

# Some technological particularities on the execution of dental prostheses realized by selective laser deposition

E. MORARU<sup>a</sup>, O. DONTU<sup>a</sup>, A. PETRE<sup>b</sup>, D. VAIREANU<sup>a</sup>, F. CONSTANTINESCU<sup>a</sup>, D. BESNEA<sup>a</sup>

<sup>a</sup>Politehnica University of Bucharest, Bucharest 060042, Romania

<sup>b</sup>Carol Davila University of Medicine and Pharmacy, Bucharest 050474, Romania

The tooth loss due to caries, periodontal disease, injuries or primary absence of teeth due to dental pathologies, it is currently estimated as a serious health problem. A wide range of methods and techniques for replacing missing teeth appeared in dentistry. They are constantly improved with the evolution of the scientific base and at the same time new methods, materials and technologies are found to minimize or eliminate the inherent deficiencies in some methods of treating edentate. The selective laser sintering technology allows the execution of dental prosthesis considering all individual particularities of the patient's anatomy to realize them more comfortable and supportable. In addition, this process has considerable advantages compared with traditional methods used in prosthetic dentistry.

(Received August 22, 2017; accepted April 5, 2018)

**Keywords:** Dental prostheses, Selective laser sintering, Selective laser deposition, Biomaterials

## 1. Introduction

The tooth is the hardest tissue in the human body which has a characteristic shape and structure, occupies a definite position in the dentition, and has its own nervous apparatus, blood and lymphatic vessels. Teeth are located in the alveoli of the jaws, take part in the mechanical processing of food, articulation of speech and perform an aesthetic function [1, 2]. Tooth loss is very common and it happens as a result of disease and trauma; therefore, the use of dental prostheses to replace missing teeth is indispensable and has a long and multifaceted history [3].

Modern prosthetic dentistry has taken the best ideas from antiquity and multiplied them into current technologies and materials. As a result of this symbiosis the current prostheses that are worthy of admiration have appeared. Dental prostheses are constructions designed to restore the anatomy and physiology of the dental system [4]. In the figure below are presented dental prostheses realized by selective laser deposition [5].

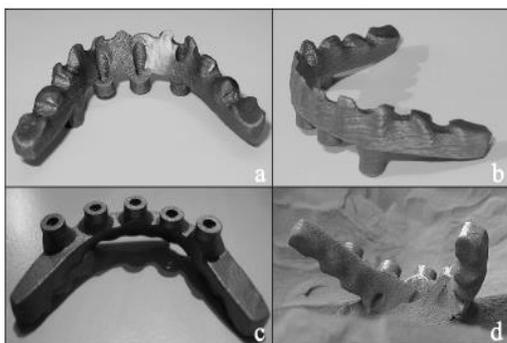


Fig. 1. Stainless steel frameworks produced by SLS (a, b) and Ti6Al4V (c, d). d shows the framework coming out from the powder

Among the main conventional techniques for making dental prostheses are casting, plastic deformations of metallic materials, polymerization, galvanofarming and others [6 – 9].

Each process has its advantages and disadvantages, but with the evolution of the scientific level appeared the so-called CAD-CAM technique with the help of which are obtained prostheses with the highest performances. Application of CAD/CAM systems have become a real revolution in the field of dental prosthetics due to the transition to a fundamentally new level of accuracy and consistency in the manufacture of crowns and bridges. Modern restoration is unthinkable without computer technology, and CAD/CAM in dentistry is a system that is one of the last and best achievements in this domain. CAD/CAM is a new technology for manufacturing dental prostheses with the help of computer modeling and milling on CNC machines or selective laser deposition on special equipment [10].

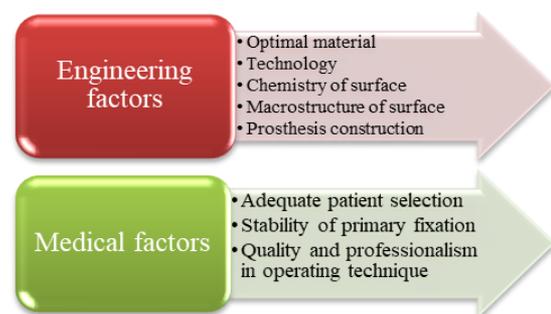


Fig. 2. Factors that influence the duration of prosthesis functioning

Dental treatment with prostheses has a great interest among specialists and attracts a growing number of

patients. Currently, the high efficiency of dental prostheses, predictability and long-term reliability after treatment has been demonstrated. It has been established that on average 92% of orthopedic dental prostheses can be used for more than 10 years.

It results from the above figure that according to the modern concepts of prosthetic biomechanics, only 3 of the 8 factors that determine long-term stability in the human organism are of medical nature, most of which are of engineering nature [11].

## 2. Experimental

### 2.1. SLS process

The laser is used in many medical fields such as surgery, therapy, dermatology, ophthalmology, and has recently gained much ground in dentistry through appearance of selective laser deposition technique [12-19].

Selective laser sintering (SLS) is a layer manufacturing process that allows the generation of 3 D complex pieces by consolidating the successive layers of the pulverized material over one another. The consolidation is achieved by processing the selected areas using the thermal energy provided by a focused laser beam. With a beam deviation system (Galvano mirrors), each layer is scanned according to the correspondence cross section calculated from the CAD model. The deposition of successive layers of powders with a typical thickness of 20 to 150  $\mu\text{m}$  is achieved by a powder deposition system. Fig. 3 shows a schematic example of an SLS system. Commercial installations differ, for example, by way of deposition of powder, atmosphere (Ar or  $\text{N}_2$ ) and the type of laser used ( $\text{CO}_2$  laser, Nd: YAG, laser fiber).

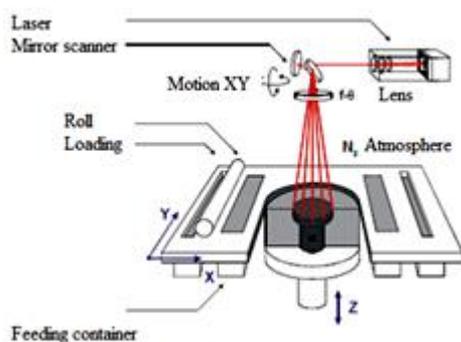


Fig. 3. Scheme of the SLS process [20]

Unlike other 3D printing methods, SLS requires a small number of additional tools once an object is printed, which means that objects do not usually have to be polished or otherwise modified once they are out of the SLS.

SLS doesn't require the use of additional supports to keep an object together while it is being printed. Such additional supports is often needed with other 3D printing

methods, such as stereo lithography or others, which makes these methods more time consuming than SLS.

SLS is a complex thermo - physical process and the determination of parameters is very important to achieve high precision. Table 1 divides the process parameters into four groups: material, laser, scan and environmental parameters. The optimal parameter setting can be found through the combination of empirical research and numerical simulation. Energy density is an absolute process parameter for a particular type of powder. This parameter represents the energy supplied by the laser beam to a volumetric unit of the powder material and combines some important laser parameters and scanning:

$$E_{density} = \frac{P_{laser}}{v_{scan} \cdot s_{oper} \cdot t_{layer}} \quad (1)$$

Table 1. Process parameters of SLS/SLM (Selective laser melting) technology

Material	Laser	Scan	Environment
Composition	Mode	Speed	Pressure
Density of the powder	Wavelength	Layer thickness	$\text{O}_2$ level
Morphology	Power	Impulse distance	Type of gas
Diameter of the granules	Frequency	Scaling factor	Preheating
Distribution	Pulse width	Operating surface	
Thermal properties			
Rheological properties			

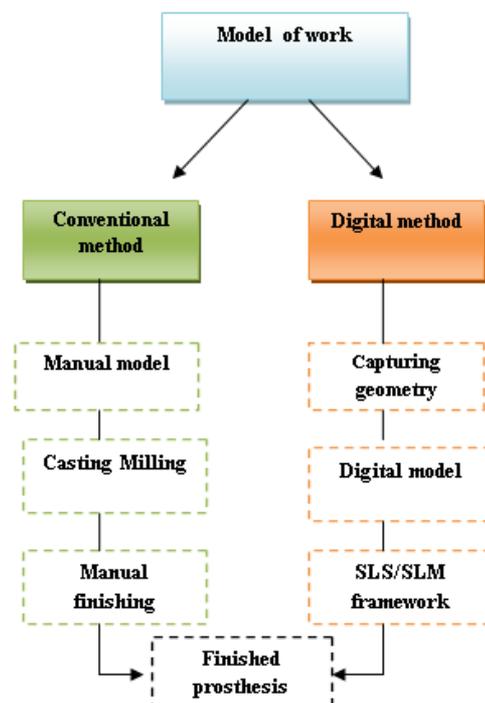


Fig. 4. Comparison of prosthesis manufacturing methods [5]

## 2.2. Material

Choosing the right material is one of the most important factors in the process of realizing dental prostheses. All materials used in dentistry should be evaluated for biocompatibility in order to protect patient health and safety. The need for biomaterials for use in restorative dentistry has generated a requirement for cytotoxicity assays to examine compounds and to characterize the potentially harmful effects of a material on oral tissues prior to clinical use. A biocompatible material can be defined as a material that does not cause significant adverse reactions with adjacent tissues or better said biocompatibility is the ability of a restorative material to induce an appropriate and advantageous response of the host during its clinical use [21]

Nowadays biomaterials are divided into four general categories of metals, ceramics, polymers and composites as shown in fig. 5:

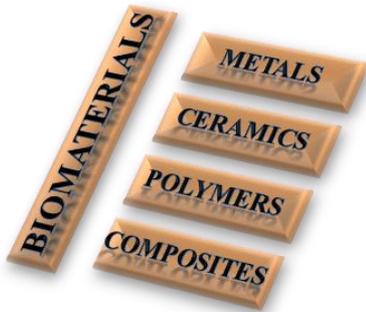


Fig. 5. Classification of biomaterials in dentistry [22, 23]

In this study the powder of the Co-Cr metallic alloy was used as the material with the following component: Co 59%, Cr 25%, W 9.5%, Mo 3.5%, Si 1%, C, Fe, Mn, N<1% [24, 25]. These alloy powders for the manufacture of very complex restorations in the dental sector consist of high quality alloys and allow the production of dental prostheses with outstanding performance in mass production using SLS/SLM systems.

Apart from the very good biocompatibility of the material, this alloy also has the following advantages: no cooling phase required, depending on ceramics, very high corrosion resistance, excellent veneering, a coefficient of thermal expansion of  $14,4 \cdot 10^{-6} \text{K}^{-1}$  permits great flexibility in ceramic selection and possesses very good technical properties shown in Table 2.

Table 2. Technical properties of Co-Cr alloy [26]

Technical property	Value
Proof stress (Rp 0.2)	720-1130 MPa
Ultimate tensile strength	990-1250 MPa
Elongation	2-10 %
Elastic modulus	195-200GPa
Vickers hardness	345-490 HV 10
Melting range	1305-1400 °C
Coef. therm. expansion	$14.4 \times 10^{-6} \text{K}^{-1}$
Density	8.8g/cm <sup>3</sup>



Fig. 6. Co-Cr alloy powder with diameter of granules <math><30 \mu\text{m}</math> and <math>>50 \mu\text{m}</math> respectively

Typically granules with a diameter of maximum 30 microns are usually used; those over 50 microns do not pass through a spherical sieve after the process, as shown in fig.6. This is done to delimit granules smaller than 50 microns for use in the following processes. During the process, glasses, gloves and masks are used to eliminate infiltration of the alloy powder into the skin, eyes or respiratory pathways.

## 2.3. SLS equipment and the steps of realization

Following the SLS process three-dimensional models are formed using powdered materials with the help of the laser energy inside the sintering equipment. The equipment with which the dental prostheses in this study were made is Sisma MYSINT 100. The Sisma MYSINT100 is an industrial metal 3D printer made by Sisma, a manufacturer from Italy. The Sisma MYSINT 100 uses the selective laser deposition technology to build objects in a wide range of metals: from precious metals to bronze, cobalt, stainless steel, nickel alloys, aluminum, titanium and more. With its MYSINT range of metal 3D printers, Sisma offers specific additive manufacturing solutions for dental, jewelry or industrial applications.

The main parts of the equipment are: laser source, mirror system, roller mechanism, powder substrate, part-build chamber, powder container and computer. The power supply is single phase 220-240V – 50-60Hz. Table 3 presents the technical characteristics of the equipment.

Table 3. Technical characteristics of Sisma MYSINT100

Wavelength	1070 nm
Laser Source	Fiber Laser 200W
Laser spot diameter	<math><30 \mu\text{m}</math>
Precision Optics	Quartz F - Theta Lense
Typical layer thickness	15-20 $\mu\text{m}$ typically
Power supply	230V 50/60Hz 1Ph
Oxygen concentration	0,3%
Inert gas	Nitrogen, Argon
Noise	<math><70 \text{ dB}</math>
Machine dimensions	1390 x 777 x1600 mm
Net weight	650 Kg

In the Fig. 7 are illustrated parts of the equipment:



Fig. 7. The structure of Sisma MYSINT100

In the following are presented the steps of the realization of dental prostheses by selective laser deposition on the Sisma MYSINT100 equipment.

- 1) Preparing 3D CAD data in a standard STL format. At this stage, future restoration is planned in specialized software Autofab, after which the data is exported to the Sisma program of the equipment (Fig. 8).

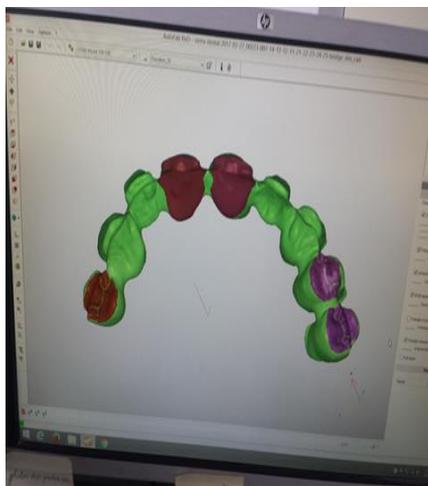


Fig. 8. Design of the future prosthesis

- 2) At the beginning of the SLS process, a thin layer of material powder is applied to the working platform on the movable Z axis.
- 3) CAD data are arithmetically converted into two-dimensional section with fixed thickness. The laser is controlled by using this data so that the surface of the powder layer is heated to its melting point and the thermal image of the cross-section is realized. The applied energy sinters the scanned surface in a uniform layer. The laser is controlled so that only surfaces belonging to the piece is sintered.

- 4) With a special roller mechanism, a new layer of powder is applied.
- 5) The process is repeated until completion of the construction. This resulted in pieces of any complexity. The powder substrate forms exactly the supporting structure, which does not require any other support structures [27-29].

The roller mechanism comes with 20 microns of powder. Its speed can be controlled by the computer. The computer also controls the laser power, concentration of nitrogen and oxygen, volume of air entering and leaving. Additionally, the equipment does not operate at temperatures above 30°C, stopping automatically.

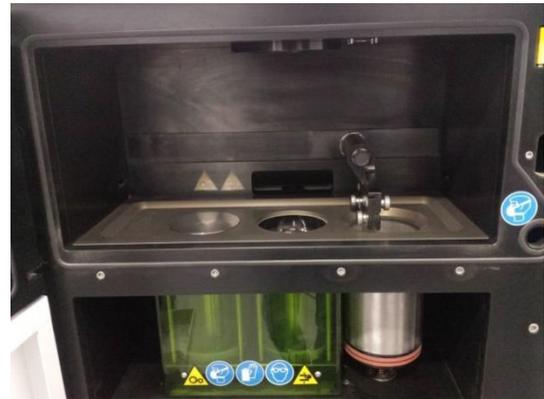


Fig. 9. Part-build chamber

### 3. Results and discussion

Dental prostheses were realized in the “Precident” Buzau dental laboratory on the Sisma MYSINT100 selective laser sintering equipment. The material used was the Co-Cr alloy.



Fig. 10. The prosthesis in rough form

High-quality prostheses with unmatched mechanical and biocompatible properties were obtained. After finishing with electrochemical polishing they are ready to be sent to the dentist and then installed to the patient. Execution time is very small compared to other methods

of prosthesis manufacturing, which makes this method gain a lot of popularity among dentists and patients with dental deficiencies. The finished dental prosthesis is shown in Fig. 11.



Fig. 11. Finished dental prosthesis

#### 4. Conclusions

In conclusion, dental prostheses have been successfully realized by selective laser deposition on Sisma MYSINT100 equipment for experimental purposes and also study their finishing processes. Of all computerized technologies, lately SLS (Selective Laser Sintering) technology has gained more ground. This technology provides an efficient and rapid method for designing and manufacturing biocompatible metal frameworks for complex dental prostheses. SLS technology covers the disadvantages of milling technology – excellent manufacturing precision and don't give uneven edges. In addition, it is an additive material technology. Unused material can be used in the following processes, which makes this technology more efficient from an economic point of view than milling. It is technology of the future what will certainly gain even more interest among specialists and patients, offering remarkable quality prostheses.

#### Acknowledgements

This work was supported by "Precedent" Buzau Dental Laboratory and especially by Joseph Sakal, the director of "Precedent" Buzau Dental Laboratory.

#### References

- [1] Samuel D. Hodge Jr., Jack E. Hubbard, Anatomy for litigators, ALI ABA, Philadelphia, (2011).
- [2] I. V. Gaivoronskiy, T. B. Petrova, Anatomia zubov cheloveka, ELBI-SPB, Saint Petersburg, (2005).
- [3] Laura Gaviria, John Paulo Salcido, Teja Guda, Joo L. Long, J. Korean Assoc. Oral Maxillofac. Surg. **40**(2), 50 (2014).
- [4] <http://www.rusmedserv.com/toothreplacement/denture/>
- [5] J. P. Kruth, B. Vanderbroucke, J. Van Vaerenbergh, I. Naert, Manufacturing of dental prostheses by means of Selective Laser Sintering/Melting, Proc. 2<sup>nd</sup> Int. Conf. on Adv. Res. in Virtual and Rapid Prototyping, Leirias, Portugal (2005).
- [6] T. F. Danilina, V. N. Naumova, A. V. Jidovinov, Litio v ortopediceskoi stomatologii: Monografia, VolgGMU, Volgograd (2011)
- [7] S. Naumovici, S. Ivashenko, A. Borunov, A. Gorbaciov, A. Kruglik, D. Polhovskii, Ortopediceskoe lechenie defektov koronok zubov iskusstvennimi koronkami, BGMU, Minsk, (2011)
- [8] D. B. Barbosa, D. R. Monteiro, V. A. Barão, A. C. Pero, M. A. Compagnoni, Gerodontology **26**, 225 (2009).
- [9] Christina Tietmann, Frank Broseler, Clinical Implant Dentistry and Related Research **4**(1), 53 (2002).
- [10] <http://thdental.am/catalog-categories/cat1/>
- [11] S. Naumovici, A. Homici, V. Sharanda, A. Borunov, Tehnologii zubnogo protezirovania na dentalnih implantah, BGMU, Minsk, (2011).
- [12] D. Savastru, S. Miclos, C. Cotirlan, M. Mustata, E. Ristici, T. Brezeanu, S. Dontu, M. Rusu, V. Savu, A. Stefanescu, Romanian Journal of Physics **51** (5-6), 833 (2006).
- [13] D. Savastru, S. Miclos, C. Cotirlan, E. Ristici, M. Mustata, M. Mogildea, G. Mogildea, T. Dragu, R. Morarescu, J. Optoelectron. Adv. M, **6** (2), 497 (2004).
- [14] R. Dabu, R. Banici, C. Blanaru, C. Fenic, L. Ionel, F. Jipa, L. Rusen, S. Simion, A. Stratan, M. Ulmeanu, D. Ursescu, M. Zamfirescu, J. Optoelectron. Adv. M. **12**(1), 35 (2010).
- [15] M. N. Tautan, S. Miclos, D. Savastru, A. Stoica, Optoelectron. Adv. Mat. **8**(7), 622 (2013).
- [16] O. Dontu, Tehnologii de prelucrare cu laser, Ed. Tehnica, Bucuresti, (1985).
- [17] C. Cosma, N. Balc, M. Moldovan, L. Morovic, P. Gogola, C. Miron-Borzan, J. Optoelectron. Adv. M. **19**(11-12), 738 (2017).
- [18] A. Pascu, E. M. Stanciu, D. Savastru, V. Geanta, C. Croitoru, J. Optoelectron. Adv. M. **19**(1-2), 66 (2017).
- [19] K. Martha, B. Petcu, C. Bica, Optoelectron. Adv. Mat. **10**(11-12), 965 (2016).
- [20] J. P. Kruth, P. Mercelis, L. Froyen, Rapid Prototyping Journal, **11** (1), 26 (2005).
- [21] Peter E. Murray, Cristina García Godoy, Franklin García Godoy, Med. oral patol. oral cir. bucal **12** (3), 258 (2007).
- [22] Zahra Abdolapour, Zahra Saneipour, Mohammad Javad Azarhoosh, Current Trends in Biomedical Eng & Biosci. **2**(3), 7 (2017).
- [23] Amir A. Zadpoor, Journal of the Mechanical Behavior of Biomedical Materials, **70**, 1-6 (2017).

- [24] M. G. Minciuna, P. Vizureanu, D. C. Achitei, A. V. Sandu, A. Berbecaru, I. G. Sandu, J. Optoelectron. Adv. M. **18**(1-2), 174 (2016).
- [25] M. G. Minciuna, P. Vizureanu, D. C. Achitei, A. V. Sandu, J. Optoelectron. Adv. M. **18**(7-8), 717 (2016).
- [26] <http://scheftner.dental/starbond-cos-powder-en.html>
- [27] [http://www.sisma.com/eng/additive-manufacturing/prodotti/additive-manufacturing/laser-metal-fusion--jewellery/mysint100\\_\\_php](http://www.sisma.com/eng/additive-manufacturing/prodotti/additive-manufacturing/laser-metal-fusion--jewellery/mysint100__php)
- [28] <http://www.aniwaa.com/product/3d-printers/sisma-mysint100/>
- [29] <https://www.livescience.com/38862-selective-laser-sintering.html>

---

\*Corresponding author: eddy\_milan91@yahoo.com