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The computer-aided design and rapid prototyping fabrication of removable partial denture framework for occlusal rehabilitation: clinical report

Projeto auxiliado por computador e prototipagem rápida para fabricação de estrutura de prótese parcial removível para reabilitação oclusal: relatório clínico

El diseño asistido por computadora y la fabricación rápida de prototipos de estructuras de prótesis parciales removibles para rehabilitación oclusal: informe clínico

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Abstract

The objective of this case report was to describe the clinical sequence for occlusal vertical dimension (OVD) recovering with the manufacture of removable partial dentures (RPD) produced by computer-aided design and rapid prototyping. The patient presented to the Dentistry Department of the Federal University of Rio Grande do Norte reporting dissatisfaction with the superior RPD. At clinical investigation, a fracture in the minor connector and support at the region of tooth 15 was observed, in addition to severe OVD loss. In this case, after obtaining correct OVD, four more sessions were necessary for RPD fabrication. In the first appointment, intraoral scanning was performed to generate STL files used for path of insertion determination in the CAD software. The need for a guide plane on tooth 15 was observed, thus a preparation guide was designed and 3Dprinted to aid axial tooth reduction. At the second visit, after mouth preparation, another intraoral scanning was performed to acquire virtual working models. The RPD framework was designed and 3D printed in a castable resin pattern and invested for cobalt-chromium alloy melting. In the third visit, clinical evaluation of the framework and teeth and artificial gingiva colors selection were performed. The articulated models were then 3D printed, enabling pre-fabricated teeth to be assembled and acrylized. On the fourth appointment, RPD was installed and the patient received routine instructions. In this sense, the use of CAD/CAM technologies presented as a valuable tool to enhance restoration of OVD by the manufacturing of RPD.

Keywords: Removable Partial Denture; 3D Printing; Computer Aided Design; Vertical Dimension of Occlusion.

Resumo

O objetivo deste relato de caso foi descrever a sequência clínica do reestabelecimento da dimensão vertical oclusal (OVD) com a confecção de próteses parciais removíveis (PPR) produzida por desenho auxiliado por computador e prototipagem rápida. A paciente apresentou-se ao Departamento de Odontologia da Universidade Federal do Rio Grande do Norte, relatando insatisfação com o PPR superior. Clinicamente, observou-se fratura do conector menor e apoio na região do dente 15, além de perda de DVO. Neste caso, após o reestabelecimento da DVO, mais quatro sessões foram necessárias para a fabricação da PPR. Na primeira, foi realizado o escaneamento intraoral para obtenção dos arquivos STL utilizados para determinação do eixo de inserção no *software* CAD. Observou-se a necessidade de um plano-guia no dente 15, portanto, um guia de preparo foi desenhado e impresso em 3D para redução axial do dente. Na segunda, após o preparo de boca, foi realizada um novo escaneamento intraoral para aquisição dos modelos virtuais de trabalho. A estrutura da PPR foi projetada e impressa em um padrão de resina fundível e destinada à fusão da liga de cobalto-cromo. Na terceira, foi realizada uma avaliação clínica da estrutura e seleção dos dentes e cor da gengiva artificial. Os modelos articulados foram então impressos em 3D, permitindo a montagem e acrilização dos dentes pré-fabricados. Na quarta, a PPR foi instalada e o paciente recebeu instruções de rotina. Assim, o uso de tecnologias CAD-CAM se apresenta como uma ferramenta valiosa para a fabricação de PPR com necessidade de reestabelecimento de DVO.

Palavras-chave: Prótese Parcial Removível; Impressão Tridimensional; Projeto Auxiliado por Computador; Dimensão Vertical.

Resumen

El objetivo de este reporte de caso fue describir la secuencia clínica del restablecimiento de la dimensión oclusal vertical (OVD) con la fabricación de prótesis parciales removibles (PPR) producidas por diseño asistido por computadora y prototipado rápido. El paciente se presentó al Departamento de Odontología de la Universidad Federal de Rio Grande do Norte, refiriendo insatisfacción con el PPR superior. Clínicamente se observó fractura del conector menor y soporte en la región del diente 15, además de pérdida de DVO. En este caso, tras el restablecimiento del DVO, fueron necesarias cuatro sesiones más para la fabricación del PPR. En el primero, se realizó un escaneo intraoral para obtener los archivos STL utilizados para determinar el eje de inserción en el software CAD. Se observó la necesidad de un plano guía en el diente 15, por lo que se diseñó e imprimió una guía de preparación en 3D para la reducción axial del diente. En el segundo tras la preparación de la boca, se realizó un nuevo escaneo intraoral para adquirir los modelos de trabajo virtuales. La estructura de PPR fue diseñada e impresa en un patrón de resina fundible y pensada para fundir la aleación de cobalto-cromo. En el tercero se realizó una evaluación clínica de la estructura y selección de los dientes y el color de la encía artificial. A continuación, los modelos articulados se imprimieron en 3D, lo que permitió el montaje y la acrilación de los dientes prefabricados. En el cuarto, se instaló el PPR y el paciente recibió instrucciones de rutina. Así, el uso de tecnologías CAD-CAM se presenta como una valiosa herramienta para la fabricación de PPR con la necesidad de restablecer DVO.

Palabras clave: Dentadura Parcial; Impresión Tridimensional; Diseño Asistido por Computadora; Dimensión Vertical.

1. Introduction

Digital technology and its application to the design and fabrication of partial and complete-arch prosthesis is advancing rapidly. Computer-aided design and computer-aided manufacturing (CAD-CAM) systems, using both intraoral and laboratory-based digital scanning strategies, are being widely used in the design and fabrication of fixed, implant, and removable prostheses (Campbell, et al., 2017). The fully digital workflow was associated with advantages, including reduced risk of distortion during impression making, disinfecting and shipping to the dental laboratory, lowest cost and increased patient comfort and acceptance (Gimenez, et al., 2015; Marghalani, et al., 2018; Kattadiyil, et al., 2015).

In Removable Partial Denture (RPDs)-related therapy, adapting the RPD metal framework, relating the edentulous areas to the metal framework, are decisive for the longevity of the prosthesis and patient adaptation (Campbell, et al., 2017). So, accurate custom planning and fabrication of the RPD for each patient is a critical component of success. Previous studies showed promising results for the fit of RPDs fabricated by CAD-CAM systems, especially for Kennedy class III and IV defects (Arnold, et al., 2018; Chen, et al., 2019; Lang & Tulunoglu, 2014; Arafa, 2018; Carneiro Pereira, et al., 2020). Digital flow has become a reality for making RPD structures, from the use of scanning, planning and manufacturing, either by subtractive or additive method (Arnold, et al., 2018).

However, despite the numerous advantages, the currently practiced CAD-CAM methods for RPDs still have limitations, with regard to dentomucosupported RPDs (Kennedy class I and II framework). This occurs because the impressions are taken with the inclusion of soft tissue, such as a partially edentulous ridge, as well as the residual teeth (Hayama, et al., 2018). Some in vitro studies showed digital workflow provides better fit than traditional methods of impressions (Chen, et al., 2019; Ye, et al., 2018), which was also observed in a clinical study previously carried out (Tregerman, et al., 2019).

In dental treatment, the digital impression must be accurate to satisfactorily register the supporting soft tissues. Additionally, the posterior steps of manufacturing should provide good accuracy and excellent mechanical properties (Koutsoukis, et al., 2015). In this field, the literature has shown promising results for fully digital workflow in Removable Partial Dentures. And with regard to more complex cases, for example in large OVD (occlusal vertical dimension) losses and reestablishment of occlusal plans, successful treatment is also possible. So, this report describes a clinical sequence used in the fabrication of a removable partial denture (RPD) involving large OVD losses with a digital workflow (intraoral scanning and rapid prototyping for metallic framework).

2. Case Report

A 55-year-old patient attended the Dentistry Department of the Federal University of Rio Grande do Norte, reporting dissatisfaction with the upper partial removable prosthesis (RPD) that had a fracture in the support and minor connector at the region of tooth 15. Clinically, there was absence of dental elements 13, 16, 26, 34, 35, 36 and 46, configuring class II modification 2 in upper arch and class III modification 1 in lower arch, according to Kennedy's classification. In addition, it was identified severe loss of occlusion vertical dimension (OVD), unsatisfactory restorations at elements 14, 12, 11, 21, 22, 23 and 45, diastemas between dental elements 22 and 23, and changes in the smile curve on the right side (Fig 1). Prior to rehabilitation treatment to replace the RPDs, unsatisfactory restorations were replaced.

Figure 1: Old Removable Partial Prosthesis. (1A/1A2) Front view of the smile. (B) Occlusal view of the upper arch. (C) Occlusal view of the lower arch.

Source: Authors.

After conducting the clinical and radiographic examination, the vertical dimension was reestablished by adding acrylic resin to the occlusal surface of the patient's lower RPD artificial teeth, followed by the registration of maxillomandibular relationships in a Centric Relationship (CR). Therefore, the patient reported after 15 days of the aforementioned intervention, relief in facial muscles and improvement in chewing.

Intraoral scanning (3Shape-TRIOS) was performed by an experienced technician according to the sequence: occlusal/incisal face, buccal face and ending with the lingual/palatal face. STL (*Standard Tessellation Language*) files of digitalized arches and bite registration, were uploaded into *Dental Wings* software (DWOS v.9.06, Montreal - Canada) for RPD framework design procedures.

The CAD process began with model surveying and prosthesis path of insertion and removal determination according to the presence of guiding plans, retentive areas, interference and aesthetics factors. The CAD software allowed to ease surveying, guiding the operator with color gradient tools, ranged from light blue to red, that determines the amount of retentivity on each surface. Thus, path of insertion was determined to provide less retentive areas on the proximal surfaces, and ideal retentivity (0.25mm) at selected sites of abutment teeth, in addition to good reciprocity.

Thus, considering the limit between the blue and green colors, the software indicated desirable horizontal retention for the cobalt-chromium alloy (Co-Cr) for all the abutment teeth, absence of interference and need to prepare for the guide plane on the distal face of tooth 15 (Fig 2). In this case, the "*Bite Splint*" module of the *Dental Wings software* (DWOS v.9.06, Montreal - Canada) was used to fabricate a preparation guide to aid the clinician to prepare the axial walls of tooth 15 according to determined insertion path, (Fig 3). Once finished the preparation guide design it was converted into an STL file (Fig 4) and produced by additive manufacturing (Form 2 - Formlabs) in biocompatible resin (Cosmos DLP Clear - Yller).

Figure 2: Digital design. (A and C) Graphic interface of Dental Wings during the definition of the insertion and removal trajectory and analysis of the retentive areas. (A) Upper arch. (C) Lower arch. (B and D) Evaluation of the calibration in the regions planned to receive the active tip of the retaining clips. (B) Upper arch. (D) Lower arch.

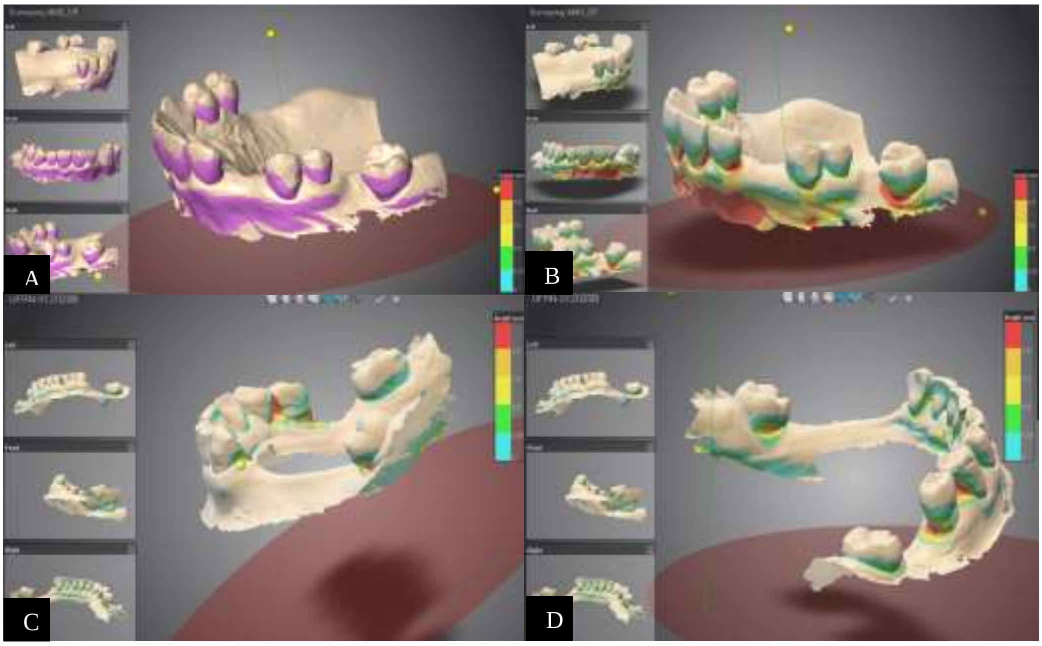

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Figure 3: Planning the transfer guide. (A) Alignment of the occlusal table surface with the insertion axis defined in the outline. (B and C) Vestibular and palatal view of the correct positioning of the guide. (D) Transfer guide finalized.

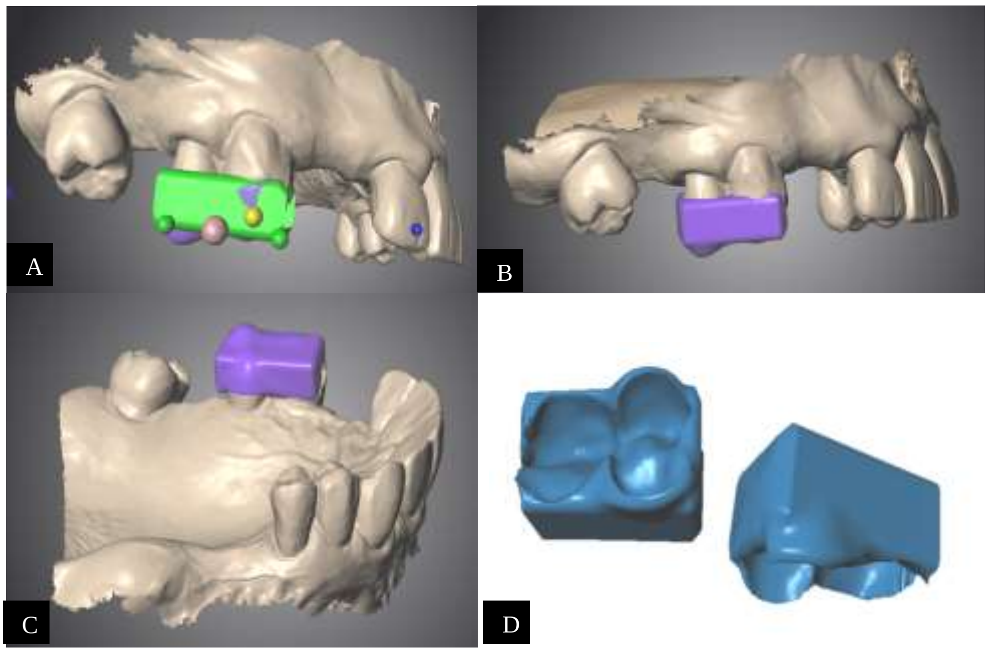

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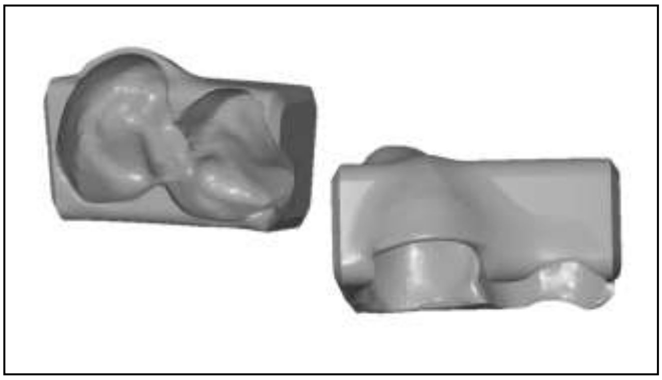
Figure 4: STL file of the transfer guide.



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The 3D printed preparation guide was positioned on tooth 15 to aid wear of the distal surface using a diamond bur (KG 4219), aiming to provide a surface parallel to previously defined path of insertion (Fig 5), and lingual and occlusal rest seats were prepared in the abutment teeth 12, 14, 15, 16, 25, 38, 45, 47 with a diamond bur (KG 2130) to provide support. After mouth preparation, intraoral scanning (3Shape-TRIOS) of the arches was performed again following the same technique described above. In these moment maxillomandibular relationships was recorded by intraoral scanning using an interocclusal device (Lucia's JIG) (Lúcia, 1964) made with self-curing acrylic resin, with arches in centric relationship and with restored occlusion vertical dimension (Fig 6).

Figure 5: Adaptation of the transfer guide printed on tooth 15. (B) Preparation of the axial wall of tooth 15.

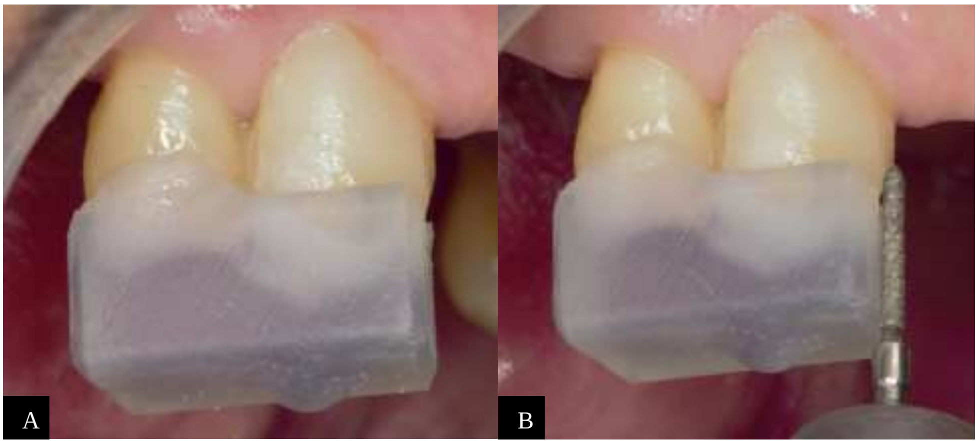

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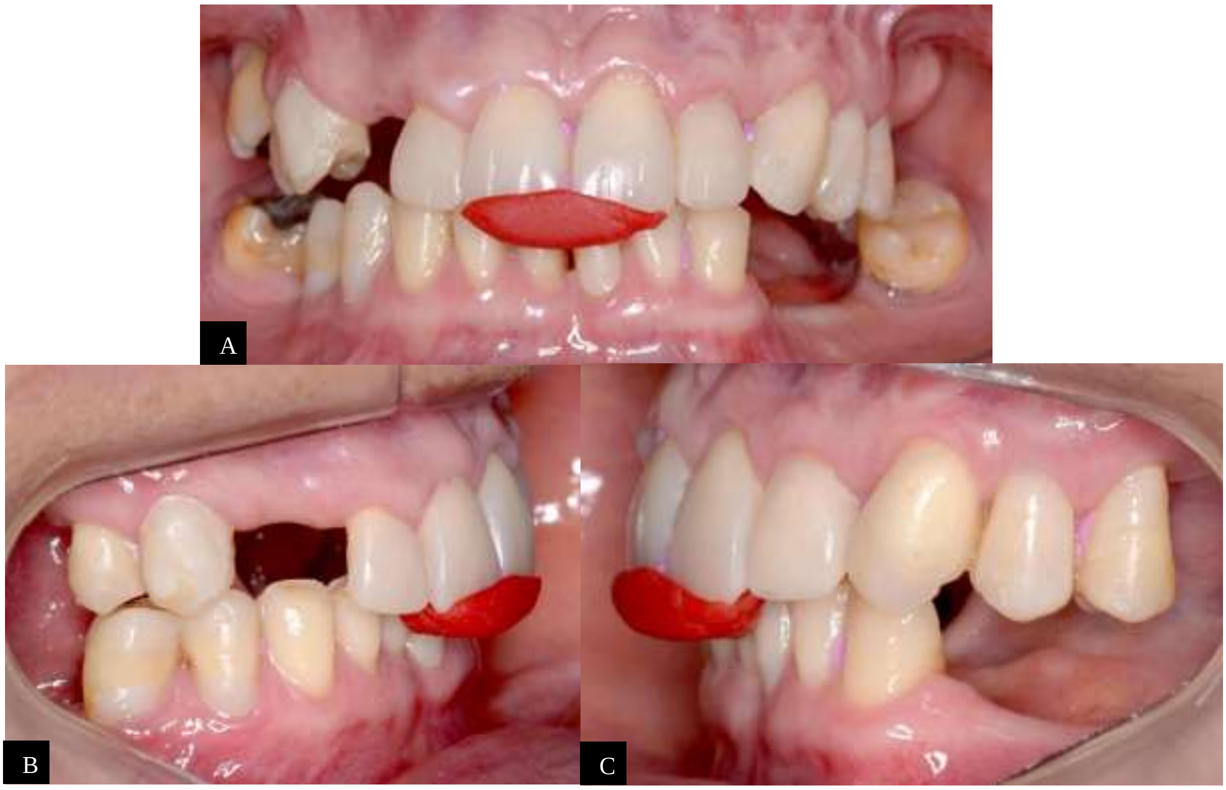
Figure 6: Interocclusal device. (A) Front view of partially edentulous arches in occlusion with the interocclusal device. (B) Right side view. (C) Left side view.



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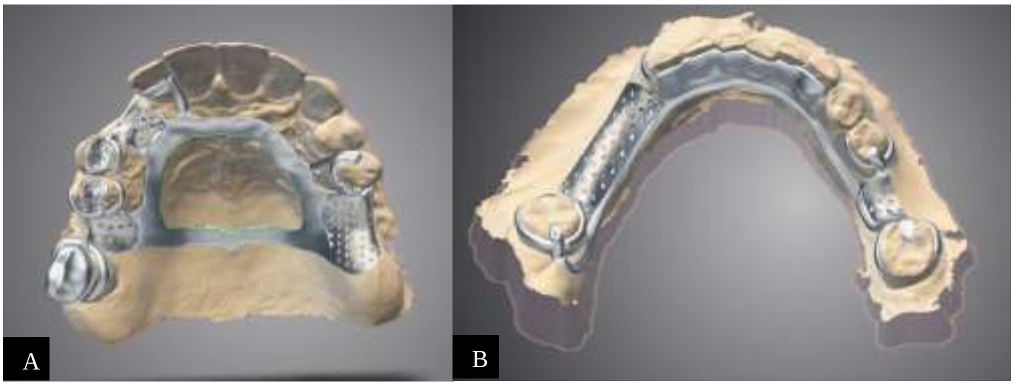
STL files corresponding to the working models (upper and lower), were uploaded to *Dental Wings CAD software* (DWOS v.9.06, Montreal - Canada) for RPD framework design. The CAD design workflow began with path of insertion determination and surveying analysis. Then the software performed the blocking of retentive areas, and the technician proceeded the design of RPD´s metal framework. This proccess was digitally performed under the same biomechanical precepts involved in conventional planning. To restore the OVD, metal overlays were projected on teeth 17, 14 and 15 (Fig 7).

Figure 7: Digital planning of the metallic structure. (A) Metallic overlay structure on teeth 17, 14 and 15 to restore occlusion. (B) Lower metallic structure.

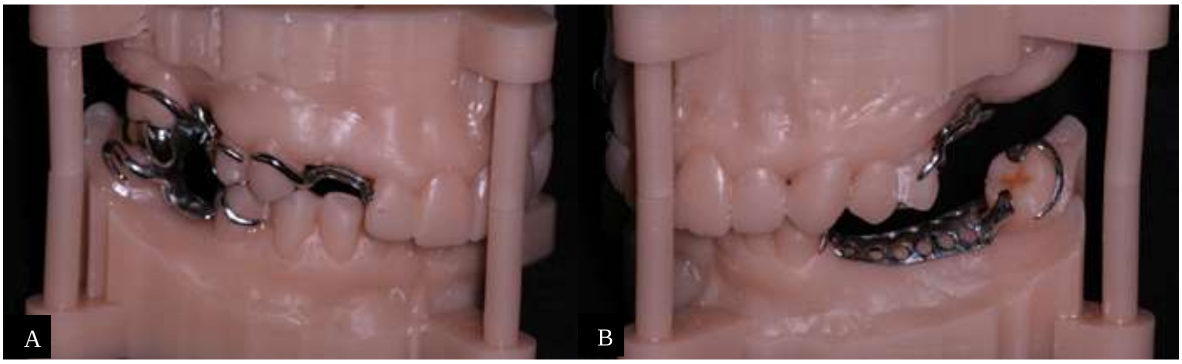


Source: Authors.

Once concluded the design, maxillary and mandibular metallic frameworks and articulated models were exported to a 3D slicer software to prepare them for production by additive manufacturing in a DLP/LCD 3D printer (Anycubic®, Guarulhos, São Paulo, Brazil) using a castable light curing resin (Envisiontec, Gladbeck, Germany). The 3D printed frameworks were then invested for cobalt-chromium alloy (Remanium® GM 280, São José do Rio Preto, São Paulo, Brazil) lost-wax technique. The invested frameworks were placed in a gas burning oven (Midither 200 MP, Bego) and heated to 650°C for 30 minutes, and then the temperature was raised to 1010°C. Afterwards, alloy was casted at 1440ºC in an induction casting machine (Fornax T; Bego).

The metallic frameworks were finished and polished in a conventional manner. Afterwards, the fit was evaluated on 3D printed models, in order to access the adaptation (Fig 8). With the structure in the mouth, the trajectory of insertion and removal and total seating of the supports on the rests were evaluated, as well as retention, stability and occlusion revealing good adaptation with no necessary adjustment (Fig 9). Then, gingiva and teeth colors were selected from the scanner *software* used for digitizing the arches (3Shape-TRIOS). Thus, the pre-fabricated teeth were assembled to the framework using articulated 3D printed models on interocclusal record acquired by intraoral scanning. The prosthesis processing was finalized by conventional press and pack of microwave heat polymerized acrylic resin.

Figure 8: Clinical proof of the metallic structure. (A) Front view of the smile. (B) Right side view. (C) Left side view.



Source: Authors.

Figure 9: 3D printed articulated models and adapted metal structure under them.

Source: Authors.

The both removable partial dentures showed good adaptation (Fig 10), that was confirmed with the use of pressure indicator paste (Pressure Indicator Paste; Henry Schein), and minor occlusal adjustments. During the installation appointment patient also received routine instructions for insertion, removal and maintenance of the new RPD. The patient was scheduled for follow-up visits after 7 days, when minor adjustments were needed only on left posterior vestibular flange of maxillary prosthesis, and after 15 days, when no adjustment was needed and patient reported comfort and satisfaction with the treatment.

Figure 10: Removable partial denture manufactured by computer aided design and rapid prototyping. (A and B) Front view of the smile. (C) Right side view. (D) Left side view.

Source: Authors.

3. Discussion

The use of sophisticated 3D modeling programs associated with additive methods for planning and manufacturing a removable partial denture with restoration of the vertical dimension of occlusion has proved to be an option in view of the limitations found in the conventional workflow.

Traditionally, RPD involves the use of impression materials that certainly promote discomfort (Soltanzadeh, et al., 2019). In this perspective, intraoral scanning can be a solution to minimize gagging and, consequently, provide greater comfort for the patient. However, intraoral scanners for scanning soft tissues have disadvantages that may limit their application. The technology used by these devices requires the succession of images to be sewn to form the three-dimensional image of dental morphology and soft tissues, necessary for the digital planning and preparation of RPD (Lee, et al., 2017). In this sense, intraoral scanners do not capture with such fabrics that would normally be by the conventional method.

Despite this, intraoral scanning to capture the morphology of the oral cavity proved to be a precise alternative to the construction of structures by the conventional workflow. We believe that this was possible, even in the case of a class II (upper arch), whose limitations involve the capture of distal extensions of the mobile mucosa (Kattadiyil, et al.,2014) and class III (lower arch), presence of soft tissues (Mansour, et al.,2016), due to the extension reduced edentulous areas.

In this case, the metallic structure of the RPD was made from the printing of a pattern of the structure in castable resin for, later, conventional casting. The results of previous studies (Kattadiyil, et al.,2014; Mansour, et al.,2016; Hu, Pei & Wen,2019; Mendes, et al.,2019) as well as this clinical case, did not eliminate the clinical stage of testing the metal structure, and also demonstrated excellent adaptation under printed and mouth models. Although it was not used in this clinical situation, the impression of the calcinable structure (Lee, et al.,2017; Kattadiyil, et al.,2014; Pereira, et al.,2019) allows clinical testing before the casting of the cobalt-chromium alloy, allowing possible adjustments.

The use of *software* to perform the digital design provided the identification of preparation of the axial walls of the abutment teeth, retentive areas and the need to change the prosthetic equator. This makes it possible to eliminate the molding step, eliminating the conventional model. In addition, it reduces the working time, possible transfer errors found in the conventional method and also allows the archiving of the executed planning.

In line with the indication of the software for determining the guide plan presented by the present case, two previous studies also showed similar results (Lee & Kwon, 2019; Loney, Lee & Michaud, 2017). The first (Lee & Kwon, 2019), presented the manufacture of a device to guide the guide plans and reciprocity with precision. He suggested that the use of *software* facilitates the making of transfer guides in comparison to conventional methods and produces an accurate product. However, the results are *in vitro* and have not been compared with the conventional method. The second study (Loney, Lee & Michaud, 2017) described a technique using an intraoral scanner and, from the generated images, prepared and evaluated the form of occlusal rest and the guide plans for the RPDs. This technique proved to be efficient, but it requires preparation software that is not attached to scanners.

The "*Bite Splint*" module is part of the package of the main CAD *software* available (EXOCAD, 3SHAPE, DWOS), so it can be part of all laboratories that wish to introduce the digital workflow. No additional investment is necessary and for its production, additive or subtractive technologies can be used with precision, regarding the adaptation of the guide under the tooth to be prepared. In addition, it is not known to us studies that presented the identification of retentive areas by the *software* as well as addressed by this clinical case.

As for the prosthesis base and artificial teeth, we believe that the conventional method is still superior to the digital one, given some limitations. The teeth when designed by the *software* even make it possible to change the size and shape, duplicate or mirror existing teeth and perform occlusal adjustment in virtual articulators to promote better alignment with adjacent teeth (Virard, et al., 2018). However, they need to be polished or glued to the base of the prosthesis and in some situations characterized using coloring materials (Hamanaka, Isshi & Takahashi, 2018). In this sense, additional time is needed for more technical work and improvement of skills for the application of this technique (Takahashi & Nishiyama, 2020).

In this case, the use of the images obtained by intraoral scanning for digital design of the 3D model, preparation of guides plans for the abutment teeth and modeling of the metal structure, reduced clinical steps and minimized errors inherent to the conventional method. However, despite the advantages mentioned above, we highlight the acquisition of high-cost equipment, team calibration and mastery of rapid prototyping techniques.

Regardless of the workflow used, adequate planning for prosthetic rehabilitation should not imply the restoration of OVD to new prostheses, and the patient may not adapt. In view of this, it is still necessary to perform this step when necessary, using graphical software resources to measure the amount of addition required or conventional method. Both allow to evaluate the relation of the added material with the maxillomandibular relations, through the trajectory of mandibular disocclusion, observing possible interferences during excursive movements. In view of the possibilities and absence of studies that prove the superiority of any of the methods, we opted for the conventional flow to obtain a new OVD.

In this perspective, the use of design *software*, rapid prototyping and the conventional workflow can be easily used as an alternative to the steps already known for making the RPD with occlusal rehabilitation. Thus, the use of intraoral scanning and 3D programs can be used to determine the axis of insertion and removal of the metal structure, as well as, the identification of retentive areas and the need for a guide plane. In addition, rapid prototyping can provide structures with acceptable clinical fit and is an option when applied.

4. Conclusion

The intraoral scanning and the 3D *software* used for digital design showed potential to determine the regions of the guide planes, retentive areas and prosthetic equator. The rapid prototyping allowed the design and production of guides for preparing the abutment teeth in a precise and fast way, eliminating the need for moldings, physical models and allowing, through a resin guide, to direct the clinician regarding the area, angulation and depth of the necessary preparation. In addition, it made it possible to make part of the process necessary for making the metal structure of the RPD with the involvement of a new OVD, with clinically acceptable results regarding the adjustment.

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