USAGE OF „SELECTIVE LASER MELTING" TECHNOLOGY CAPABILITIES IMPLEMENTATION FOR TEETH IMPLANTS METAL CONSTRUCTION IN TU-SOFIA

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Abstract. This paper reviews a possible application of the method of Selective Laser Melting (SLM) for designing and producing a dental implant - metal dental "cap" which is the foundation for a dental metal ceramic crown. First, a patient's measurements are taken and a gypsum model is made and then scanned. Thereafter a precise virtual model is created by a specialized dental CAD system. It is followed by operations using another software package in order to create Operation Control Program for the equipment applying the SLM method. Finally, there comes a real physical model which is precise enough and has the desired quality. The life cycle of this progressive process of operation is significantly reduced compared to traditional approaches.

Keywords: dental, implants, rapid prototyping, selective laser melting

1. Introduction

The purpose of this research is to develop a complex innovative technology for production of dental elements (in this case – bearing inserts) through the combined use of traditional and new, purely mechanical-engineering techniques applying a very precise 3D scanner, specialized 3D CAD software package and SLM machine.

The classical manual technique is based mainly on casting technologies and comprises the following:
• measurement of the jaw and surrounding teeth – silicone/polyether imprint (this is done at the dentist's);
• it is sent to the dental lab;
• the imprint is used to build manually the form of the implant (bearing inserts, crowns or bridges, etc) using technical wax;
• the handmade model is used for casting the implant (as melting model for single use).
• the casting is then manually cleaned, shaped additionally if necessary and sent back to the dentist's to treat the patient.

The above technology requires lots of time and it largely depends on the skills and current condition of the dental technician.

The innovative efficient CAD technology offered is mostly computerized and basic operations replace casting technology with highly precise production by the means of prototyping equipment. The whole work process repeats only the first step – physical measuring (dental imprint) related to jaw and surrounding teeth (done at the dentist's office). The material used for the imprint (the best way is to used mono or two stage approach) is either polyether or A-silicon.

The next phases and steps are entirely different and they imply up-to-date computer technologies:
♦ Automatic evaluation of the form and sizes of the dental imprint is done by means of a 3D scanner for the purposes of designing the future model – a dental "cap" in our case. In such a way a very good precision is guaranteed. A three-dimensional NextEngine laser scanner available at the Technical University is used for this study;
♦ Applying of 3D CAD software for Reverse Engineering which processes the data provided by the scanner and uses it to design a three-dimensional model of the object scanned;
♦ Application of specialized 3D CAD software for modelling crowns, bridges, implants, etc. instead of moulding them with technical wax. The application also allows the usage of out-of-the-box "library" elements which can be reshaped. Specialized EXOCAD software package of the Technical University has been used for this study;
♦ Creating an Operation Control Program to construct a real model. AutoFab 1.6 software developed by Marcam Engineering is used for this purpose. This product is specialized in the design of metal products through Selective Laser Melting technology [1];
♦ Thereafter the implant element is physically produced;
♦ Final phase – the model is dismounted from the work station and the supporting elements; cleaned; then polished by means of sand blaster to make its surface smooth.

2. Preparatory phase

Start with an existing gypsum model made in a

dental lab. It is pattern based on the patient's imprint made at the dentist's. In this case have a patient's lower jaw, more specifically a problematic tooth which requires creating a composite dental crown consisting of main element - a cap and a metal-ceramic cover top element. This study focuses on how the cap is made.

The gypsum model is placed on the work area of the 3D NextEngine scanner which is provided with a 360°-rotation plot, [2] as shown in figure 1. The scanning process is accomplished by its software driver ScanStudio: the physical data about the model is copied into its virtual replica. This software package is also a reengineering product which allows making a precise and consistent 3D model of the scanned example built up on the so called "dot cloud" resulting from the 3D scanning (Precision and error rates depend strongly on the accuracy of the scanner; it is 0.005…). The time necessary for scanning and creating a three-dimension model is 45 minutes. The output file format is STL (Standard Tessellation Language).

Figure 1. Dental imprint mounted on an occluder

The imprint is delivered mounted on an occluder. On it each tooth is a separate composite model pinned to a common base. It allows focusing on the desired zone only – in our case tooth no. 47 according to a dental notation method, depict at figure 2 and 3.
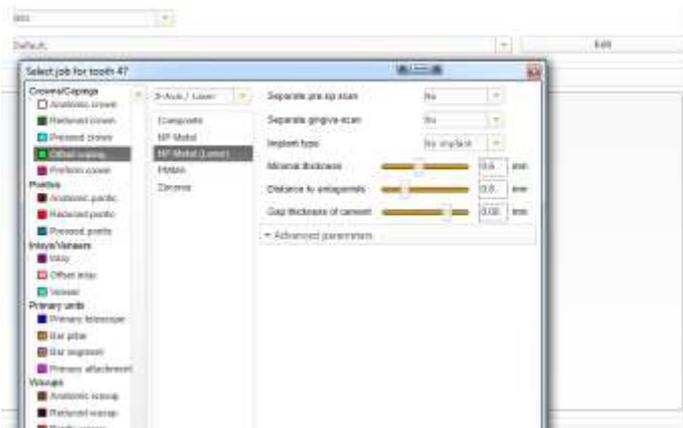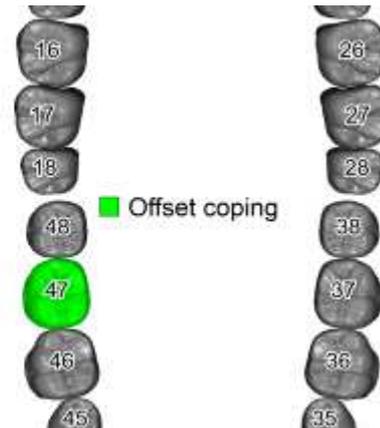

Figure 2. Tooth selection

3D NextEngine scanner is shown on figure 4.

Figure 3. A composite model

Figure 4. 3D scanner NextEngine

The model thus created represents an exact virtual replica of the physical prototype (the possible error is negligible for the purposes of this study) and it is now ready for the next phase:

Implementation into a specialized dental CAD system – EXOCAD

Offset copying technology is selected for the task. At this phase it is indicated that the future model will be created under SLM method. [3] The dentist has provided some information necessary for the process: the distance to the antagonist tooth – 0.8 mm, as well as the minimum thickness of the object – 0.6 mm [4].

The model is then imported into EXOCAD which is followed by positioning in the work zone – figure 5.
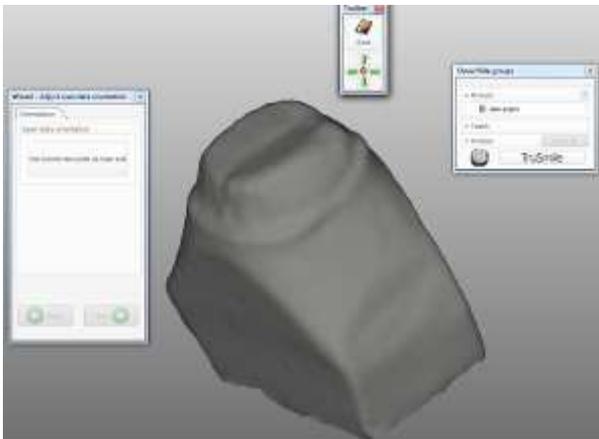

Figure 5. Scanned model imported into specialized dental CAD software package EXOCAD

Required geometry is segmented by separation from the surroundinggeometry by setting borders – figure 6 (adjustment may be either automatic or manual in case a precision option hasn't been set in advance).
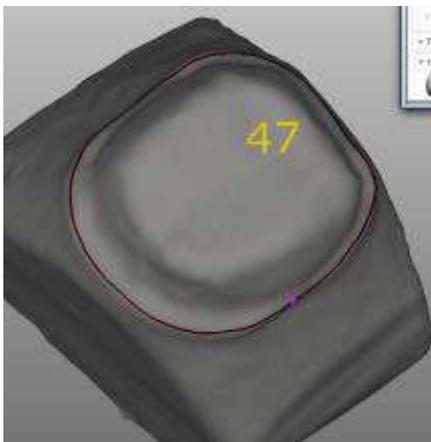

Figure 6. Geometry segmentation and separation from surrounding geometry by setting borders

The following parameters are set:
- Occlusion 0.02 mm;
- Thickness of cement basis 0.08 mm.

The next phase is to build an anatomic cap, depicted in figure 7, which is generated from the model and the parameters set:
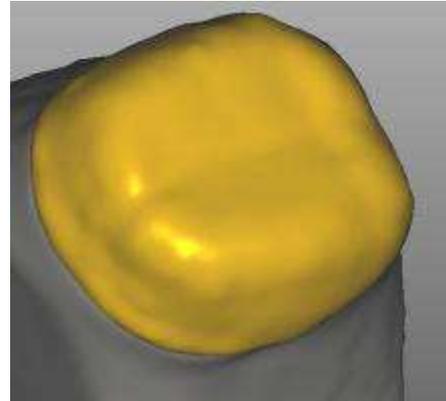

Figure 7. Building an anatomic root implant

Shaping final three-dimensional geometry

The output file format is again STL and it must be of very good quality for the purposes of the steps coming next. "Merge for Selective Laser Melting" option is set in order to create a mesh model.

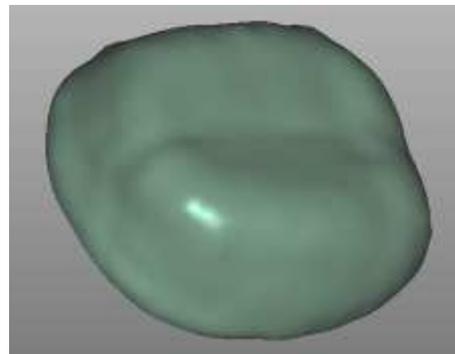Here is how the new element looks as shown on figures 8 and 9:
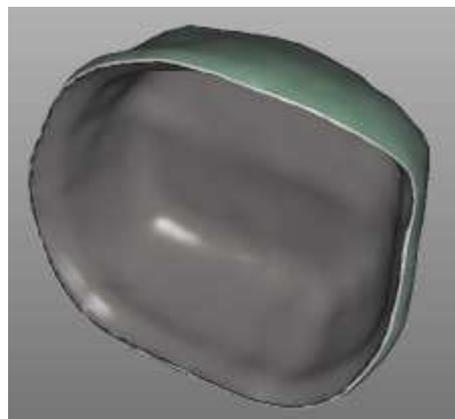

Figure 8. Finished model – view A

Figure 9. Finished model – view B

The time required for creating a 3D model by specialized EXOCAD software platform is about 45 minutes.

Making the product by means of SLM technology

SLM – selective laser melting is a method to melt powder material by means of a laser ray in order to obtain a metal element the form of which may be unlimitedly complex [3, 5].

The element is built under the additive system – by adding layer by layer, each layer being 30 micrometers thick [3]. Such a process practically allows building very complex shapes created by three-dimensional CAD geometry (STL file) automatically for just a few hours without any tools [5]. The resulting products are highly precise in terms of geometry; they have a good level of smoothness and remarkable physical features [6].

The current research focuses on how to build a bearing inserts – the so called dental "cap", by applying Selective Laser Melting. The process covers the following steps:
- Obtaining a three-dimensional computer model (by specialized dental CAD software package);
- Creating an Operation Control Program for the selective laser melting equipment – SLM 125 HL;
- Producing the element according to optimal parameters for high-quality dental implants which have been a subject of a former research [1].

The model is prepared for manufacturing with the help of AutoFab software. This is a tool which supports manufacturing of metal products by laser sintering and layer melting. [1, 7] It verifies and fixes imported dental CAD data concerning the model geometry parameters – the model should have a closed volume and shouldn't have any geometry defects. The direction of layers is set. Thickness of the object is added (shell). A supporting structure is created. Before manufacturing the product it has to be divided into layers of set thickness. The thickness depends on the composition of the powder material used for making the element. Stainless steel AISI 304L is used for this study which requires layer thickness $\delta = 30$ µm. Steel is less expensive but it has bigger weight and higher diathermancy than CrCo (chromium-cobalt) alloys usually recommended for such purposes. The latter are much corrosion resistant, mechanically stronger, durable and bio-resistant.

The machine used for the research is SLM125HL model, shown on Figure 10. The equipment is located in "Industrial CAD/CAM/CAE" laboratory of the Machine Technology Faculty of the Technical University in Sofia.

Figure 10. View of the machine

The equipment is set off by the operation program created in advance and production of the element is started.

After the production process is over the model is carefully cleaned from remains of the material. It looks like shown on figures 11 and 12 below.

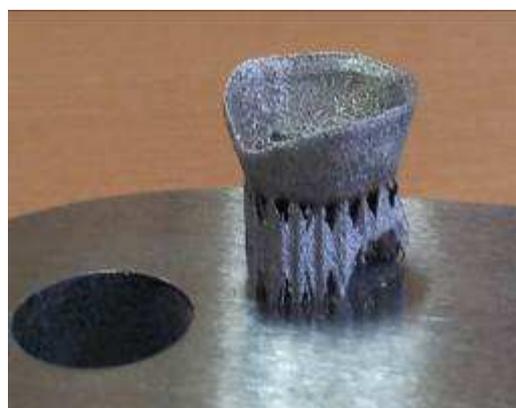Figure 11. Finished element on the base

Figure 12. Finished element and supporting structure

Now finishing operations, such as separating the model from the supporting material, and polishing with a sand blaster to make its surface smooth, have to be accomplished, as shown on figure 13.

Figure 13. Finished element after polishing

The model is ready to be implanted on the patient and to serve as a steady foundation for building a metal-ceramic crown.

3. Conclusion

This study reveals how the technology of Selective Laser Melting implemented by the Machine Technology Faculty of the Technical University in Sofia is used to produce premium quality implants, such as metal dental "caps", in a highly automated and precise way.

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