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Case Report

Metal Framework for Removable Partial Denture Fabrication by Selective Laser Melting

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Abstract

The appearance of CAD/CAM has led to a disruption of conventional laboratory manufacturing techniques. Some design steps are added, modified or removed.

In both cases, whether digital or conventional technique, the goal is to achieve the same result: a stable prosthesis, adjusted and integrated into the patient's dental and mucous structures. Selective Laser Melting (SLM) is an additive manufacturing technique producing metal pieces (crowns, bridges, metal frames) using a high-power laser. This manufacture is direct, so, instead of making models in wax or calcinable resin, we directly manufacture metal fittings, mainly cobalt-chrome. Through this article we will describe the SLM technique for removable partial denture metal framework, the advantages and disadvantages of this technique compared to the conventional procedure.

Keywords: Laser Melting, Denture Fabrication

Introduction

Rehabilitation by metallic removable partial denture (RPD) still indicated, despite the considerable development of surgical and implant techniques allowing fixed prosthetic rehabilitation to be considered for many situations [1].

Thus, metallic removable partial denture is a therapeutic alternative demonstrating effectiveness, to fully benefit from technological advances.

The metal framework is the key element of the removable partial denture, providing a structural support for the fixation of artificial teeth. It offers superior strength and durability compared to other partial removable prosthesis. However, its manufacture by the conventional method can be a long and costly process. Actually, two different processes are used for RPD framework fabrication: Manufacturing by subtraction (machining) and fabrication by addition (stereo lithography, Fused Deposition Modelling, laser sintering and fusion) [2].

Selective laser melting (SLM) is then an additive manufacturing method that has emerged as a promising alternative for the production of metal frameworks [3].

The objective of this work is to illustrate through a clinical case the technology of metal frames production by SLM technique and to present the difference between two additive manufacturing techniques: selective laser sintering (SLS) and selective laser Melting (SLM) commonly used for frameworks.

Case Presentation

A clinical situation of a Class I mod 3 of Kennedy Applegate edentulism was chosen to describe its fabrication with SLM.

After scanning the master model, Computer-aided design (CAD) of the metallic RPD was made. The CAD steps were performed using "DENTAL WINGS" design software. It is actually the most advanced and the most fluid software.

The technician modeled the framework from an STL file after saving the scanned master model. In its latest version 7.0, the Dental Wings software offers the ability to combine the realization of fixed and removable prosthesis.

The procedure started by determination of the insertion axis using a digital surveyor. A first default axis was given, then it can be modified in the software to obtain the best insertion and optimal retention of the prosthesis.

The back-cuts will then be indicated by the software, presented on the model by a color code varying according to its depth (Figure 1).

In a second time, automatic parallelization of the model was made by adding virtual wax to backfill undercuts and to get space to properly place the clasps retention arms. Then, framework modelling may be made.

All preforms are presented in the "Partial design tools" section, then the installation of all the components was made: clasps, plates, resin stops, rests….

The technician can change the diameters and thicknesses of different elements.

After modeling, the virtual design is transformed into an STL file (Figure 2).

Once the framework is designed, the next step was to move to Computer-aided manufacturing (CAM) using SLM process

Preparation of the file for the manufacturing step in the laser micro-fusion machine: Once all the modeling steps have been completed and controlled, the design was imported to the manufacturing unit as an STL file.

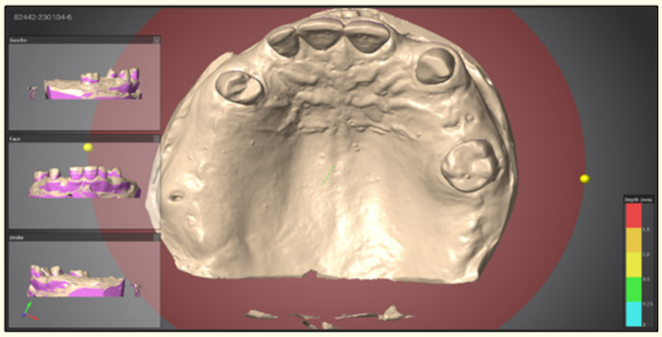

Figure 1: Determination of the insertion pathway and presentation of undercuts.

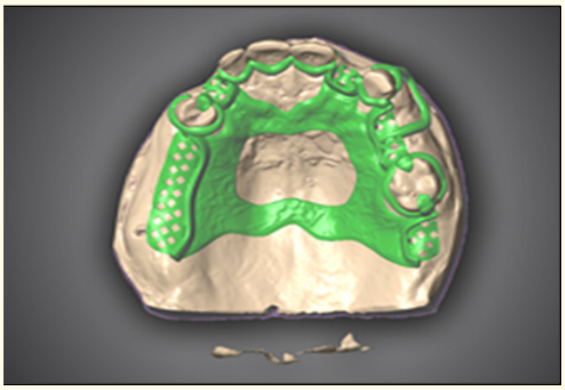

Figure 2: STL file of the final framework design.

The 3D printing process is provided by "Magics Print for HanBang 22.32".

Magics Print for HanBang 22.32 is a file preparation software for 3D printing by checking the quality of the file. However, it should be noted that the software is intended to be used with HanBang 3D printers specifically. It is important to check that your printer goes with before using it.

The software allows to create supports for complex parts of the parts. It also allows to configure print settings and reduce the time of the operation by using the appropriate settings.

Using Magics Print for HanBang 22.32 can improve the quality of 3D prints. The choice of material and the thickness of the layers that define the precision of the part are made in the list of materials contained in this software. The STL file is then opened in the software (Figure 3).

The supporting rods are then positioned at different points on the frame, and these rods are used to secure the frame to the construction platform. They are very thin and easy to remove (Figure 4).

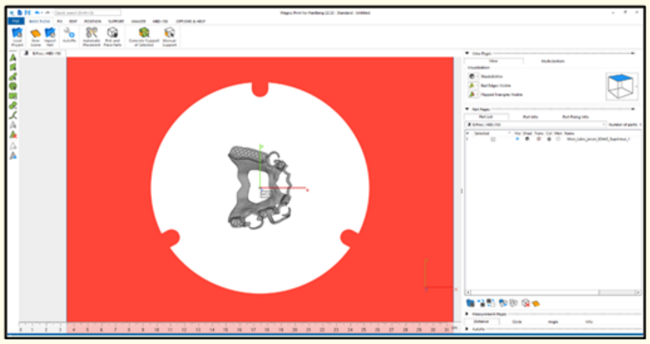

Figure 3: Positioning of the piece.

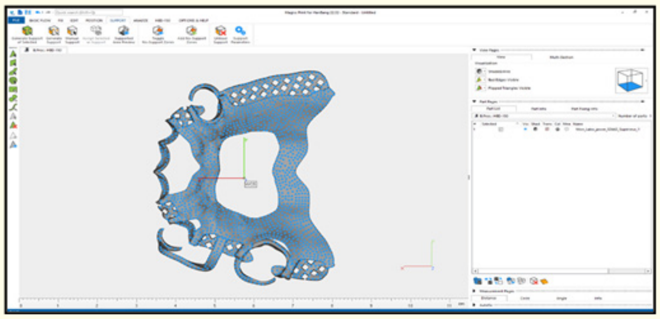

Figure 4: Positioning of the supporting rods.

Preparation of the selective melting device by laser consist firstly on preparation of metal powder: Metal powder is prepared according to the material of the piece and the specifications of the device. For this framework the material was Cr-Co. The powder is usually distributed evenly on a plate, the laser micro-fusion device is configured with the appropriate manufacturing parameters for the material and design of the piece.

The laser beam is directed towards the metal powder which is then melted beyond its melting point to achieve complete fusion. The laser beam scans the construction area along the contours of the part, fusing and solidifying the metal powder layer by layer. The layers are fused together to form a solid part (Figure 5).

Removal of the framework after fabrication

Once the piece is manufactured, the next step is to remove the frame from the unit. But waiting for cooling is mandatory. After manufacture, the part should be left to cool at room temperature before removing the frame. This allows the piece to solidify completely and reduces the risk of deformation (Figure 6).

After removing the piece, it should be cleaned to remove any metal powder. Cleaning can be done with brushes and compressed air. The framework must be inspected to ensure that it meets design specifications and quality standards.

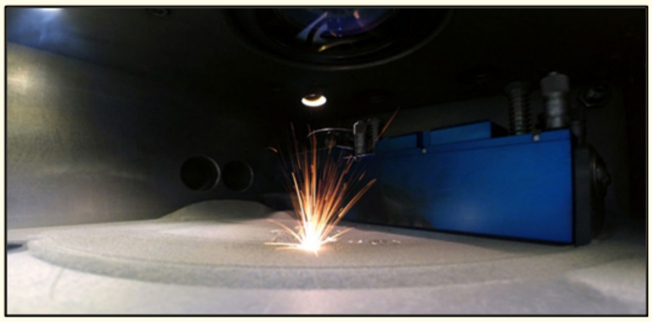

Figure 5: Fabrication in process.

Figure 6: Fabrication in process.

Post-treatment consists on heat treatment

The rapid heating and cooling of the metal during the manufacturing process causes internal stresses. For this, the framework was subjected to a stress relaxation treatment by heat treatment which consists of a controlled heating and cooling process of the materials in order to modify their physical and mechanical properties.

This treatment is carried out using a specific oven to regulate the microstructure of the material and improve its mechanical properties.

The main steps of heat treatment are

Heating: The piece is placed in an oven and heated to a specific temperature for a specified time. The temperature and time depends on the material of the part and the desired thermal properties. In our case this process was done at 900°C.

Maintenance: Once the piece has reached the desired temperature, it is maintained at this temperature for a period of time. This step allows the material to undergo the necessary structural changes. Heat treatment time for our metal frame: was two hours in the oven.

Cooling: The piece is then cooled at a controlled speed, which can be fast or slow depending on the desired heat treatment. The cooling rate also affects the material properties.

After heat treatment, we proceed to

Positioning, Rod Cutting then Sand blasting: This involves the projection of steel balls onto the framework to remove impurities and powder residues that may have been created during the melting process. Sandblasting increase wear resistance of the piece.

Finally a polishing is needed: This operation consists of smoothing the surface of manufactured parts to remove the roughnesses and imperfections that are created during manufacture. Polishing can be done manually or by machine.

The dry electropolishing machine «DLytePRO500», the most advanced and powerful of the electroless surface finishing machines, was used for electro-polishing.

Using the «DLyte» technology, electrofinishing dry, allows to polish parts with complex shapes by combining the power of electrochemistry with a precise mechanical movement.

The plaster model on which the first scan was performed has been fractured. So, a computer-aided manufacturing (CAM) of resin model by 3D printing (Figure 7) on which the framework was positioned to verify fitting, was necessary. A model in lumina optiprint® resin was made by 3D printing since we have all the data recorded in the software «Dental Wings». (Figure 8).

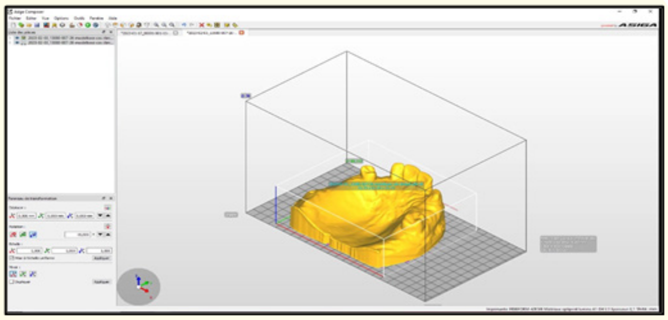

Figure 7: Model positioning on print tray.

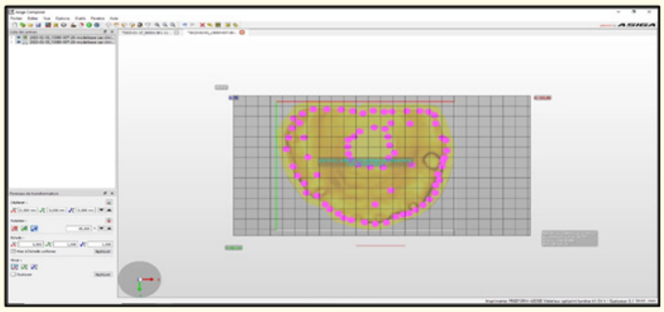

Figure 8: Positioning rod control required.

Figure 9: Final metal framework

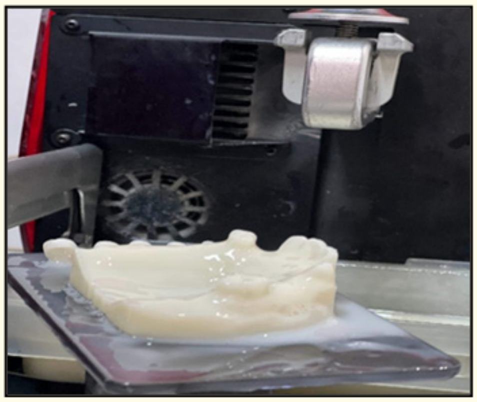

Figure 10: The resin model.

The final step is the adaptation of the finished metal frame [9]. on the resin model so we have to adapt it on the printed model (Figure 10).

Discussion

The main 3D printing processes used in dentistry are

- The FDM (Fused Deposition Modelling).
- Photopolymerization: It is a chemical process used in SLA (Stereolithography) and DLP (Digital Light Processing) technique.
- Metal additive manufacturing: mainly represented by SLM (Selective Laser Melting or Fusion Laser) and SLS (Selective Laser Sintering or Sintering Laser).

Compared to subtractive milling methods, additive printing is not only more cost-effective and less material-intensive, but also allows the production of complex 3D geometries directly from digital designs [4,5].

Manufacturing of metal RPD can exploit these two processes of CAD/CAM technologies, except that the subtraction process does not give efficient results because of the complex forms of frameworks, especially in clasps. Machining is not a suitable shaping process [6]. It is important to differentiate between SLM and SLS (Selective Laser Sintering). For sintering (SLS) is a manufacturing process consisting of heating a powder without bringing it to fusion. The laser then "coagulates" the powder passing through according to the diagram defined by the computer [7,12].

Under the effect of heat, the grains are welded together, which forms the cohesion of the piece. It allows hard materials to be obtained with "controlled porosity" [8].

At the same time, SLM's fabrication of metal reinforcement is a competing technique to SLS and seems promising for routine clinical practice.

Micro metal laser melting consists of the total melting of metal powder grains by a laser beam, then the molten powder is quickly solidified forming parts produced 100% density. This method has the advantage of ensuring perfect homogeneity of the alloy and better resistance to aging in the oral cavity and allows any type of simple or complex parts [9].

SLS and SLM can therefore be used to print cobalt-chrome alloy (Co-Cr) or even titanium.

Advantages of SLM Laser micro-fusion are multiple

Durability and resistance: Dental parts made with the SLM technique are generally very durable and resistant, as they are composed of metallic materials such as titanium. They offer good wear resistance and can last a long time.

Geometric complexity: SLM laser micro-fusion allows for the manufacture of complex dental parts with internal shapes and structures that would be difficult or impossible to achieve with other manufacturing techniques.

Precision and adaptation: SLM laser micro-fusion allows the manufacture of dental prostheses and implants tailored to the specific morphology and needs of each patient. This allows for optimal fit and increased comfort [10].

Limits of SLM technique are especially

Cost: The implementation of SLM equipment and the use of high quality metal materials can lead to high costs. This can make prostheses and implants made with this technique more expensive for patients. (11)

Finishing and adjustments: Although the SLM technique offers high precision, additional adjustments may be required to achieve a perfect fit of the prosthesis or implant into the patient's mouth. Manual touch-ups or finishing may be required [13,14].

Digital frameworks manufacturing is still in its beginning, but as the number of design software available increases and manufacturing technology advances, opportunities for adjustment and precision improve [15].

Conclusion

3D printing with its range of techniques and materials has become a must in dentistry thanks to its flexibility in production, efficiency, speed and precision.

Additive techniques allow the optimization of manufacturing processes for prosthesis and various dental appliances long dominated by machining technology, thus compromising the final quality of products.

Their main interest lies in the manufacture of custom-made devices, a major problem in medicine and particularly in dentistry.

Manufacture of prosthesis frames by laser micro-fusion is a direct manufacturing that has the most future for the manufacture of frames. It is faster and more cost-effective than the conventional process or machining process.

3D modelling of the chassis is directly materialized in its final material in cobalt chrome (or titanium). The handling required for finishing is limited to heat treatment and cutting of the support rods, then a simple polishing.

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