflow (using intraoral scans, the dental restorations were made through CAD and later CAM processes).

The patients inclusion criteria were: therapeutic indications of fixed unidental and/or pluridental prosthetic restorations on dental abutments or on implants, the antagonist teeth being natural or with fixed prosthetic restorations and there being sufficient, simultaneous and stable occlusal contacts (so that other steps are not required, such as using record bases and wax rims to register the intermaxillary relationships, which, in addition to requiring some extra steps, would have led us to go out of the digital sphere and use traditional technology as well).

The patients exclusion criteria were: patients who were going to be treated using a digital process, but starting with the traditional method (using the classic impression, the physical model is made, then it is to be scanned and after that, the digital realization of the prosthetic restorations is to be carried out); patients with indications for prosthetic restorations performed digitally, from zirconia, but for which classical steps are to be used afterwards (ceramic covering of zirconia copings); patients who do not have antagonist teeth.

Data for patients selection were collected from the computer system of the dental laboratory were we performed the laboratory phases.

The workflow. All impressions were taken by intraoral scanning using the *Medit i500* scanner.

To create the design of dental restorations, the data obtained by scanning were transmitted in STL format to *Exocad* software (Exocad DentalCAD, version 2.4 Plovdiv, Exocad Gmbh, Germany, 2020).

After virtual modeling, the prosthetic restorations were fabricated using the *Coritec 350i* milling machine (manufacturer: *Imes-Icore Gmbh*); as dental materials for restorations were used: zirconia, multilayer zirconia and PMMA. For zirconia restorations, respectively multilayer zirconia restorations, after milling, the sintering stage followed, using the *HTS-2/M/ZIRKON-120* sintering furnace (manufacturer: *Mihm Vogt*). The physical models were made of resin, by 3D printing, using the *Phrozen Shuffle 4k* 3D printer.

The entire digital process for the realization of fixed prosthetic restorations in the dental laboratory included two stages:

- CAD realization of the prosthetic restorations: the virtual design, using the impressions from intraoral scanning;
- CAM realization of the prosthetic restorations: the manufacturing of the dental restorations by milling.

3. Results and discussions

We performed 6 fixed prosthetic restorations, for a number of 4 patients.

Depending on the materials used, we distinguish: 2 restorations made of PMMA, 3 restorations made of multilayer zirconia and 1 restoration made of zirconia.

Depending on the type of restoration, we made 5 crowns and 1 bridge (Figure 1, Table 1).

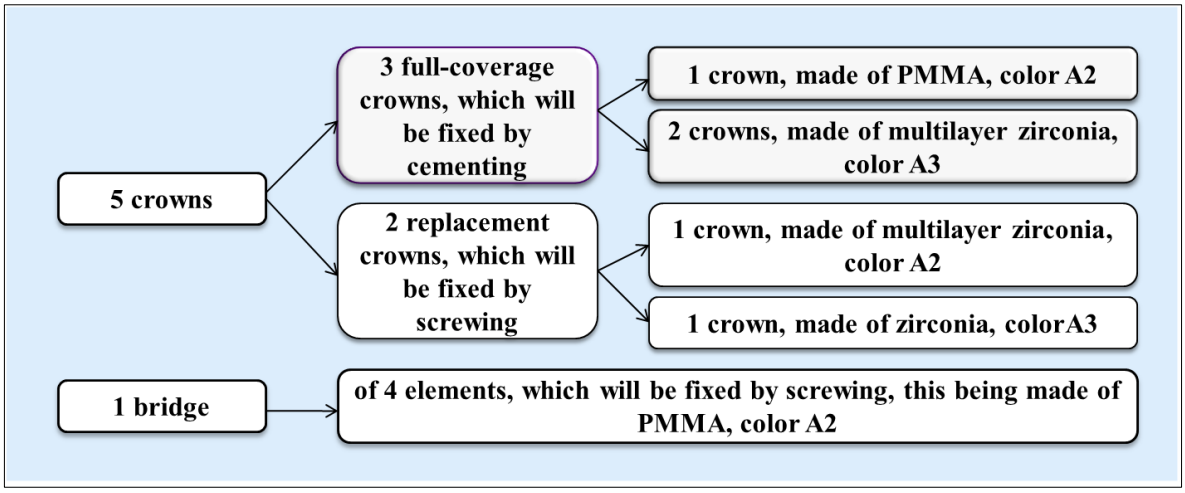


Figure 1. Types of prosthetic restorations

Table 1. Number of prosthetic restorations

Material		PMMA		Multilayer zirconia		Zirconia		Total
Color		A2	A3	A2	A3	A2	A3	
Restoration type	Crown	1		1	2		1	5
	Bridge	1						1
Total		2		3		1		6

As can be seen in Table 2, we made a total of 9 prosthetic elements, as follows:

- for case 1, it was necessary to make a number of 5 prosthetic elements (1 crown and 4-element dental bridge);

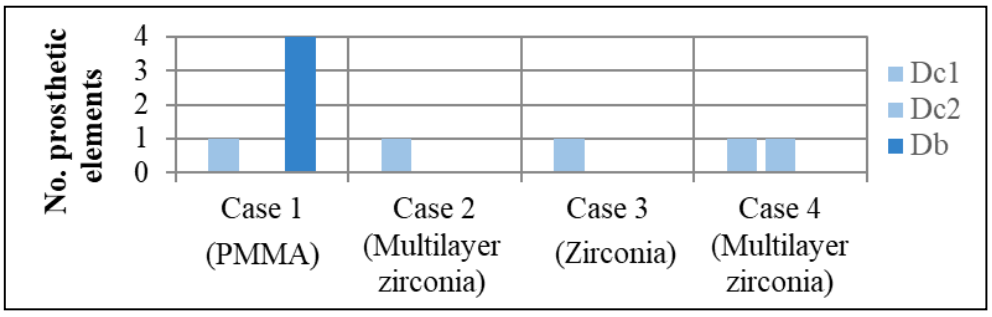
-for case 2, we made 1 prosthetic element (1 crown);

-for case 3, we made 1 prosthetic element (1 crown);

-for case 4, we made 2 prosthetic elements (2 crowns), all of which are illustrated in Figure 2.

Table 2. Number of prosthetic elements for each case

Case	Prosthetic elements			Total (elements)
	Dental crown (Dc)		Dental bridge (Db)	
	Dc_1	Dc_2	Db	
Case 1	1		4	5
Case 2	1			1
Case 3	1			1
Case 4	1	1		2
Total (elements)	5		4	9



*Dc1=Dental crown 1, Dc2=Dental crown 2; Db=Dental bridge

Figure 2. Illustration of the number of prosthetic elements for each case

In the following, we present aspects from the digital realization of prosthetic restorations for the 4 cases.

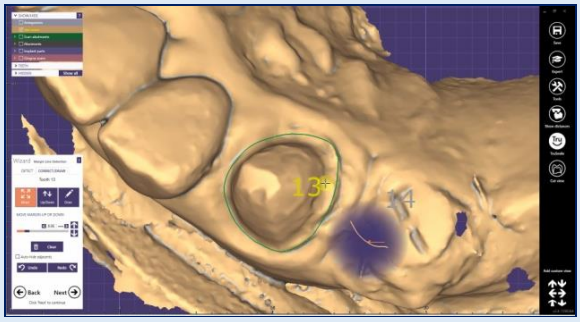
Case 1

The patient has, on the upper right hemiarch, a multi-dental terminal edentation (1.4-1.7) and a prepared tooth (dental abutment: 1.3).

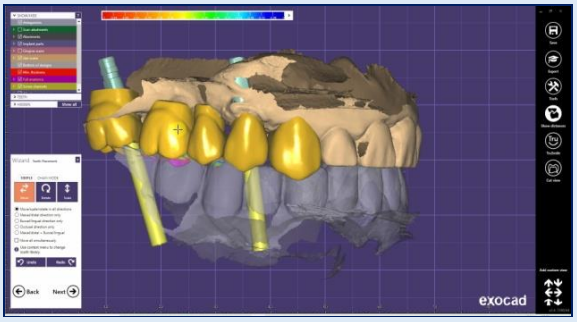
The therapeutic solution proposed by the dentist is the realization, in the frontal area, of a full-coverage crown (for tooth 1.3), which will be fixed by cementing on the dental abutment, and for the lateral area, the realization of a dental bridge, made of four elements (corresponding to 1.4-1.7), which will be fixed by screwing (at the level of 1.4 and 1.7), on the dental implants.

CAD realization of prosthetic restorations

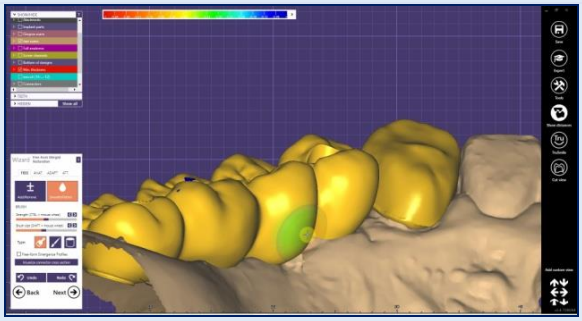
Using the Exocad software, the virtual design of the prosthetic restorations was made; in Figure 3 sequences from the digital workflow are presented.



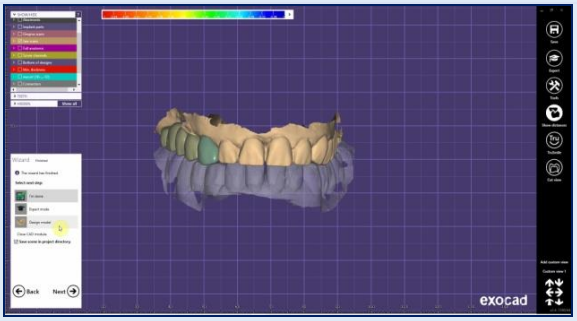
Defining margin line for the tooth 1.3



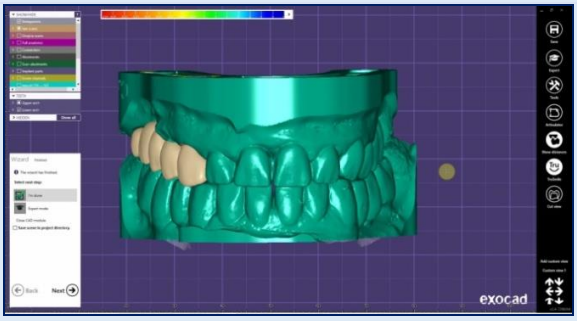
Adjusting the position and size of the teeth



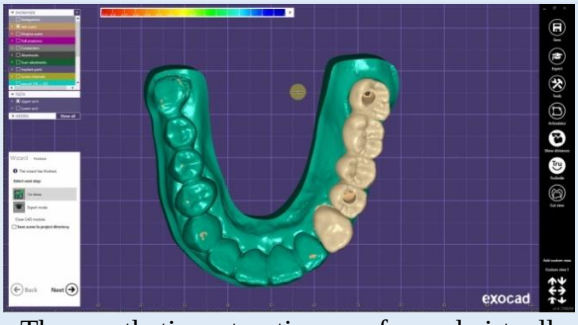
Teeth smoothing



The two arches in occlusion, with the prosthetic restorations



The two models in occlusion, with the prosthetic restorations, from the frontal norm

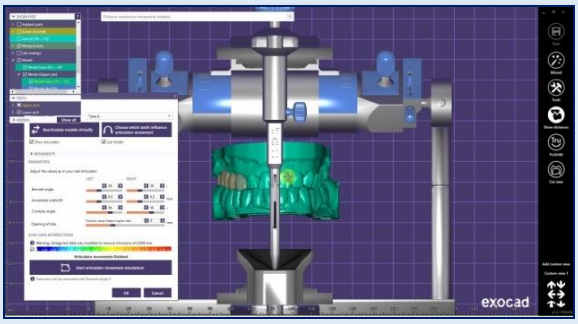


The prosthetic restorations performed virtually, from the occlusal norm

Figure 3. Sequences from the realization of the virtual design of prosthetic restorations using Exocad software (case 1)

a. b.

The prosthetic restorations performed virtually, from the fronto-lateral norm:
a. with antagonists; b. without antagonists



Checking the dynamic occlusion with the virtual articulator

Figure 3. Sequences from the realization of the virtual design of prosthetic restorations using Exocad software (case 1 – continued)

CAM realization of prosthetic restorations

The two fixed prosthetic restorations (the full-coverage crown and the dental bridge) were milled (using *Coritec 350i* milling machine), being made of PMMA (color A2), and they are illustrated in Figure 4.

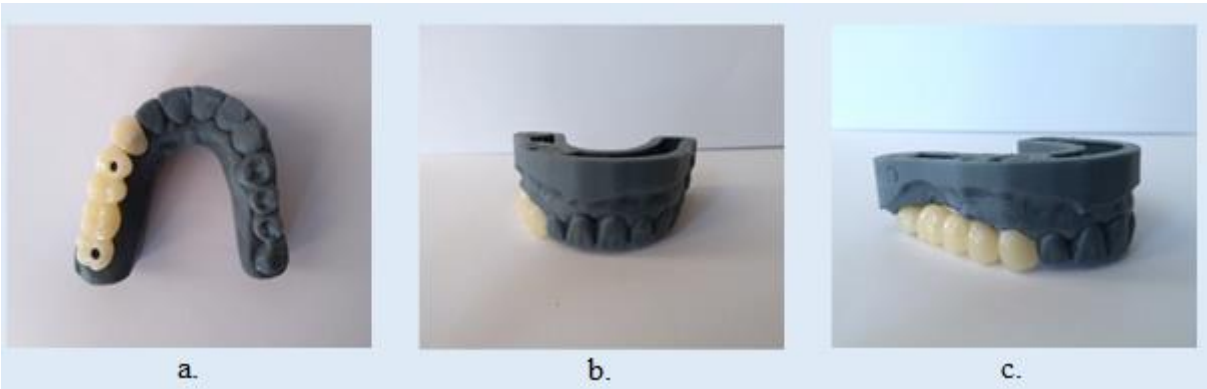


Figure 4. Fixed prosthetic restorations made of PMMA, on the printed model (case 1):
a. from the occlusal norm; b. from the frontal norm; c. from the fronto-lateral norm

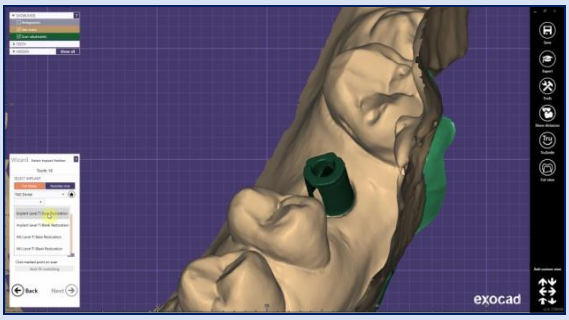
Case 2

The patient has an unidental lateral edentation (1.6), on the upper right hemiarch.

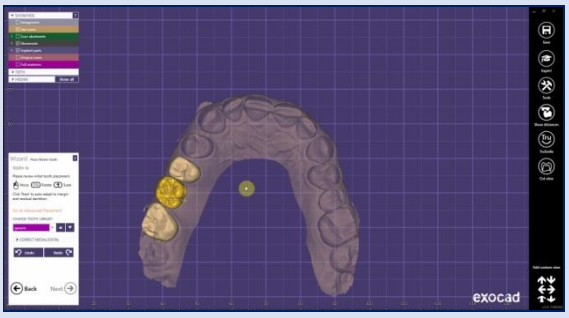
As a prosthetic treatment, it is necessary to make a replacement crown (for 1.6), which will be fixed by screwing on the dental implant.

CAD realization of prosthetic restoration

The virtual design of the prosthetic restoration was made using the Exocad software; in Figure 5 aspects during the digital workflow are illustrated.

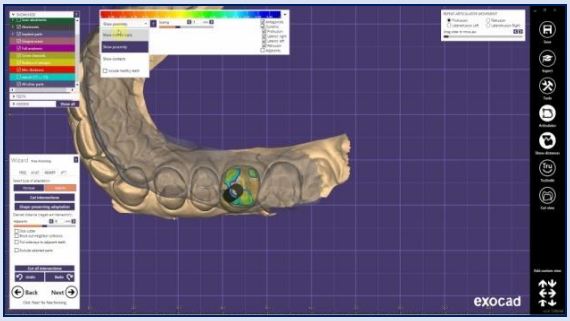


Choosing the type of implant

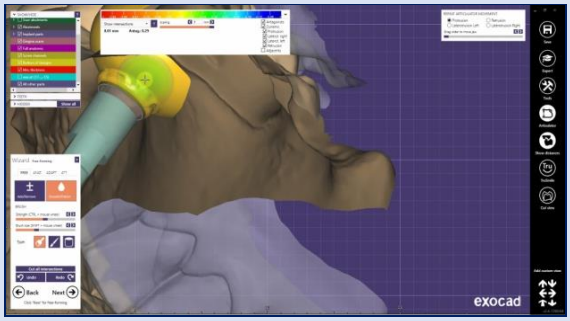


Marking the adjacent teeth and placing the tooth to be restored

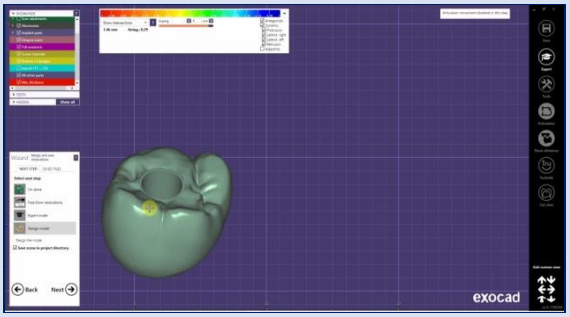
Dental arches in the virtual articulator



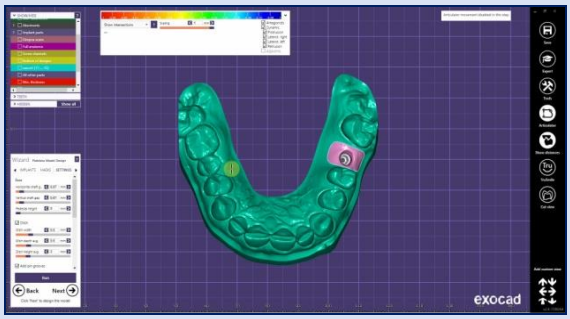
Tooth adaptation to the antagonists



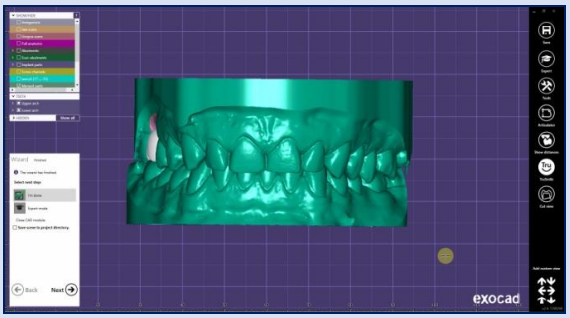
Smoothing the tooth, for a natural-looking



The prosthetic restoration performed virtually

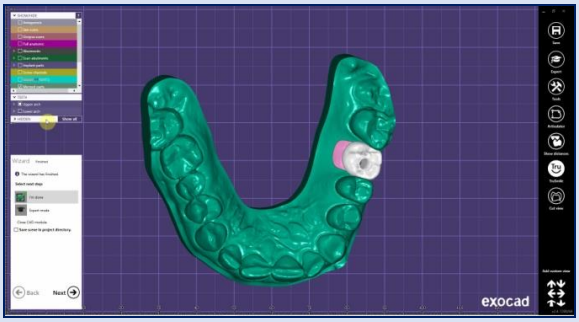


The maxillary 3D model, with gingiva mask

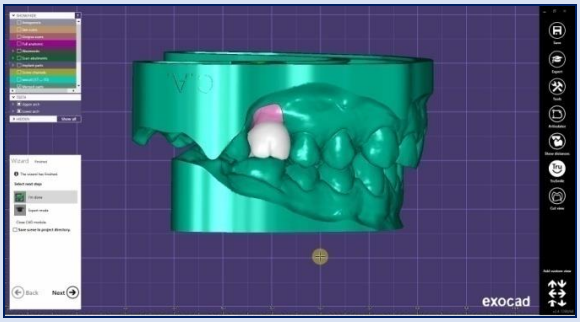


The two models in occlusion, with the prosthetic restoration, from the frontal norm

Figure 5. Aspects of the virtual design realization of the prosthetic restoration using Exocad software (case 2)



The prosthetic restoration performed virtually, from the occlusal norm



The prosthetic restoration performed virtually, from the lateral norm

Figure 5. Aspects of the virtual design realization of the prosthetic restoration using Exocad software (case 2 - continued)

CAM realization of prosthetic restoration

The fixed prosthetic restoration (the replacement crown) was milled, later sintered, the material being multilayer zirconia (color A2); in Figure 6 the milled restoration is presented.

a.

b.

c.

Figure 6. Fixed prosthetic restoration made of multilayer zirconia, on the printed model (case 2): a. from the occlusal norm; b. from the lateral norm; c. from the frontal norm

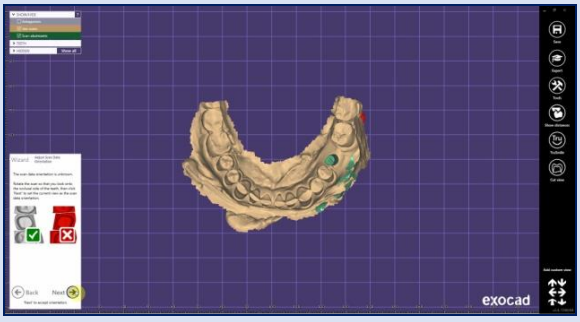
Case 3

The patient has an unidental lateral edentation (3.6), on the lower left hemiarch.

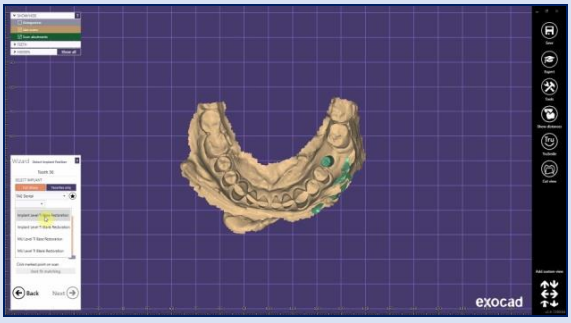
The therapeutic solution: making a replacement crown (for 3.6), which will be fixed by screwing on the dental implant.

CAD realization of prosthetic restoration

To make the virtual design of the prosthetic restoration, the Exocad software was used (Figure 7).

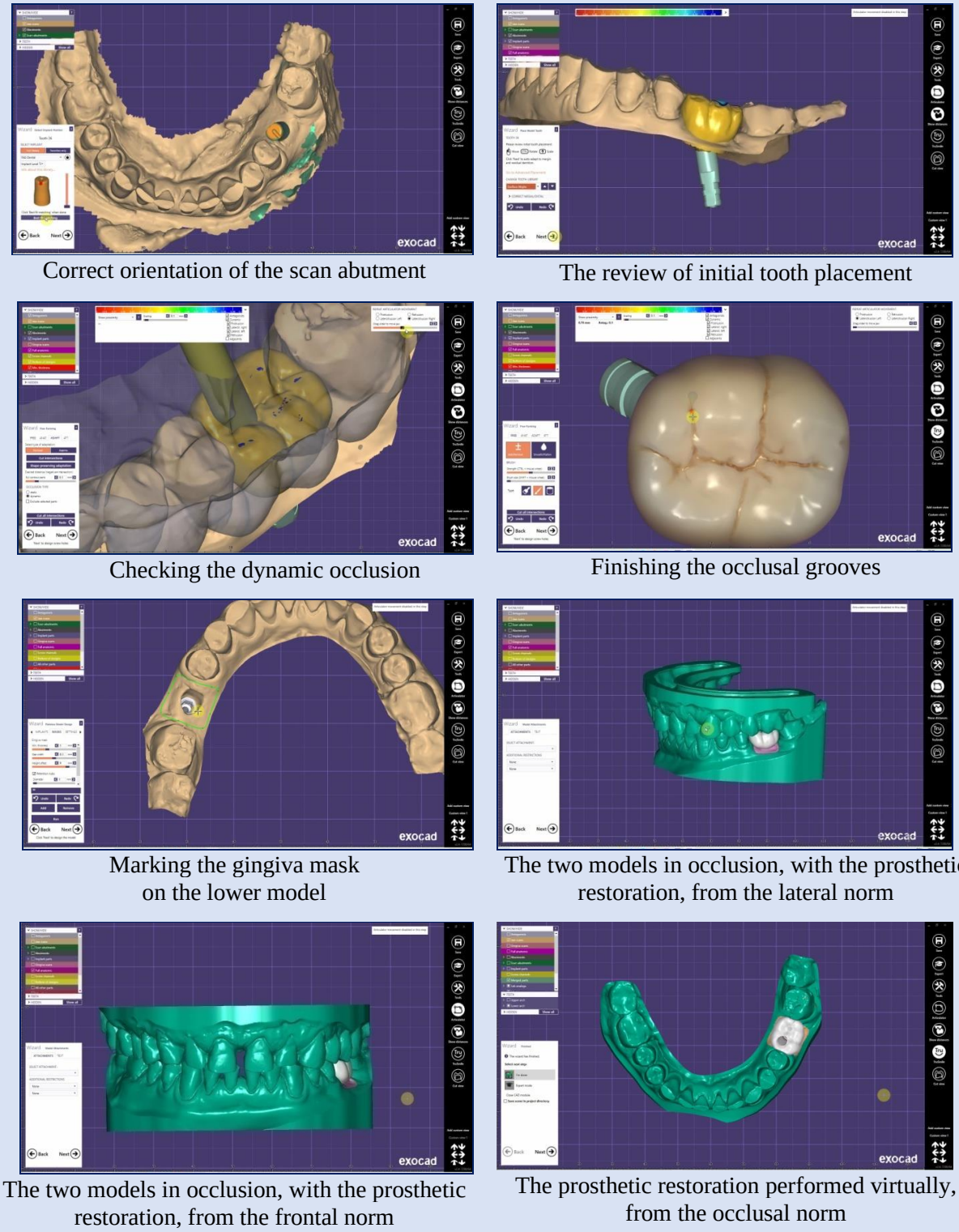


Adjusting the scan data orientation



Choosing the type of implant

Figure 7. Moments from the realization of the virtual design of the prosthetic restoration using Exocad software (case 3)



Correct orientation of the scan abutment

The review of initial tooth placement

Checking the dynamic occlusion

Finishing the occlusal grooves

Marking the gingiva mask on the lower model

The two models in occlusion, with the prosthetic restoration, from the lateral norm

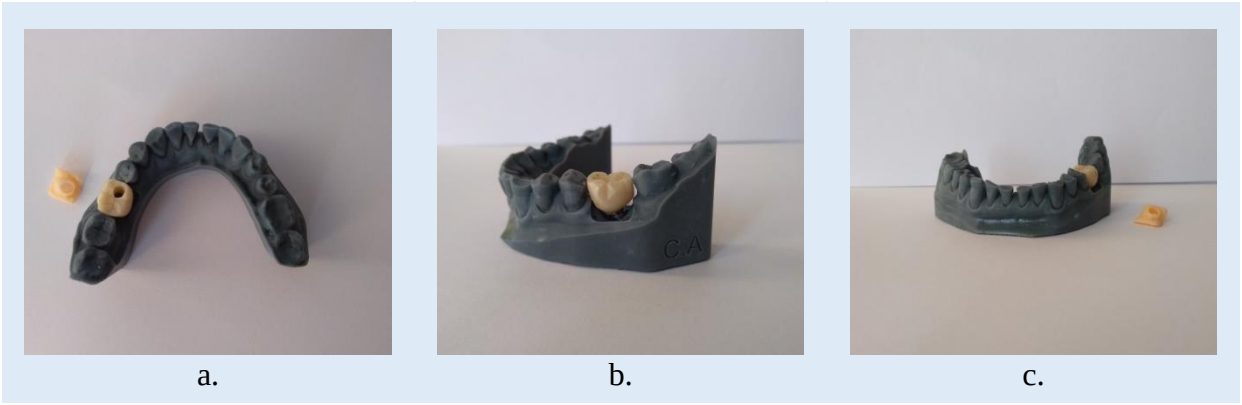
The two models in occlusion, with the prosthetic restoration, from the frontal norm

The prosthetic restoration performed virtually, from the occlusal norm

Figure 7. Moments from the realization of the virtual design of the prosthetic restoration using Exocad software (case 3 – continued)

CAM realization of prosthetic restoration

The fixed prosthetic restoration (the replacement crown) was milled (using *Coritec 350i* milling machine), then sintered (using the *HTS-2/M/ZIRKON-120* sintering furnace), the material being zirconia (color A3); the restoration is illustrated in Figure 8.



a. b. c.

Figure 8. Fixed prosthetic restoration made of zirconia, on the printed model (case 3): a. from the occlusal norm; b. from the lateral norm; c. from the frontal norm

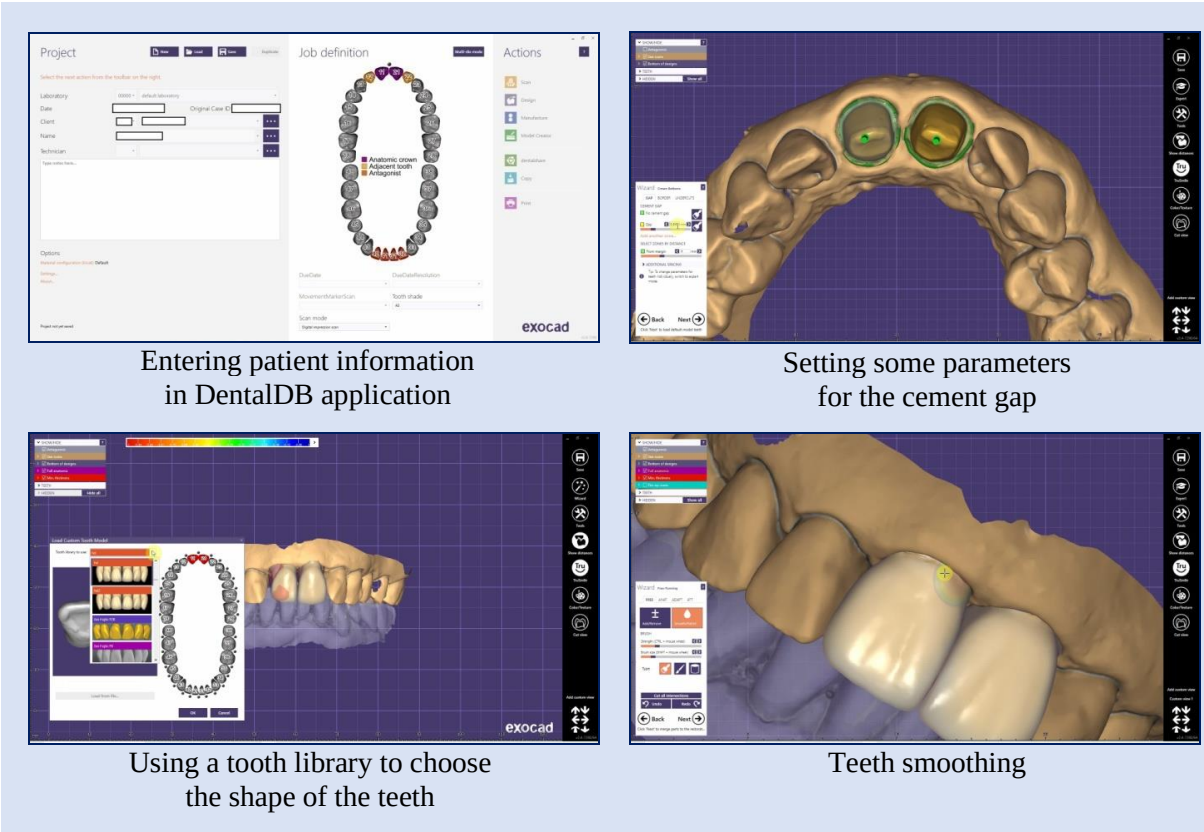
Case 4

The patient has, in the upper frontal area, two prepared teeth (two dental abutments: 1.1 and 2.1).

As a therapeutic solution, the dentist proposed the realization, in the frontal area, of two full-coverage crowns (for teeth 1.1 and 2.1), which will be fixed by cementing on the dental abutments.

CAD realization of prosthetic restorations

Using the Exocad software, the virtual design of the prosthetic restorations was made; in Figure 9 sequences during the digital workflow are presented.



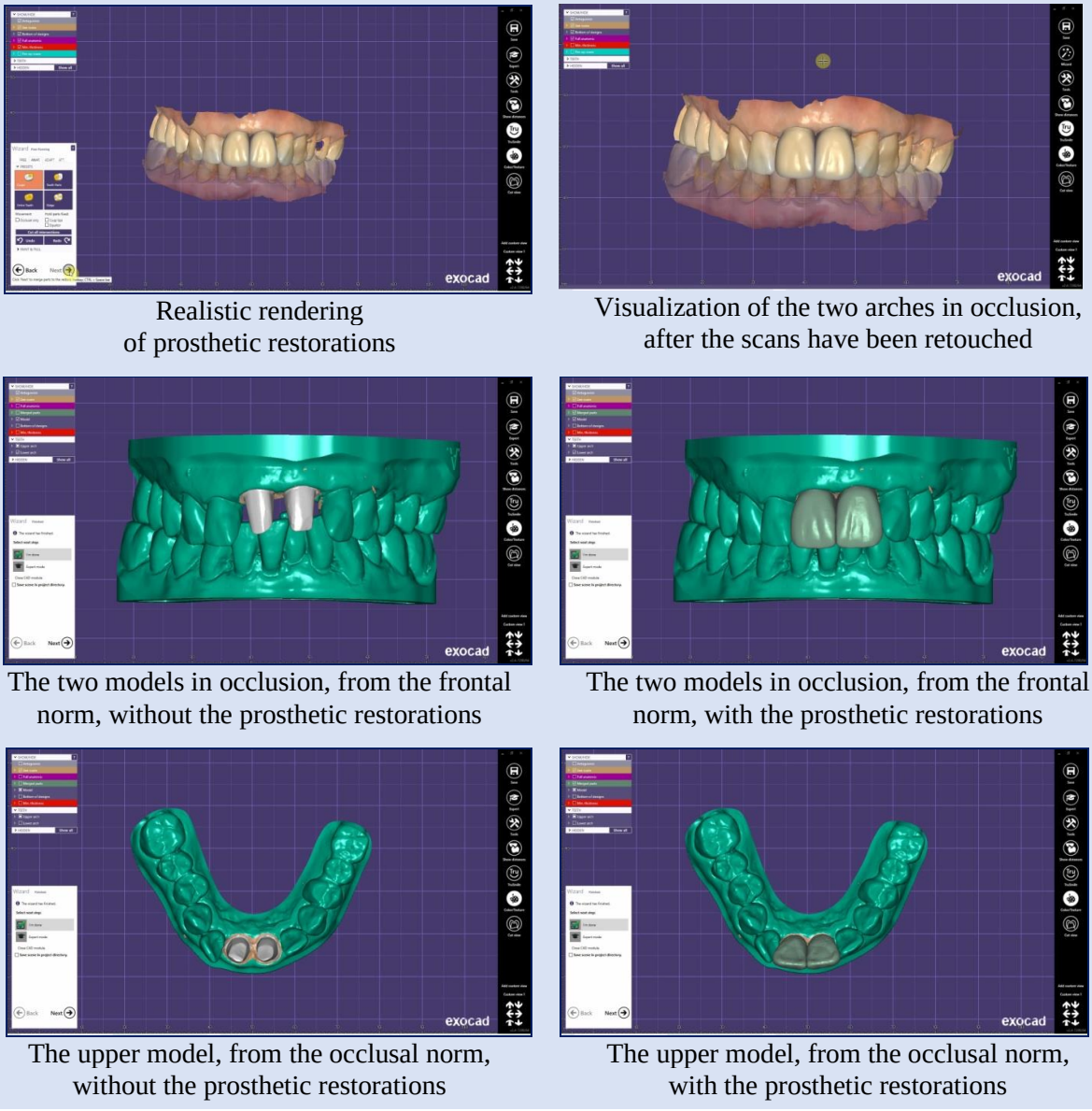
Entering patient information in DentalDB application

Setting some parameters for the cement gap

Using a tooth library to choose the shape of the teeth

Teeth smoothing

Figure 9. Sequences from the virtual design of the prosthetic restorations using Exocad software (case 4)



Realistic rendering of prosthetic restorations

Visualization of the two arches in occlusion, after the scans have been retouched

The two models in occlusion, from the frontal norm, without the prosthetic restorations

The two models in occlusion, from the frontal norm, with the prosthetic restorations

The upper model, from the occlusal norm, without the prosthetic restorations

The upper model, from the occlusal norm, with the prosthetic restorations

Figure 9. Sequences from the virtual design of the prosthetic restorations using Exocad software (case 4 - continued)

CAM realization of prosthetic restorations

The two fixed prosthetic restorations (the two full-coverage crowns) were milled, then sintered; the material was multilayer zirconia (color A3); the restorations are illustrated in Figure 10.

a. b.

Figure 10. Fixed prosthetic restorations made of multilayer zirconia, on the printed model (case 4): a. from the frontal norm; b. from the occlusal norm

Since the entire workflow was done digitally, the laboratory phases took less time than in the case of traditional or combined workflow (such as using classic impression and then scanning the physical model for the digital realization of the prosthetic restoration).

Digital technology allows the use of higher quality materials, resulting in more resistant and more aesthetic prosthetic restorations; helps to reduce the occurrence of errors; obtaining a better marginal adaptation and a perfect adaptation to the anatomical structures of the patient`s teeth.

Digital modeling allows adjustments of the prosthetic restoration before its manufacture, depending on the feedback received from the dentist, following the visualization of the design by him and the patient, and thus the dentist - patient - dental technician collaboration is improved.

The use of the virtual articulator, included in the software, together with the *Show distances* function (which helps to visualize the distances/the intersections with the antagonists) are of great help for the realization of occlusally adapted restorations, with stable and harmonious intermaxillary relations, thus preventing the occurrence of premature contacts and of interferences, the appearance of occlusal disharmonies that could lead, in the case of implanto-prosthetic restorations, to their overloading, affecting the longevity of implants and prosthetic restorations.

4. Conclusions

Using digital technology, in this study we performed 6 fixed prosthetic restorations, of which 5 unidental restorations (5 dental crowns) and 1 pluridental restoration (a 4-element dental bridge); of the 6 prosthetic restorations, 3 restorations will be fixed by cementing on dental abutments, and 3 restorations will be fixed by screwing on implants.

The use of a fully digital workflow in the realization of fixed prosthetic restorations is recommended, due to the advantages offered to the members of the entire team: dentist - patient - dental technician, starting from reducing the time and the number of stages for the realization of a prosthetic restoration of high quality and aesthetics, to reducing the number of necessary sessions until the restoration will be inserted into the oral cavity.

The Exocad software, which we used in this study to design prosthetic restorations, is easy to use, even for dental technicians who do not have much experience in using digital technologies; also, being an open software, it allows the import of scanned data from various scanners (for this study, an intraoral scanner) and the export of data, following the realization of the design, to various milling and 3D printing machines.

The use of digital technology in dentistry represents a choice that can lead to better and better results in prosthodontics, due to the progress in the field.

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References

1. ALBU, C., GHERGUȚ, A, ALBU, M., *Dicționar de kinetoterapie*, Ed. POLIROM, Iași, 2007, p. 446.
2. BELDIMAN, M.A., TATARCIUC, M., LUCA, E., VIȚALARIU, A.M., Technological aspects in CAD/CAM fixed rehabilitation on implants, *Romanian Journal of Oral Rehabilitation*, 12(2), 2020, p.176. http://www.rjor.ro/wp-content/uploads/2020/06/TECHNOLOGICAL-ASPECTS-1.pdf
3. IONESCU, T., STANCIU, D., Restaurări estetice ale dinților frontali devitali. *Revista Română de Stomatologie*, Vol. LV, Nr. 1. 2009, p. 13.
https://zdocs.ro/doc/restaurari-estetice-a-dintilor-frontali-devitali-w1knwvx3n31r
4. BÜHRER SAMRA, A.P., MORAIS, E., MAZUR, R.F., VIEIRA, S.R., RACHED, R.N., CAD/CAM in dentistry – a critical review, *Revista Odonto Ciencia*, 31(3), 2016. p. 141, 143.
https://www.researchgate.net/publication/316818725_CADCAM_in_dentistry_-_a_critical_review
5. ALMUSTAFA, N.M., *The use of CAD CAM For Fixed Partial Prostheses. A thesis submitted for the degree of Doctor of Philosophy*, University of Dundee. 2016, p. 35, 55.

https://discovery.dundee.ac.uk/ws/portalfiles/portal/8689601/The_use_of_CAD_CAM_for_Fixed_Partial_Prostheses_PhD_.pdf
6. ***exocad DentalCAD, the next generation, *CAD/CAM international magazine of digital dentistry*, *Dental Tribune International*, 6(2), 2015, p. 36:
https://www.sser.ro/rev/cad.cam.international2.2015all.pdf.pdf [Accessed December 2, 2022].
7. BECHIR, A. (coord.), COMĂNEANU, R.M., SMĂTREA, O., RĂDULESCU, E.D., BECHIR, E.S., *Aspecte specifice în tehnologia punților dentare*, Editura Printech, București, 2013, p. 69.
8. BECHIR, A. (coord.), COMĂNEANU, R.M., SMĂTREA, O., BECHIR, E.S., RĂDULESCU, E.D., *Aspecte tehnologice în confecționarea restaurărilor protetice fixe unidentare*, Editura Printech, București, 2012, p. 8-9.
9. SCATTARELLI, P., SMANIOTTO, P., LEUCI, S., CERVINO, G., GISOTTI, M., The Digital Integrated Workflow in the Aesthetic Management of the Smile: A case Report, *Prosthesis*, 2(3), 2020, p.198.https://www.researchgate.net/publication/343731728_The_Digital_Integrated_Workflow_in_the_Aesthetic_Management_of_the_Smile_A_Case_Report
10. PATIL, M., KAMBALE, S., PATIL, A., MUJAWAR, K., Digitalization in Dentistry: CAD/CAM – A Review, *Acta Scientific Dental Sciences*, 2(1), 2018, p. 15-16.
https://www.researchgate.net/profile/Amol_Patil47/publication/344679568_Digitalization_in_Dentistry_CADCAM_-A_Review/links/5f89208f299bf1b53e2bfcf0/Digitalization-in-Dentistry-CAD-CAM-A-Review.pdf
11. DOBRESCU, A.M., DOBRESCU, N., COMĂNEANU, R.M., GHERGIC, D.L., Reabilitarea estetică a aparatului dento-maxilar prin restaurări ceramice pe suport de zirconiu – prezentare de caz (Aesthetic rehabilitation of dental apparatus by ceramic restorations zirconium supported – case presentation), *Revista Română de Stomatologie*, Vol LXI, Nr. 1, 2015, p. 71.
https://rjs.com.ro/articles/2015.1/RJS_2015_1_Art-13.pdf
12.***https://wiki.exocad.com/wiki/index.php/Defining_jobs_for_individual_teeth
[Accessed December 2, 2022].
13. GIURESCU DUMITRESCU, R.A., POPESCU, A.I., DUMITRESCU, C.S., POPESCU, M., ION, M., BURCEA, A., Experimental Study of the Behaviour of Materials Used in Creating Polymer Dentures Mobilized by Irradiation Microwave, *Materiale plastice*, Volume 53, Issue 2, 2016, p. 189.
https://revmaterialeplastice.ro/pdf/DUMITRESCU%20R%20A%202%2016.pdf
14.ANDREESCU, C.F., GHERGIC, D.L., BOTOACA, O., BARBU, H.M., CERNUSCA MITARIU, I.S., PATROI, D.N., The Advantages of High-density Polymer CAD/CAM Interim Restorations in Oral Implantology, *Mater. Plast.*, **54**(1), 2017, 32-33, 35.
https://www.researchgate.net/publication/318311722_The_Advantages_of_High-density_Polymer_CADCAM_Interim_Restorations_in_Oral_Implantology
15.ANDREESCU, C.F., GHERGIC, D.L., BOTOACA, O., HANCU, V., BANATEANU, A.M., PATROI, D.N., Evaluation of Different Materials Used for Fabrication of Complete Digital Denture, *Mater. Plast.*, **55**(1), 2018, 124.
https://www.researchgate.net/publication/324779948_Evaluation_of_Different_Materials_Used_for_Fabrication_of_Complete_Digital_Denture
16.AZEVEDO, L., ANTONAYA-MARTIN, J.L., MOLINERO-MOURELLE, P., DEL RIO-HIGHSMITH, J., Improving PMMA resin using graphene oxide for a definitive prosthodontic rehabilitation – A clinical report. *J Clin Exp Dent.*, 11(7), 2019, p. 670, 673.
https://www.researchgate.net/publication/334139075_Improving_PMMA_resin_using_graphene_oxide_for_a_definitive_prosthodontic_rehabilitation_-A_clinical_report
17.CIOBANU, M.G.. *Materiale biocompatibile (Biomateriale) – Note de curs*. Universitatea Tehnică Gheorghe Asachi din Iași. Facultatea de Inginerie Chimică și Protecția Mediului, 2016, p. 67, 71.
http://www.didactic.icpm.tuiasi.ro/cv/ciobanugabriela/curs%20MATERIALE%20BIOCOMPATIBILE_master%20PFC.pdf

18.RIMONDINI, L., CERRONI, L., CARRASSI, A., TORRICELLI, P., Bacterial Colonization of Zirconia Ceramic Surfaces: An In Vitro and In Vivo Study. *The International Journal of Oral & Maxillofacial Implants*, 17(6), 2002, p. 793-798.
https://www.researchgate.net/publication/10969412_Bacterial_Colonization_of_Zirconia_Ceramic_Surfaces_An_in_Vitro_and_in_Vivo_Study
19.DRAGO, C., *Implant Restorations: A Step-by-Step Guide*, Fourth Edition. Hoboken, NJ: Wiley Blackwell. 2020, p. 50, 52.
https://books.google.ro/books?id=UnHDDwAAQBAJ&printsec=frontcover&dq=editions:nC4K6Cf76pkC&hl=ro&sa=X&ved=2ahUKEwiY2ZrmuYnuAhUDiIsKHULEARQQuwUwAXoECAIQCQ#v=onepage&q&f=false
20.HU, J., ATSUTA, I., AYUKAWA, Y., ZHOU, T., NARIMATSU, I., KOYANO, K., Effect of titanium or zirconia implant abutments on epithelial attachments after ultrasonic cleaning, *Journal of Oral Science*, 62(3), 2020, p. 333. https://www.jstage.jst.go.jp/article/josnusd/62/3/62_19-0332/_pdf/-char/en
21.GEHRKE, P., JOHANNSON, D., FISCHER, C., STAWARCZYK, B., BEUER, F., In Vitro Fatigue and Fracture Resistance of One- and Two-Piece CAD/CAM Zirconia Implant Abutments. *The International Journal of Oral & Maxillofacial Implants*, 30(3), 2015, p. 546.
https://d39fhjc8diz16r.cloudfront.net/wordpress/wp-content/uploads/gehrke-et-al-jomi-2015-cad-cam-abutm-fracture-resistance.pdf
22.FISCHER, C., BETTENDORF, A., A digital workflow for the provisional restoration, *EDI Journal - European Journal for Dental Implantologists*, 2018(1), p. 62, 64, 67.
https://bdizedi.org/wp-content/uploads/EDI-Journal/edi_journal_1_2018.pdf
23.MANGANO, F., VERONESI, G., Digital versus Analog Procedures for the Prosthetic Restoration of Single Implants: A Randomized Controlled Trial with 1 Year of Follow-Up, *BioMed Research International*, 2018(2), p. 1 – 9.
https://www.researchgate.net/publication/326483302_Digital_versus_Analog_Procedures_for_the_Prosthetic_Restoration_of_Single_Implants_A_Randomized_Controlled_Trial_with_1_Year_of_Follow-Up
24.LERNER, H., MOUHYI, J., ADMAKIN, O., MANGANO, F., Artificial intelligence in fixed implant prosthodontics: a retrospective study of 106 implant-supported monolithic zirconia crowns inserted in the posterior jaws of 90 patients, *BMC Oral Health*, 20(1), 2020, p. 1-6, 15.
https://www.researchgate.net/publication/340032019_Artificial_intelligence_in_fixed_implant_prosthodontics_A_retrospective_study_of_106_implant-supported monolithic zirconia crowns inserted in the posterior_jaws_of_90_patients

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