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THREE DIMENSIONAL PRINTING IN DENTISTRY

Marko Igić[1], Milena Kostić[1], Stefan Dačić[2], Ana Pejčić[3], Branislav Vidović[4]

Three-dimensional printing is a method that has found its application primarily in industry but also increasingly in medicine. In order to reach the desired shape of an object that would be formed using three-dimensional printing, specialized programs are used to draw three-dimensional objects, or special equipment designed for three-dimensional scanning. The three dimensional printing which is used in medicine can already be classified on the basis of the techniques and materials used in the preparation of the desired product. This technology can be used at every stage of making dentures, starting with the development of a study model, to the definitive development of mobile and fixed restorations. In order to obtain adequate prosthetic restorations bioprinting technology should be set aside from three-dimensional printing of non-living materials. In this way a series of tissues used in dentistry may be created: the printing of the skin and mucous membranes for covering defects on the face or mouth, the formation of bones and joints, artificial nerves, blood vessels, muscles, etc.

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[1]University of Niš, Medical faculty, Department of prosthodontics, Niš, Serbia
[2]University of Niš, Medical faculty, Department of Operative dentistry and Endodontics, Niš, Serbia
[3]University of Niš, Medical faculty, Department of Oral medicine and parodonthology, Niš, Serbia
[4]Specialist dental practice Ortis, Novi Sad, Serbia

Contact: Marko Igić
Cvijićeva 21/15, 18000 Niš, Serbia
E-mail: saigic@yahoo.com

A three-dimensional PRINTING OF NON BIOLOGICAL MATERIAL

Three-dimensional printing is a relatively new, additional method, which has found its application primarily in industry, to create elements that cannot be created with classic tools, or their production requires a large number of complex operations on multiple machines. To make such a structure it is required that the device for three-dimensional printing receive appropriate instructions. Therefore, a third coordinate is included in the programming, and three-dimensional object is a series of small interconnected points, the position of which is precisely defined in space.

Basically, the precision of such obtained object depends not only on the current definition of its shapes and a range of other factors, but on the characteristics of the printer, then on the quality of the program that controls the printer, material used, etc…

In mechanical engineering, in order to reach a desired shape of an object that would be formed using three-dimensional printing, specialized programs for drawing three-dimensional objects are used or, if such an object already exists, it is simply scanned in an appropriate scanner.

In medicine, the work could not be thus simplified. The problem in medicine, and especially in dentistry, is that it is most often an irregularly shaped object that cannot be easily measured or designed, nor imported in classical scanner. Therefore, it is often necessary to make scan of them, which is mainly done in two ways.

If it is necessary to perform replacement of invisible part of the body or the part that was lost (for example due to trauma), we use computer tomography which offers a three-dimensional image of the defect and surrounding structures, on the basis of which the image of the part is formed that needs to be developed to compensate existing defect. In this way such object can be developed

before the beginning of surgical procedure or other intervention. In addition, it is possible to modify the obtained data in order to improve certain characteristics of the object being manufactured.

If it is a part of the body that is visible (nose, ear ...) the so-called optical scan can be used. Optical scanning is also used for elements in the oral cavity, but since they are more or less inaccessible, scanning can be performed directly in the mouth (e.g. scanning of the brushed teeth), or by scanning model made on the basis of impression taken from the tissues of the oral cavity.

Based on the data obtained by scanning, picture of the scanned object is made and then the analysis is performed and a virtual object will be created.

The three dimensional printing which is used in medicine can be classified on the basis of the techniques and materials used in the preparation of the desired product (1).

The most commonly applied technique of a three-dimensional printing is a method that uses a photosensitive resin, and an ultraviolet laser for curing the resin. In this way, the object can be obtained which fully corresponds to the 3D drawing.

The second method instead of the photosensitive resin uses powder of a certain material, which under the influence of appropriate beam of light (ultraviolet, laser ...) polymerizes. This method of polymerization of the object is created layer by layer, until they come to their final assembly in the form of the desired object. After polymerization non polymerized powder is removed which can be mainly reused to create other object (2)?

There is a method that does not use powder in the layer but in front of light beam brings the material (usually in the form of wire of appropriate dimension), which immediately polymerizes, it adds to the second material and so on until obtaining the required shape.

Newer devices allow 3D printing of several types of materials, including metals and non-metals. So Steiner ProX™ 100 Dental system allows direct sintering of metal in order to create high quality metal dentures. This system enables 3D metal printing with obtaining chemically pure, very compact and highly precise parts (EN ISO 2768) with a tolerance of 20 microns in all three axes. It uses more than 15 materials including steel, stainless steel, super alloys, non-ferrous and precious metals as well as alumina (Figure 1.) (3).

Figure 1. Metal objects obtained by 3D printing

In order to obtain a metal object, such as, for example, skeleton of prosthesis, one method is the creation of a 3D object from plastic, then the object is flasked and casted, as well as any prosthetic restoration made using the classic method. Another method consists of making direct object of metal, for example, polymerizing layers of titanium powder.

Application of 3D technology enables the production of certain objects at a time when the need arises. This technology can be used at every stage of making dentures, starting with the development of a study model, to the definitive development of mobile and fixed restorations. So there would be no need to buy pre-made bars, attachments and other elements, but they would be made on the spot, according to the individual characteristics of each patient. In this way, in addition to greater adaptability of the casted elements to patient, the possibility of deficiency of prosthetic restorations classically made is reduced, due to imperfections and complexity of the material and the stages in the process of making the same.

The advantage of 3D printing that involves several materials with different characteristics is that it is possible to produce restorations with more elastic deeper layers and those on the surface more rigid, thereby reducing stress that the abutment teeth are subject to for prosthetic restorations as well as their supporting structures. This is consistent with the knowledge that the central part of the tooth - dentin is significantly softer and more flexible

compared to tooth enamel that makes work surface of teeth.

This way of work has certain advantages compared to currently more common technologies related to the grinding of ceramic blocks or sintering base for ceramic prosthodontic works.

Since processing of expensive ceramic blocks may cause environmental pollution there is no need to use them anymore. In addition, this requires the use of complicated and expensive devices and tools for processing, which wear out and must be replaced, which will otherwise cause deviation in the dimensions of the created object. The truth is that 3D printers are currently expensive, but this is because of their limited production. It is likely that in a short period of time their production will be doubled, the technology is getting better and lead to drastic cost reduction. It will also lead to the development of new, more adequate and reliable materials, as well as new and better printing techniques.

Bioprinting

Bioprinting technology should be set aside from three-dimensional printing of non-living materials for the purpose of obtaining adequate, usually prosthetic restorations. Having realized that the ink droplets from inkjet printers are of approximate size as human cells, Makoto Nakamura made the first bioprinter that was able to match individual living cells. Nowadays, bioprinters match and merge layer after layer of cells, those cells and layers merge with gel, thus forming tissue (4,5).

In order to develop primarily vascular elements, the company Organovo and Invitech developed bioprinter NovoGen MMX, which has two heads, one that lays down cells, and another that lays down bonding material - Biogel. Firstly, a layer of biopaper based on water, collagen, gelatin and other hydrogelsis are applied. Then, the spheroids are injected into this layer, and finally, after joining of several layers binding agent is removed by evaporation or by other methods (Figure 2.).

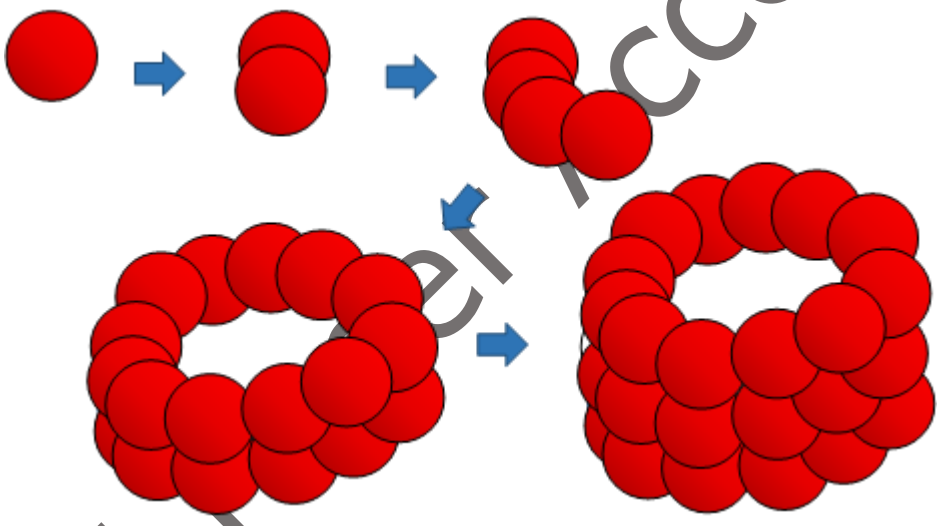

Figure 2. Composition of sferoids

Their research has shown that it is not necessary to completely print a certain part, but only to start the process, and the nature alone can complete it because the cells migrate to its natural place (as in wound healing or the development of an organism). The researchers said: "When certain cells reach appropriate place in some way they know themselves what to do." Thus, the heart tissue obtained by printing, 90 hours after merging began to beat rhythmically (6,7).

Given that with the help of 3D printers formed tissues contain cells that were not in function such as muscle cells, the application of mechanical stimuli is provided in order to prepare these tissues for normal functioning (4).

Scientists from Australia and the United States, led by Dr. Luiz Bertassoni managed to create a network of blood vessels by bioprinting (8).

Russian researchers have started using the techniques of 3D printing parts of the human body or the whole organs by merging the so-called spheroids cells (conglomerate of stem cells of the patient himself, therefore, fully compatible with its organism), after which the accelerated maturation of cells in the stimulatoris approached (9).

A group of scientists led by Jeremy Mao developed a printing technology of hard tissues - bones and teeth. Incisor made by this way was successfully implanted in the jaw bone of rat. Just nine weeks after implantation, there was a growth of fresh periodontal ligaments and newly formed alveolar bone. In another experiment, bioprinted

skeletons at the site of the rabbit's hip joint were implanted. In the period of four months new, fully functional joints formed around the skeleton. Some of the rabbits began to walk only a few weeks after surgery (4,5,10).

Bioprinting can be used to create a series of tissues that may be applied in dentistry: the printing of the skin and mucous membranes to help them cover the defects on the face or in the mouth resulting from burns or mechanical effects, the formation of bones and joints, artificial nerves, blood vessels, muscles, etc.

One of the currently applicable printer is just doing a particular type of biomaterial, while others may combine different tissues and form organs from them.Science and technology united make progresswith big steps, thus gradually erasing the border between classical treatment and production (4). It is estimated that printer designed for this purpose (Figure 3.), or a robotic arm carrying bioprinternozzle on the top, could make the missing part on the spot (eg. tooth, part of the alveolar process, or a soft tissue).

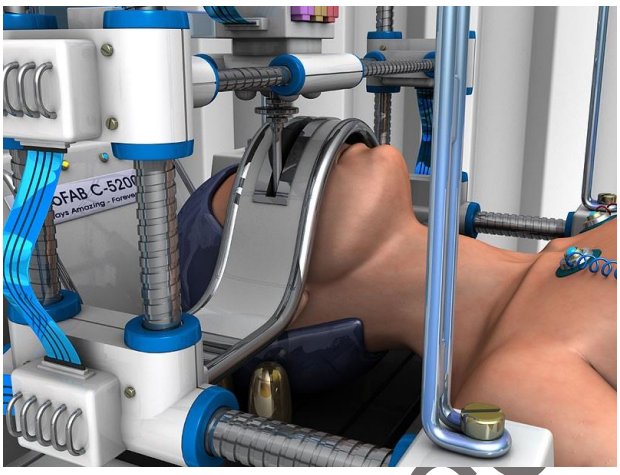

Figure 3. Bioprinter for the face

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STOMATOLOG I TRODIMENZIONALNO ŠTAMPANJE

Marko Igić[1], Milena Kostić[1], Stefan Dačić[2], Ana Pejčić[3], Branislav Vidović[4]

[1]Univerzitet u Nišu, Medicinski fakultet, Katedra za stomatološku protetiku, Niš, Srbija
[2]Univerzitet u Nišu, Medicinski fakultet, Predmet Bolesti zuba i endodoncija, Niš, Srbija
[3]Univerzitet u Nišu, Medicinski fakultet, Predmet Oralna medicina i parodontologija, Niš, Srbija
[4]Specijalistička stomatološka ordinacija Ortis, Novi Sad, Srbija

Kontakt: Marko Igić
Cvijićeva 21/15, 18000 Niš, Srbija
E-mail: saigic@yahoo.com

Trodimenzionalno štampanje je metoda koja je svoju primenu našla pre svega u industriji, ali sve više i u medicini. Da bi se došlo do željenog oblika nekog objekta koji bi se formirao trodimenzionalnom štampom, koriste se specijalizovani programi za crtanje trodimenzionalnih objekata, ili posebni aparati namenjeni trodimenzionalnom skeniranju. Trodimenzionalna štampa koja se koristi u medicini može biti klasifikovana na osnovu tehnike ili materijala koji se koristi u izradi željenog proizvoda. Ova tehnologija može se koristiti u svakoj fazi izrade protetske nadoknade, počevši od izrade modela za studije, do definitivne izrade mobilnih i fiksnih nadoknada. Od trodimenzionalne štampe neživih materijala u cilju dobijanja odgovarajućih, najčešće protetskih nadoknada, treba izdvojiti tehnologiju bioštampe koja se može koristiti za stvaranje niza tkiva koja se mogu primeniti u stomatologiji: štampanje kože i sluzokože, kako bi se njima prekrili defekti na licu ili u usnoj duplji nastali usled opekotina ili mehaničkog dejstva, stvaranje kostiju i zglobova, veštačkih nerava, krvnih sudova, mišića.

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Ključne reči: *skener, materijali, 3D štampa*