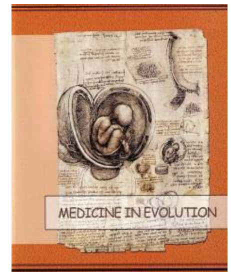
Metal-ceramic restauration with an SLM achieved framework



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Abstract

Laser Melting (SLM), a complex technique because of it requires close monitoring of the procedure. It combines modern CAD / CAM technology with the classic application of layer-by-layer ceramics, the material used allowing the selection from a wide range of colours, and thus giving the possibility of customization, aesthetic reproduction and at the same time a functional prosthetic restoration. Materials may include copper, aluminium, stainless steel, steel for tools, chromium cobalt, titanium and tungsten. The equipment used to obtain the metal frame by the SLM process is Mlab cusing 200R. Laser beam scanning is an essential task because these parameters happen to be the most influential on the characteristics.

Keywords: SLS, SLM Metal-ceramic restauration, CAD-CAM, Stereolithography

INTRODUCTION

From time immemorial, the smile and the appearance of the teeth have a special importance in appreciating a person's beauty. Both the beauty and the harmony of the face represent a continuous concern for people, having a special impact in interpersonal relationships. Human's constant preoccupation with beauty is a constant of life, regardless of the historical epoch in which he lives, that is why every human has tried by innumerable means to satisfy this demand. At the moment it can be said that a satisfactory performance has been reached. By combining two components, alloy and ceramic, one of the most resistant types of prosthetic restoration was made, combining beauty and functionality. The used technology is Selective Selective laser melting (SLM) technology was developed 25 years ago at the Fraunhofer ILT Institute in Aachen, Germany. The technique itself is not a difficult one, but rather complex, due to the procedures to be followed [1]. The process aims to combine modern CAD/CAM technology with the classic application of layer-by-layer ceramics, rendering the idea of compatibility between past and present. In terms of aesthetics, the material used allows the selection of a wide range of colours, with the ability to customize and reproduce aesthetically and functionally the prosthetic restoration.

Aim and objectives

The aim of the paper is to presents the technical process of SLM. The equipment used to obtain the metal frame by the SLM process is Mlab cussing 200R, a 3D metal industrial printer that uses powder 3D printing technology, offering a build volume of 100 x 100 x 100 mm. The virtual model was obtained using Exocad software and a laboratory scanner that scans with white light strips, Vinyl Open Air. The metal frame was clad in successive layers with ceramic. Glazing was done with powder (Vita AKZENT Plus Glaze) and liquid (Vita AKZENT plus Powder Fluid)

METHOD DESCRIPTION

Materials used to obtain the metal framework by the SLM process may include copper, aluminium, stainless steel, steel for tools, chromium cobalt, titanium and tungsten. SLM is also useful for the production of tungsten parts due to the high melting point and high temperature of ductile-brittle transition of this metal [2] [4].

In order for the material to be usable, it must be in atomized form (powder). These powders are previously atomized with gas, the most economical process for obtaining spherical powders on an industrial scale. Sphericity is desirable because it guarantees high cut ability and packing density, which translates into a fast and reproducible spread of powder layers. To optimize the flow, narrow-gauge distributions with a small percentage of fine particles such as 15 - 45 µm or 20 - 63 µm are usually used. Currently, the alloys used in the process include stainless steel, maraging steel, cobalt chromium, Inconel 625 and 718, aluminium [3][5] AlSi10Mg and titanium Ti6Al4V [6].

The mechanical properties of samples produced by using SLM differ from those manufactured by casting [7]. Improvements to the mechanical properties of SLM have been attributed to a very fine microstructure [9]. The next generation of addition is the direct laser melting process (DMLM) [8]. The power of the laser has an influence on the density and microstructure [9, 10]. Remanium star CL (Dentaurum) - powder for laser melting [11] is in the form of a powder intended for local melting with the help of a high energy laser beam with a high energy density [11].

The equipment used to obtain the metal frame by the SLM process is Mlab cusing 200R. This is a 3D metal industrial printer produced by Concept Laser (Germany), launched in 2017, which uses powder 3D printing technology, offering a build volume of 100 x 100 x 100 mm.

RESULTS

SLM uses a high density laser to melt metal powders [12]. The process itself begins by cutting the data from the 3D CAD file into layers, usually having a thickness from 20 to 100 micrometers, creating a 2D image of each layer; a standard STL file format used in most 3D printing or layer-based stereolithography technologies. It is then loaded into a file preparation software package that assigns parameters, values, and physical media that allow the interpretation and construction of the file by different types of additive manufacturing machines.

In the case of selective laser melting, the thin layers of finely atomized metal powder are evenly distributed by using a coating mechanism on a substrate plate, usually metal, which is fixed on an indexing table moving on the vertical axis (Z). Most SLM machines operate with a workspace of up to 400 mm in X&Y and can go up to 400 mm in Z. The process takes place inside a chamber that contains a controlled atmosphere of inert gas, either argon or nitrogen, at oxygen levels below 500 parts per million. Once each layer has been distributed, each 2D slice of the part geometry is fused by selectively melting the powder. This is done with a high power laser beam, usually a ytterbium fiber laser with hundreds of watts. The laser beam is directed in the X and Y directions with two high-frequency scanning mirrors. The laser energy is intense enough to allow complete melting (welding) of the particles to form solid metal. The process is repeated layer by layer until the piece is complete [13].

The type of ceramic used to veneer the metal framework is VITA VM 13, feldspathic ceramic for veneering conventional alloy metal frameworks with CTE between 13.8 and 15.2. In addition to a low firing temperature, the Vita VM13 has high bending strength, thermal stability and low solubility compared to conventional ceramics [14]. It is found in a wide range of Classical Shades: DA1, DA2, DA3, DA3.5, DA4, DB1, DB2, DB3, DB4, DC1, DC2, DC3, DC4, DD2, DD3, DD4, to which are added the shades from the Professional range [15].

The firing temperature of the dentin, 880 ° C, ensures processing reliability, especially for alloys with a low solidification temperature <1100 ° C. Due to its homogeneous, compact surface, the processing and polishing are of good quality. The accumulation of plaque on the surface of the ceramic is significantly reduced.

For the realization of the special nuance effects, for the individualization of the restorations, the following stains are available: VITA AKZENT Plus and VITA INTERNO [16]. The main advantages of using Vita VM 13 are:

- Natural effects of shadow and light, due to the fine structure;
- Minimum contraction for precise burning;
- Excellent modelling features for fast and precise application of ceramics;
- Full range of additional materials for excellent effects;
- Efficient and cost-effective processing;
- Individualization with the help of VITA AKZENT Plus and VITA INTERNO; and
- Available in VITA 3D-Master and VITA classic A1-D4 [16].

Ceramics are applied with specific brushes, of different shapes and sizes, in several layers. Due to the contraction during burning, the dental technician will shape the artificial teeth about 25% larger to compensate. At the time of application, the ceramic can have various colours (white, purple, pink) depending on the manufacturer. The final colour is obtained only after burning [17]. The base layer is the thickest, gives the base shape of the crown and defines its colour. Depending on the data sent by the doctor, the appropriate shades will be positioned for each area of the tooth. Normally, the gingival areas have a darker shade and the incisal areas are lighter [17]. The correction or retouching layer is the layer in which small corrections can be made. More importantly, it is the layer in which certain features are created that are characteristic of different areas of the tooth. The dental technician can create special colours to give a more natural look to the artificial tooth [17] The finishing layer or glaze ensures the final gloss of the ceramic. It is extremely thin and will ensure a smooth and smooth surface as well as the characteristic translucency that mimics the enamel. The icing layer will not affect the shape or size of the restoration in any way, but it can make small changes in shade [17].

To obtain the virtual model, a laboratory scanner was used, which scans with white light strips, Vinyl Open Air and an Exocad software. To start the scan, the top model had to be mounted in a holder and inserted into the scanner. (Fig. 1)

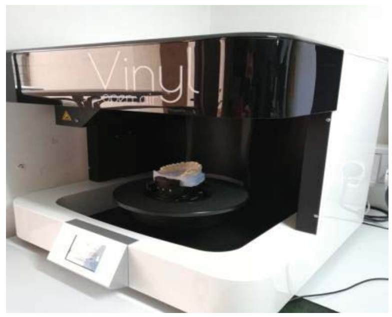


Figure 1. Vinyl Open Air scanner and superior model scanning

Before the scanner performed the scanning procedure, it was necessary to enter in its software a series of parameters necessary for scanning. For the beginning, it was considered to complete the patient file, the selection of abutments, neighbouring teeth and antagonists. (Fig. 2.a) The next step being the selection of the desired material, in this case NP Metal (Laser) (Fig. 2.b.), and finally the maxillary (Fig. 2.c) and mandibular (Fig. 3) models were scanned.

a b. c.

Figure 2. a. Completing the patient file, selecting abutments, neighbouring teeth and antagonists; b. Material type selection, in this case NP Metal (Laser); c. Scanning maxillary model

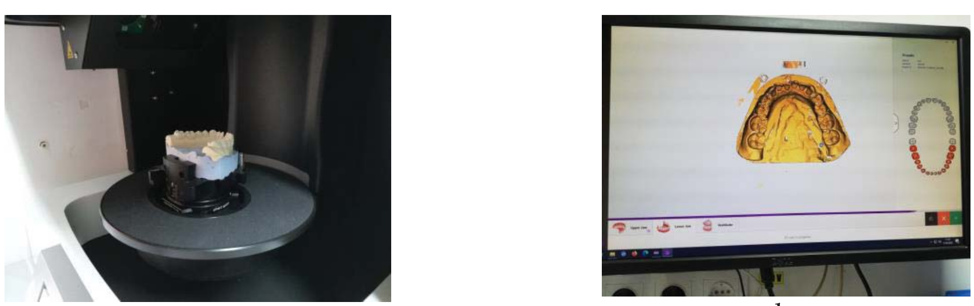
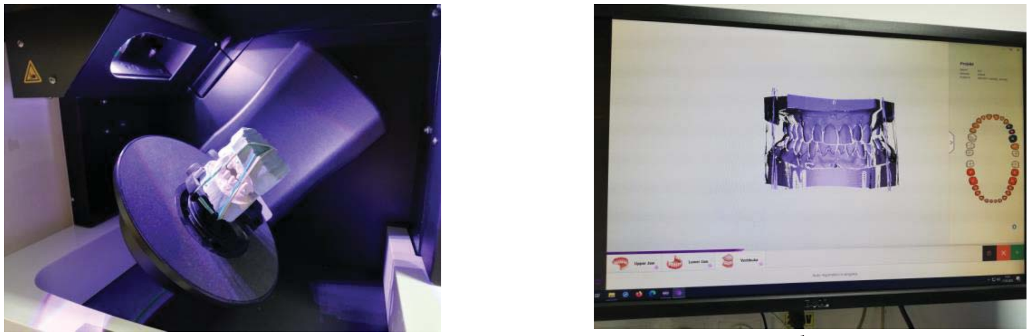

a. b.

Figure 3. a. Inferior model scanning; b. The mandibular model

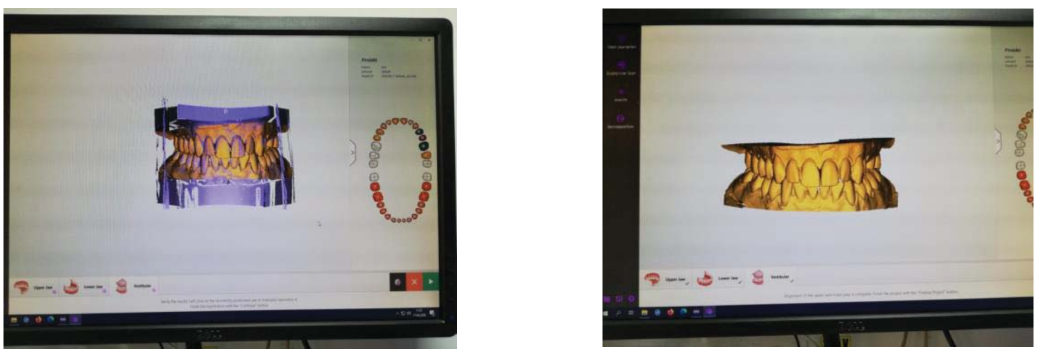
After obtaining the virtual models, they (both maxillary and mandibular models) are mounted in the maximum intercuspid position, with the help of elastics to keep them in the PIM, in order to scan the interference of the teeth in contact and occlusion. (Fig. 4)



a. b.

Figure 4. a. Scanning of models mounted in maximal intercuspidal position; b. Virtual models in MIP

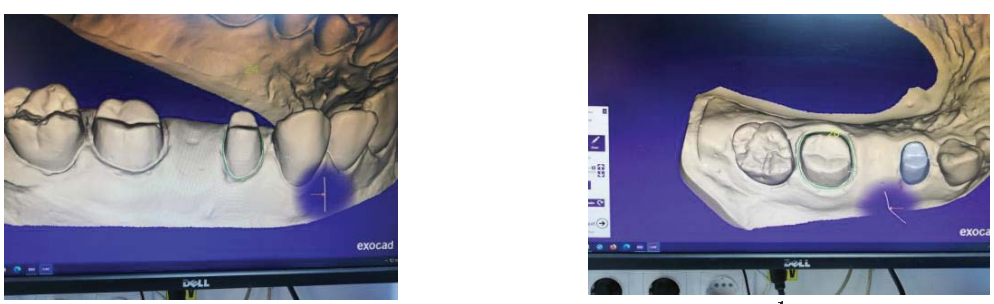
Following the scan, virtual occlusal reports of the models were obtained, but to obtain greater accuracy, three reference points of the models scanned in MIP were used, together with those scanned separately. Following this procedure, their overlap was generated (Fig. 5.a), thus reaching the final virtual models (Fig. 5.b).



a. b.

Figure 5. a. Overlapping virtual models through reference points; b. the final virtual models

After scanning the virtual models, the next step is to design the prosthetic restoration using Exocad software. The limit of the preparations of each abutment was marked (2.4 and 2.6) (Fig. 6).



a. b.

Figure 6. a. Drawing the limits of the preparations on 2.4; b. Drawing the limits of the preparations on 2.6

After this stage, the completion of the virtual restauration was obtained (Fig. 8) by passing the following stages: the thickness of the cement was marked (Fig. 7.a), the positioning the anatomical teeth (Fig. 7.b), the structural reduction the individualization of the restoration (Fig. 7.c), and the addition of the connectors (Fig. 7.e)

a. b. c. d.

Figure 7. a. Delimitation of the cement coating area and its thickness; b. positioning the anatomical teeth; c. structural reduction and the individualization of the restoration design;
d. adding connectors and changing their design

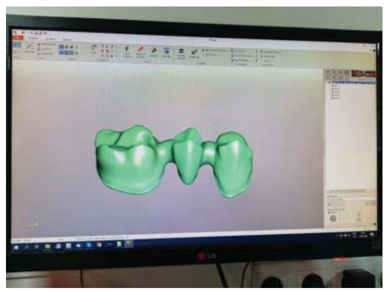
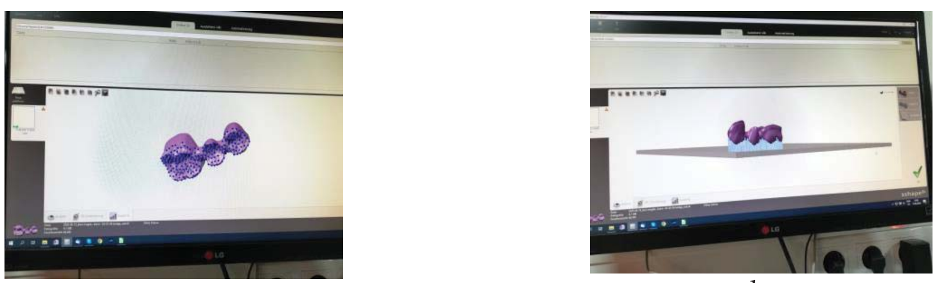


Figure 8. The completion the virtual restoration design

After scanning and designing the metal framework, the next steps are: positioning the support bracket and the virtual framework on the work plate (Fig. 9), introduction of the metal powder in the Concept Laser (Fig. 10 a.-b) and the STL data (Fig. 10.c-d);



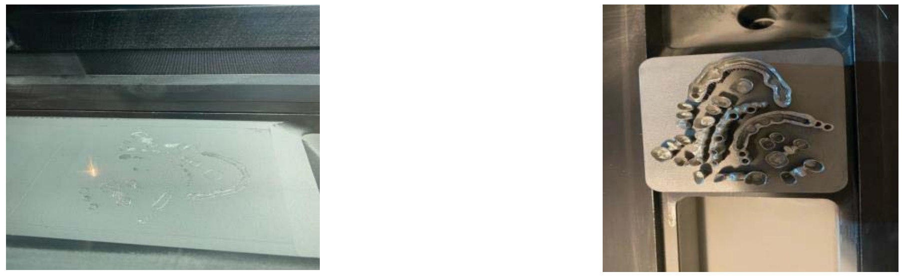
a. b.

Figure 9. a. Positioning the support bracket; b. Virtual framework on the work plate

a. b. c. d.

Figure 10. a. The used metal powder; b. Introducing the metal powder into the Concept Laser; c. Entering STL data in the Concept Laser; d. Programming for milling

Following these steps, next comes the actual sintering with laser (Fig. 11), obtaining the sintered metal framework (Fig. 12).



a. b.

Figure 11. a. The powder bed; b. The actual laser sintering on the powder bed

a. b.

Figure 12. a. Final shape from the sintering stage of the metal framework; b. The metal framework

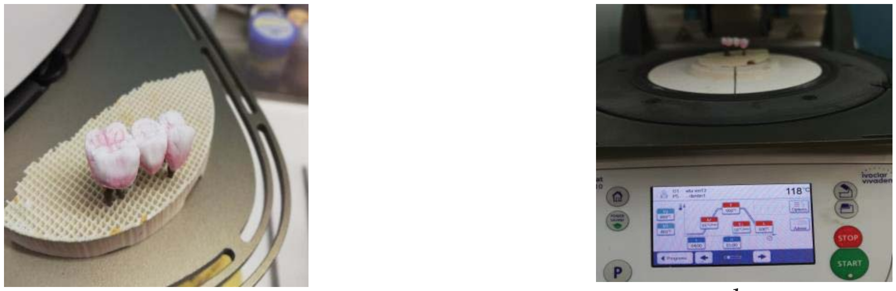
Following the sintering stage of the metal framework, the support on which it was created is sectioned (Fig. 13. a), then its sandblasting follows (Fig. 13.b), the metal being thus prepared for the ceramic veneering stage.

a. b.

Figure 13. a. Metal framework on the model; b. Metal processing and preparation for ceramic veneering

In order to prepare the metal framework for ceramic veneering, it was considered to remove all impurities using the Atoms5 steamer. After removing all the impurities, the wash-opaque was applied, making the chemical connection between metal and opaque, and then the restoration was introduced in the P310 Programmed combustion furnace (Ivoclar Vivadent), at 970 degrees C, for 20 minutes. Then Opaque OP 3 is applied and placed in the firing oven at 960 degrees C for 20 minutes. While the metal frame is in the oven, the models were mounted in the articulator in maximal intercuspal position, in order to reproduce as correctly and real as possible the movements of the mandible. After the metal framework has been removed from the oven, in order to remove any impurities, it is cleaned again with the steamer and placed on the working model for the actual ceramic veneering. The first layer of ceramic is dentin (2M3 Base Dentine VitaVM13), which combines with the liquid (VitaVM Modeling Liquid) (Fig.42) and is applied with special brushes on the entire surface of the metal framework, to cover it completely. Following the Base Dentine layer, a layer of Transpa

Dentine VitaVM13 (Ivoclar Vivadent) will be applied on the tops of the cusps and ridges, then a last layer of Enamel VitaVM13 (Ivoclar Vivadent) is applied, in order to give transparency in the occlusion area. At the end of the application of the laminated ceramics, the framework was introduced in the firing furnace on a special support (Fig. 14.a), at 900 degrees C, for 20 minutes (Fig. 14.b).



a. b.

Figure 14. a. Positioning on the support for burning; b. Laminated ceramic inserted in the firing furnace on the special support

After the first firing, the ceramic, due to shrinkage, withdraws, so it requires a second firing in order to complete and retouch. These additions will be made with Enamel VitaVM13 (Ivoclar Vivadent) (Fig. 15.a), then it will be introduced again in the firing oven at 890 degrees C, for 20 minutes (Fig. 15.b).

a. b.

Figure 15. a. Completing the ceramic shrinkage with Enamel VitaVM13 (Ivoclar Vivadent); b. putting the framework back into the firing oven at 890 degrees C for 20 minutes

After the second firing and the adaptation to the model, the preparation for glazing was done with the steamer. Powder (Vita AKZENT Plus Glaze) and liquid (Vita AKZENT plus Powder Fluid) were used for glazing. A thin layer of glaze was applied over the entire surface, then placed in the firing oven at 870 degrees C, for 17 minutes (Fig. 16).

Figure 16. Burning the glaze layer

After removing from the oven, it is allowed to cool, next step is checking the final work on the model. (Fig. 17)


Figure 17. The final work on the model

After the complete treatment the prosthesis has a very good marginal adaptation. Possibility of 3D reconstructions of imaging analysis leads to a better understanding of areas investigated. The most important operation is to pass a laser beam over the surface of a thin layer of powder, previously stored on a substrate. Identifying the optimal parameters of power and speed. Laser beam scanning is an essential task because these parameters happen to be the most influential on the characteristics of the part (porosity, hardness and mechanical properties).

DISCUSSIONS

The main advantage and at the same time the major difference between the classical and the presented method is the elimination of the errors that occur in packaging and metal casting. An important aspect is the possibility to eliminate certain steps that can be completed virtually, this approach being superior in terms of accuracy, time, structure, and lower costs, too. The potential of SLM is proven by the procedure of manufacturing frames for complex dentures. The process of selective laser melting begins with a completely defined CAD model, divided into cross sections by a special software, to be subsequently used directly in this process. Other advantages of SLM technology can be: the accuracy of the 3D model, the palette of special metallic materials, the resistance of the obtained parts, the possibility of constructing extremely complex geometries, the flexibility of the printed models. 3D prototyping/printing has recently become a global phenomenon. In addition to being a quick and easy way to manufacture, this technique allows engineers to overcome certain design difficulties in just a few hours, while using traditional methods would take several weeks. 3D printing has become a method used in a lot of fields, from the automotive industry to advanced medicine [17]

3D printing or rapid prototyping is a process of making solid three-dimensional objects from a digital model. Creating a 3D printed object is possible by using additive processes. Through such a process, an object is created layer by layer, until the final shape of the desired object is reached. [18]

CONCLUSIONS

The process used to obtain the metal framework by additive technology has the following advantages: flexibility in complexity, automation of manufacturing preparation, automation of manufacturing and precise visualization of the final result of the restoration. Additive technology, compared to subtractive technology, does not have such a wide range of materials, but it exceeds the level of complexity that a subtractive technology can achieve. Vita ceramic-veneering metal restorations are indicated even in the frontal area, due to the quality aesthetics, managing, through the complexity of the applied layers, to imitate the natural. Of course, they cannot be compared from this point of view with those entirely pressed or made by zirconium oxide subtractive technology, the latter providing the translucency necessary for an aesthetic of the highest quality, which cannot be matched when the framework is metallic.

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