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3D DIGITIZATION AND ADDITIVE MANUFACTURING TECHNOLOGIES IN MEDICINE

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Abstract

The paper discusses the use of 3D digitization and additive manufacturing technologies in the field of medicine. In addition, applications of the use of 3D digitization and additive manufacturing methods are described, focusing on the design and manufacture of individual medical aids. Subsequently, the process of designing and manufacturing of orthopedic aids using these technologies is described and the advantages of introducing the given technologies into the design and manufacturing processes in the medicine sector are presented.

Key words

3D digitization, additive manufacturing, medicine sector, medical aid

INTRODUCTION

At present, the technologies of 3D digitization and additive manufacturing (AM) are increasingly used in various sectors of industry, with increasingly widespread use being made in the field of medicine. From the beginning of AM, that is, from the initial prototype production in the future product development phase, we are currently in the design and manufacture of final products designed for use in practice.

This is the result of the ever-evolving field of AM that improves and thus increases the efficiency of the manufacturing process, the parameters of manufacturing machines ("3D printers"), and the adaptation and development of new types of component materials. As a result, AM is becoming more and more used and is expanding its application in practice (1).

The purpose of this article is to describe the design and manufacture of the individual orthopedic aids using 3D digitization and AM. The result is a simple, fast, and therefore an efficient process of designing and manufacturing of orthopedic aids with regard to its functionality, suitability for use and practical application (2).

In design and manufacturing processes using 3D digitization and AM in the field of medicine, these technologies are used in many applications. Particularly in the field of medicine, the technologies are applied in several areas and new areas of their use are being gradually developed. This is primarily about acquiring image data of the patient through 3D digitization and after computer editing of these data is followed by the AM of such models. The use of these technologies in this area appears to be an effective way of design and manufacture of various components (2).

3D digitization in medicine

Currently, several methods of 3D digitization are used to obtain patient data, which may be in the image form or directly in the form of a 3D digital model of the patient's body or its individual parts. These methods are Computed Tomography (CT), Magnetic Resonance Imaging (MRI) and active triangulation (structural light measurement) (3).

The following part of the article describes the principle of active triangulation used in 3D scanning of parts of the human body, which subsequently serves as a basis for design and manufacture of an individual orthopedic aids. This 3D digitization method was chosen for a number of reasons compared to the previously mentioned CT and MRI methods. These are as follows:

- lower acquisition cost of 3D scanning equipment and accessories,
- sufficient accuracy of the shapes and dimensions of the objects thus scanned for the purpose,
- speed and practical usability of a handheld 3D scanner when scanning a part of the human body.

Active triangulation is based on obtaining the coordinates of points represents the surface of the scanned object (point cloud) or component by transmitting light patterns from the light projector to the scanned object´s surface. The patterns on the surface are captured by the sensors of the cameras - charge coupled device (CCD) or complementary metal-oxide semiconductor sensor (CMOS) and the exact position of the scanned points is then calculated on the principle of triangulation (Fig. 1) (4).

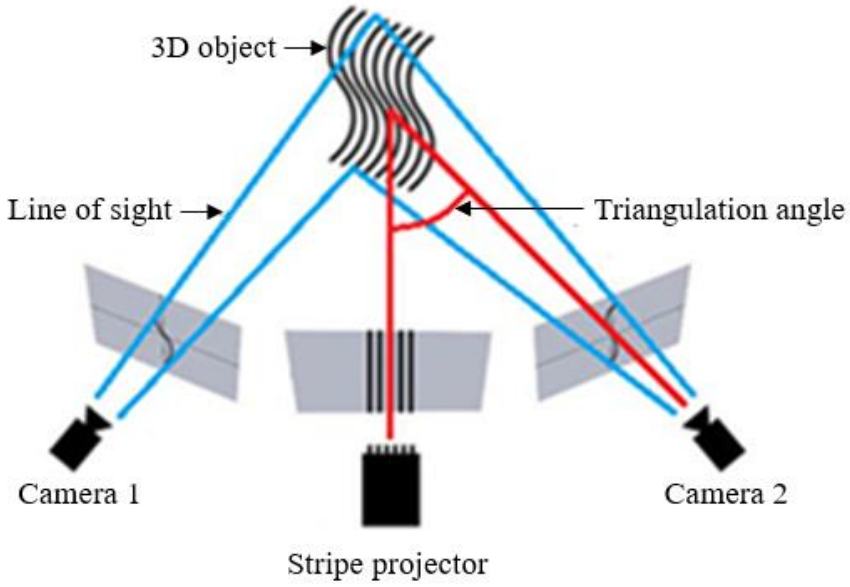

Fig. 1 *Principle of active triangulation (2)*

Additive manufacturing in medicine

Several methods of AM are used in the field of medicine. These are, in particular, methods of Stereolithography (SLA) (5), Selective Laser Sintering (SLS) (5) and Selective Laser Melting (6, 7), Poly Jet Modeling (PJM) (8) and Fused Deposition Modeling (FDM) (8). These methods belongs to the most frequently used in the various fields of medicine; SLS - manufacturing of medical devices and accessories; SLA, FDM - preoperative planning models or FDM - the production of various orthopedic and prosthetic aids (2).

The following part of the article describes the principle of AM method FDM, mainly used for the manufacture of various individual orthopedic aids in medicine, due to the low price of the machine, the material as well as the use of various types of materials.

FDM is one of the most common and also the most used AM method in practice. Fused thermoplastic fibers are extruded from the tip of a heated nozzle that moves in the X and Y axes. Thin fibers are deposited on a platform that has a significantly lower temperature, which ensures fast cooling of the melted thermoplastic. After the platform has been reduced to a precisely defined thickness of one layer, another layer is deposited. In this way, a component is created (Fig. 2) (9).

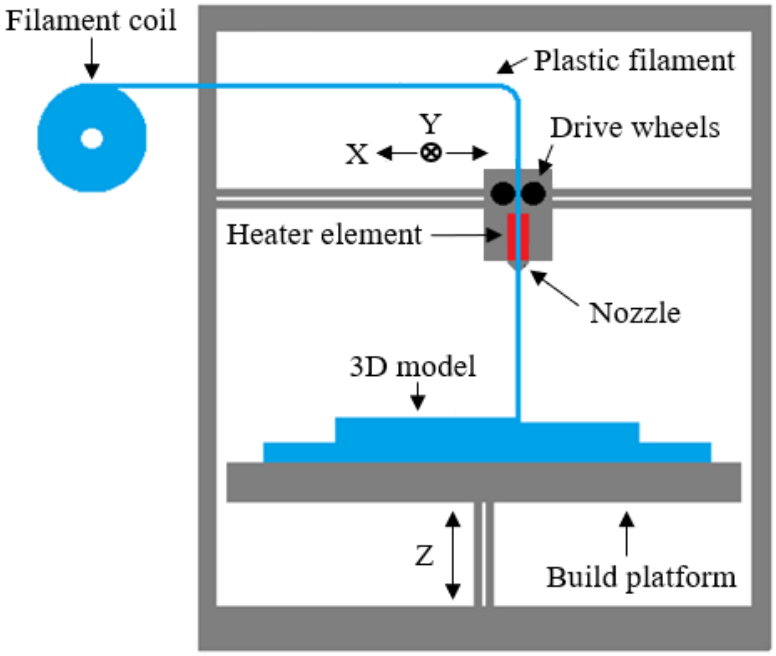

Fig. 2 *Principle of Fused Deposition Modeling*

The height of individual layers ranges from 0.05 to 0.3 mm, depending on the quality requirements of the resulting surface of the component. In this method, depending on the complexity of the component, it is also necessary to use the support material. This is used when there are hollow parts, holes or protruding parts on the component (9).

DESIGN AND MANUFACTURE OF INDIVIDUAL ORTHOPEDIC AIDS

In the design and manufacture of individual orthopedic aids by 3D digitization (active triangulation) and AM (FDM method), two variants of designing and manufacturing can be made. It is a variant to design and manufacture a 3D model of the individual medical aid, or to design and manufacture a "2D" model of the individual medical aid.

A 3D model of the orthopedic aid is created using CAD software according to the data obtained by active triangulation, a model that will be designed and manufactured in the shape and size according to the particular patient, and then it is possible to use after manufacture.

A "2D" model of orthopedic aid is created in a plane, i.e. as a unfolded 3D model, using CAD software according to data obtained by active triangulation. This model will be shaped on the body of the patient after manufacturing.

The process of designing and manufacturing an individual orthopedic aids using mentioned two variants by 3D digitization and AM is shown in Fig. 3 (2, 10).

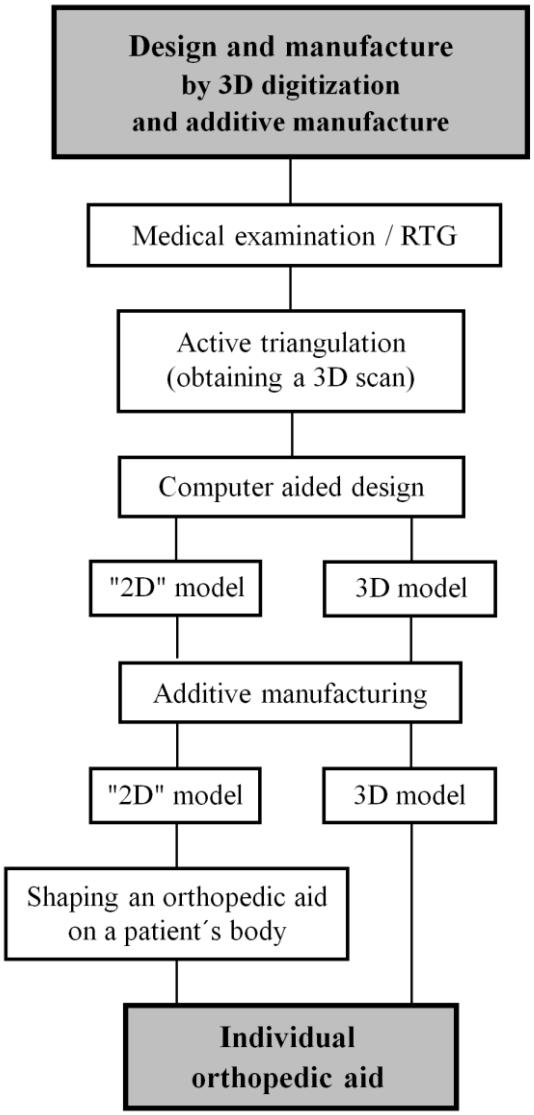

Fig. 3 *Design and manufacture of orthopedic aids (2)*

It is the design and manufacture of a "2D" model with its subsequent shaping that appears to be a more effective variant in terms of the speed of the design and manufacturing processes and also the resulting accuracy of the orthopedic aid due to its shaping on the body of the patient after manufacture. The shaping is possible thanks to the polylactic acid (PLA) material, which is not only a health-conscious and biocompatible material, but also a very good formable material, which, after shaping, retains the new shape with the required strength (11, 12).

The process consists in performing the following steps:

1) obtaining a scan of the part of the body using active triangulation,
2) editing and converting to STL format (input format to AM),
3) automated production using FDM,
4) individual orthopedic aid.

Such a design and manufacturing process has many advantages over both doctors and patients. They are:

- low material consumption,
- automated production,
- easy, comfortable, airy and visually appealing solution for the patient,
- cost savings,
- higher accuracy of orthopedic aids (by shaping the PLA material) (2).

CONCLUSION

The use of 3D digitization and AM for the design and manufacture of individual orthopedic aids is an effective way of designing and manufacturing them. With these technologies, it is possible to design and manufacture quickly and efficiently orthopedic aids, which have many advantages for the patients themselves as well as the doctors.

The use and benefits of such solutions have been described in the article, which points to the fact that the use of these technologies for the purpose is an effective way to design and manufacture individual orthopedic aids. In order to increase the performance of the AM machines ("3D printers") and searching for the design and manufacturing methodology, this efficiency will continue to increase and provide patients with a comfortable, visually appealing and functional solution to their health problems.

The paper discusses the process of design and manufacture of orthopedic aids using the above-mentioned technologies, which are applied in the research of the methodology for the effective solution of these processes for the design and manufacture of a particular orthopedic aid in dissertation thesis: *Research of design and manufacture of orthopedic appliance by 3D digitizing and additive manufacturing*.

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