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Computer-aided designing and manufacturing of partial removable dentures

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ABSTRACT

Purpose: The goal of this article is to present the developed methodology of computer-aided designing and manufacturing of removable partial dentures on the example of the free-end situation in the mandible.

Design/methodology/approach: The method of designing and manufacturing of removable partial dentures was developed on the basis of real clinical data coming from a patient with a free-end situation in the mandible. The method is focused on completely virtual designing of the partial dentures made of titanium and chrome-cobalt alloys covered with aesthetic acrylic material.

Findings: The CAD/CAM produced prosthesis adheres tightly to the tissue improving its stability, retention and evenly transferring loads on the tissue, causing less interference in the oral mucosa.

Research limitations/implications: The development of the precise design procedures, including CAD/CAM, for fabrication of partial dentures is justified because there is still a large group of patients who would benefit from improving the accuracy of these solutions.

Practical implications: The development of the precise design procedures, including CAD/CAM, for fabrication of partial dentures is justified because there is still a large group of patients who would benefit from improving the accuracy of these solutions.

Originality/value: This paper presents an original method of designing and manufacturing of removable partial dentures. This allows for precise planning of the shape of the denture frame in relation to individual anatomy of the teeth and the soft tissue of the oral cavity. The execution of the CAD/CAM technology allows to avoid changes of the volume and shape of the prosthesis that is very common in conventional manufacturing procedures.

Keywords: Removable dentures; Partial dentures; CAD/CAM

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ANALYSIS AND MODELING

1. Introduction

Modern dentistry uses a wide range of dentures recovering missing teeth, both in cases of total edentulism (based on implants or on the oral mucosa) as well as partial tooth deficiencies. In cases of partial lack of teeth bridges based on natural teeth or on the implants are preferred. However, in some cases, despite the lack of financial constraints, it is necessary to supply a patient with partial dentures which have been commonly used in dentistry for many decades [1-3]. In particular, such situations occur when the patient's teeth are arranged in a way that makes it impossible to use bridges based on natural teeth, particularly in the case of deficiencies in back regions of the jaws when the volume of the alveolar bone precludes implant placement without advanced surgical procedures to regenerate the bone volume with bone substitute materials or autografts [4-7]. It applies also to cases when this type of treatment failed for some reason. Removable partial dentures are also used as temporary solutions during implant treatment. The patient may wear these dentures after all surgical procedures and implantoprosthetic phase of treatment [8, 9].

To meet aesthetic and functional expectations of the patients, new materials and new methods of manufacturing of the dentures are introduced which are based mainly on new technologies.

For proper functioning of the removable dentures it is extremely important to ensure their close adhesion to the tooth around the denture attachments [10-12]. It is particularly important because these dentures are often asymmetrical and therefore transfer the load non-uniformly in different areas of the jaws. Thus, any geometrical deviation in relation to the original design of the denture often means the malfunction of the entire structure.

The goal of this article is to present the developed methodology of computer-aided designing and manufacturing of removable partial dentures on the example of the free-end situation in the mandible.

2. Clinical case presentation and methodology

2.1. Clinical case presentation

The female patient at the age of 49 was presenting multiple missing teeth in the maxilla and the free-end situation in the mandible on one side. She was a healthy, non-smoking individual. Because of economic reasons she demanded to have her mandibular dentition replaced with a removable denture.

2.2. Methodology of designing and manufacturing of the lower removable denture

Firstly, digital models were prepared by scanning directly the impression trays and then producing the plaster master cast. The whole procedure was scheduled as follows:

- Impression taking with a precise functional silicone material. (Alternatively it is possible to carry out the intraoral scanning).
- Designing of the frame of the denture using CAD software.
- Execution of the denture frame using the CAM software and a CNC milling in CoCr or titanium.
- Installation of the frame of the prosthesis on the master cast.
- Carrying out of the re-scan of the master cast with the metal frame.
- Designing the outlines of the restoration based on the designed frame.
- Manufacturing of the denture in PMMA using a CNC milling machines.
- Connecting the frame with the denture.
- Performing the characterization of the restoration.

After scanning of the impression tray a digital model of the teeth is obtained (Fig. 1). On the basis of the project it is possible to start the production of the partial denture. Firstly, the designer must choose the path of introduction of the prosthesis taking into account the specific anatomic conditions of the teeth (Fig. 2). It is important to select a path of the introduction where the undercuts have the smallest possible values and are located at the places where the prosthesis would not hurt the tissues. The software allows for visual inspection of the path of the introduction and the occurrence of possible undercuts. After preparing a virtual model, it is possible to proceed to designing of the prosthesis.

The project of the denture should be prepared with regard to the basic principles of creating partial dentures. The first thing is to plan the lingual part of the denture frame that links both sides of the denture (Fig. 3). It should be led close-tight to the oral mucosa and hard tissues of the teeth. Then, the project of the attachments should be done enabling the closest possible relation to the teeth (Figs. 4 and 5). In particular, the designer should ensure the proper shape of these elements in order to ensure the stability of the whole structure.

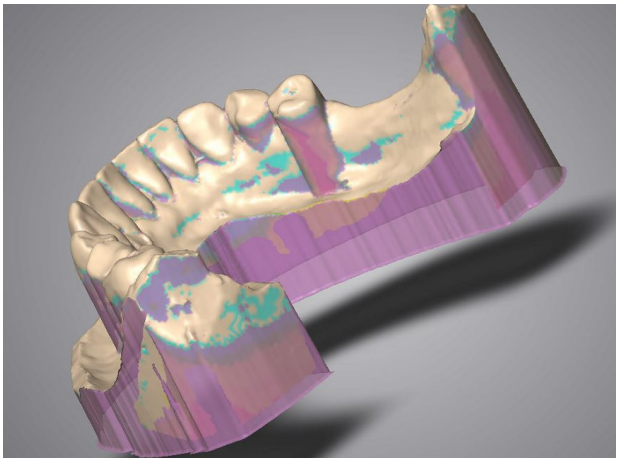

Fig. 1. The digital master cast prepared by scanning the prosthetic impression tray eliminating the necessity of preparing the plaster model and maximizing the accuracy

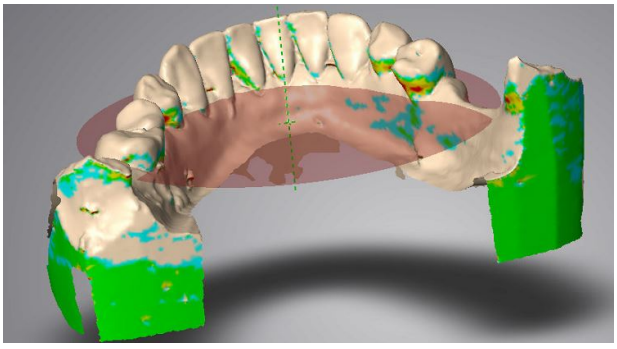

Fig. 2. Planning the path of the introduction of the denture with regard to the anatomy of the teeth and the soft tissues of the oral cavity

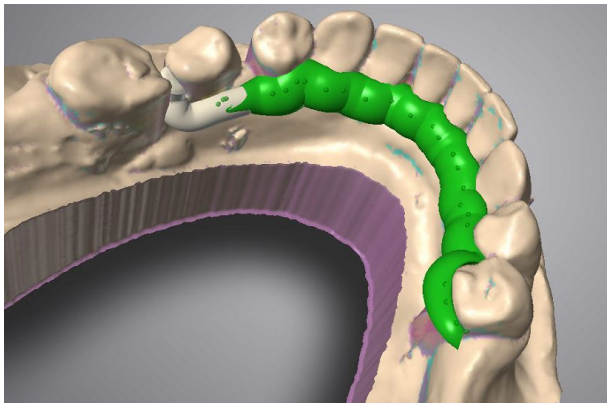

Fig. 3. Designing of the lingual part of the frame of the denture linking both sides of the structure; the lingual part is led in close proximity to the lingual surfaces of the teeth

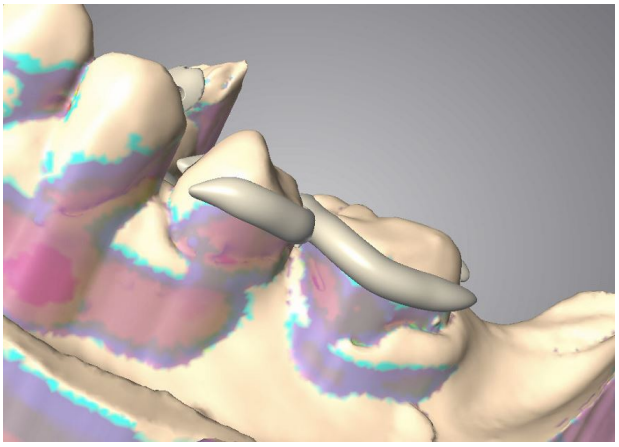

Fig. 4. Designing of the clasps ensuring proper retention and stability of the frame and the whole prosthesis

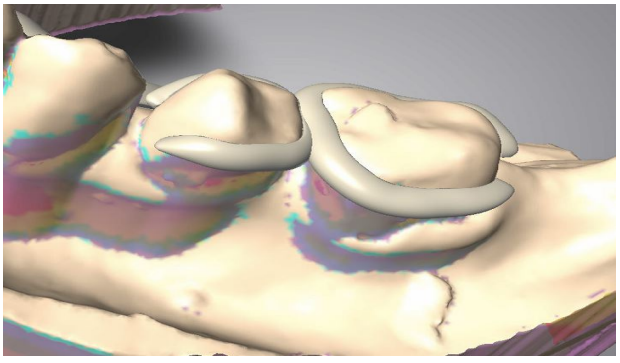

Fig. 5. CAD software enables to estimate all the aspects of the teeth to ensure proper retention of the denture with regard to undercuts on the teeth surfaces

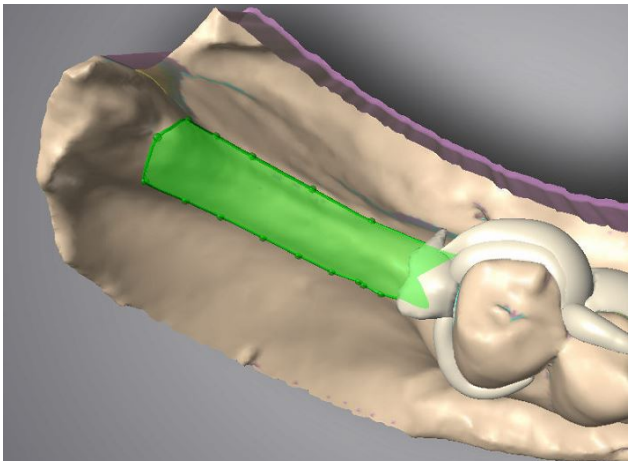

Fig. 6. Planning the position of the basal plate of the denture frame with regard to the configuration of the alveolar ridge

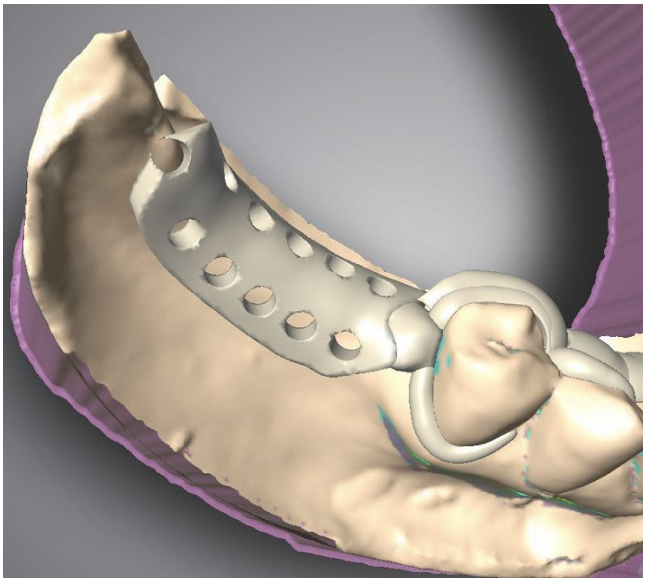

Fig. 7. Designing of the basal plate of the denture frame; the holes in the plate are planned to ensure maximum retention of the acrylic material to the metal

It is understood that the implementation of the project should be made with the maximum accuracy in relation to the tissues with an offset of 0.05-0.1 mm.

Having designed the lingual part of the denture and the shape of the clasps in relation to the undercuts on the teeth surfaces, the designer may proceed to planning the outlines of the basal plate of the frame (Figs. 6 and 7).

Having prepared the design of the frame, it is possible to continue with the manufacturing of the frame using the CNC milling machines (Figs. 8 and 9).

Fig. 8. The denture frame is milled in a metal block

Fig. 9. Connectors linking the denture frame with the metal block must be precisely cut to ensure accuracy of the whole structure

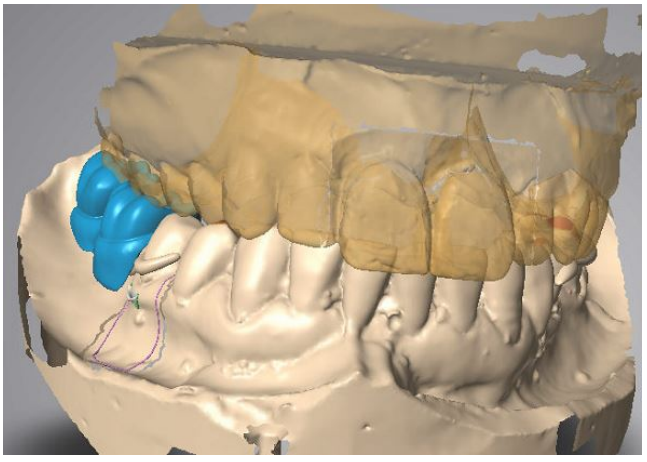

Fig. 10. Designing of the prosthesis in relation to the occlusal contacts determined by the teeth of the opposing jaw

Then, using the same software and performing the re-scan of the master cast with the frame installed, it is possible to design the final shape of the restoration. It is necessary to ensure proper occlusal contacts of the partial denture (Fig. 10). It is extremely important with regards to stability of the restoration. The occlusal contacts must be thoroughly checked in virtual environment of the CAD software. For this purpose, intraoral scanning of opposing dentition must be performed. Alternatively, impressions of the opposing jaw must be taken and the impression tray must be scanned in the laboratory. According to our experience to date, the best results are achieved when intraoral scanning is performed. According to the patients'

feedback the process of the intraoral scanning is also the most comfortable way of obtaining information about the configuration of the soft tissue and alignment of the teeth.

Then the design of the restoration must be reduced on the whole volume surface (Fig. 11). It is necessary to ensure enough space for aesthetic finishing of the denture with an aesthetic material, for example a composite material. The denture prepared in this way can be milled in PMMA or may be finished by a dental technician.

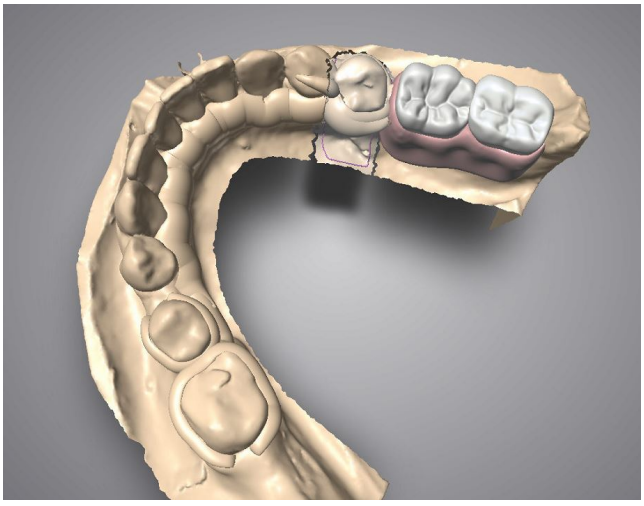

Fig. 11. Designing of the shape of the acrylic parts of the prosthesis including the artificial teeth

Alternatively, the restoration may be prepared in a traditional manner using acrylic and composite teeth. The final partial removable denture is shown in Figure 12.

Fig. 12. The final partial removable denture on the physical plaster master cast produced by CAD/CAM techniques

The procedure allows to produce the denture in both conventional materials, such as chrome-cobalt alloy with acrylic and composite teeth, and new composite materials suitable for milling. The method is therefore very versatile.

3. Discussion

Traditionally, manufacturing procedures do not guarantee the repeatability of many parameters. We can distinguish two main groups of dentures that are made of different materials and are fabricated with different methods. The first group consists of functionally unstable dentures whose basic construction material is acrylic. Fastening elements in this type of prostheses are typically made of wire clasps which are in contact with the adjacent teeth or protruding acrylic elements that surround the natural teeth [13]. The primary phenomenon ensuring the retention of these dentures is their adherence to the basal mucosa. Due to the fact that the soft tissue volume changes and deforms it is very difficult to ensure good accuracy during manufacturing of those dentures. This type of solutions, due to the limited physical strength of acrylic material and a relatively large space that should be devoted to the support structures in very difficult circumstances characterized by limited occlusal conditions and the non-effective retention elements, should only be used for economic reasons [14].

The second groups of partial dentures is composed of so-called "frame dentures" which include in their structure the carrier frame made of chrome-cobalt alloy. Like in the first case the missing natural teeth are replaced with prefabricated composite teeth embedded in acrylic. The advantage of this solution is the fact that all attachments are made of a material that provides a constant relationship of the attachments to each other and to the tissues of the teeth to provide permanent mounting and thus more comfortable function. The basic problem with these structures is that their manufacturing is based on the traditional method for their preparation. These prostheses are made directly on a plaster model by stacking the respective layers on prefabricated shaped wax and lost wax casting with chromium-cobalt alloy. This procedure has many limitations that cause visible deformations from the proposed initial shape of the final denture [15, 16].

These solutions over the years have undergone many variations, especially new varieties of the material of which they are made were invented. It should be noted that in general, all of these solutions are very similar to each other.

Improving the method for producing partial dentures is therefore an important issue, which allows the use of such dentures in patients disqualified for the use of fixed restorations. By using computer-aided design/computer-aided manufacturing (CAD/CAM) technology it is possible to design and produce the partial dentures [17, 18]. CAD software allows continuous control of sections of individual elements of the prosthesis, and hence the control of the implementation of planned mechanical parameters, and at the same time designing of minimally visible attaching elements. Then, using the CAM, it is possible to precisely produce the whole prosthesis with an accuracy of up to 0.1 mm [19].

To increase the accuracy of the whole process it seems reasonable to eliminate one of the steps to increase the inaccuracy of the working model. Up to now, using a scanner for scanning the prosthetic impression tray it is possible to eliminate the inaccuracy resulting from the expansion of the plaster cast. Then, to ensure the workflow it is necessary to produce a master cast for further prosthetic stages. It is also possible to prepare a master cast based on intraoral scanner, which eliminates both the contraction of the impression material and the expansion of gypsum used to make a master cast. The accuracy of the 3D models made with an intraoral scanner is in the range 50-70 microns and is close to the maximum precision of a milling machine [19].

The procedure is particularly useful for the production of precision dentures with precise attachments (Figs. 13-15). An important problem in the manufacturing of dentures with precise attachments is to ensure parallelism of the components (female and male parts) in the bridge and a denture. The execution of the bridge with bolts in the procedure of CAD/CAM may guarantee a perfect reproduction of the shape of the introduction way and ensure their full parallelism. When performing prosthesis on bolts in daily practice it should be stated that it is extremely difficult or even impossible to guarantee full parallelism and adhesion over the entire length of the bolts to the matrix. Due to the deformation of the shape of the prosthesis in the casting process it is often necessary to modify the shape of the tunnel manually in the male and the female element. The only commonly available manufacturing procedure that ensures the retention of the elements on the entire length is the CAD/CAM technology based on a CNC milling machine. In the illustrated procedure, it is possible to precisely produce the entire frame, even with an integrated matrix, so as to avoid the risk of lack of retention of the prosthesis to the matrix and to the lock [10,11].

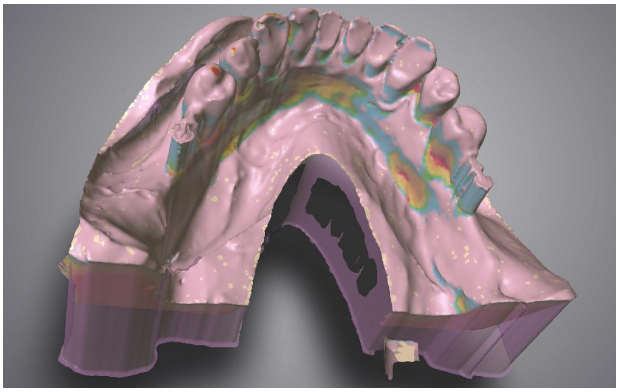

Fig. 13. Designing of the male parts of the removable denture replacing free-ends on both sides in the mandible

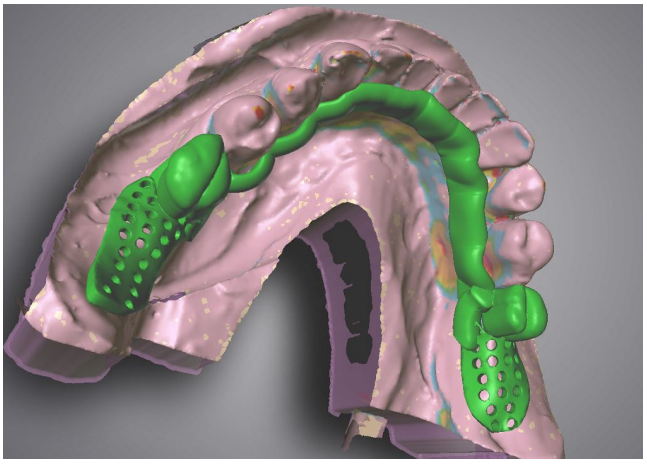

Fig. 14. Designing of the female parts of the removable denture replacing free-ends on both sides in the mandible

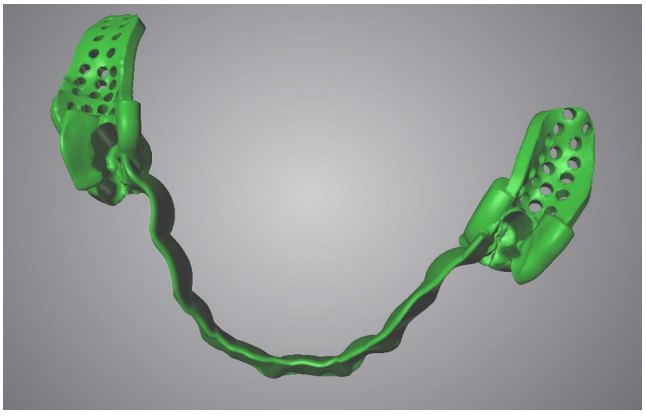

Fig. 15. The final shape of the frame denture with precise attachments replacing free-ends on both sides in the mandible

The described procedure is also used for the manufacturing of orthodontic braces, particularly in patients who are allergic to chromium, cobalt and nickel. In this case it is necessary to make the braces out of titanium. Due to the lack of availability of ready-made elements of this type it seems reasonable to use CAD/CAM procedures to produce such braces (Figs. 16 and 17).

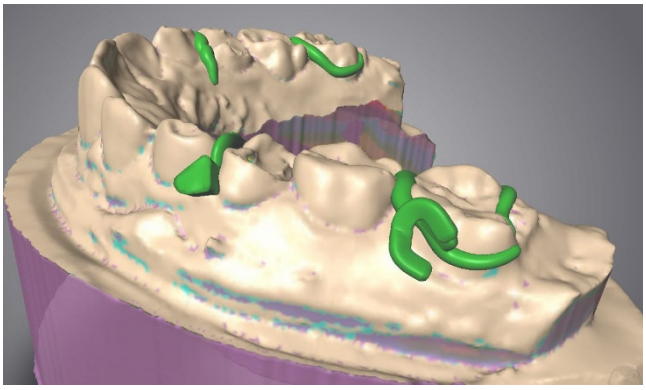

Fig. 16. Planning of the orthodontic braces to be produced out of titanium

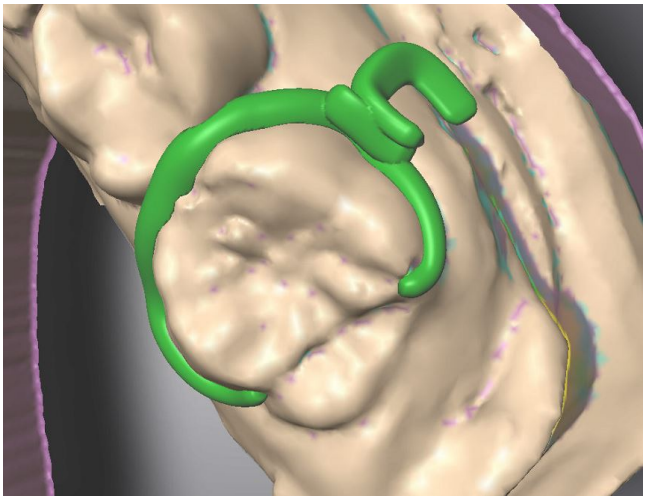

Fig. 17. Orthodontic appliances designed virtually in CAD/CAM software

The authors performed this type of work for a 10-year-old patient who was allergic to chrome, cobalt and nickel, and previously used braces that caused severe allergic reactions in the mouth after a few days of use. Orthodontic braces were made of milled titanium, only titanium orthodontic wires and screws were used. All the elements were embedded in a transparent non-allergic acrylic material.

4. Conclusions

The development of the precise design procedures, including computer-aided design and manufacturing CAD/CAM, for fabrication of partial dentures is justified because there is still a large group of patients who would benefit from improving the accuracy of these solutions. The procedure may eliminate the impression materials which would allow to perform partial dentures for people with gag reflex. It is possible to produce the entire prosthesis as a monolith. This greatly increases the strength and durability of the prosthesis. The execution of the CAD/CAM technology allows to avoid changes of the volume and shape of the prosthesis that is very common in conventional manufacturing procedures. The produced prosthesis adheres tightly to the tissue improving its stability, retention and uniformly transferring loads on the tissue, causing less interference in the oral mucosa.

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