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REVIEW

3D printing in the medical field

La impresión 3D en el área de la medicina

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ABSTRACT

Introduction: 3D printing has represented a technological advance in the field of health sciences. This additive manufacturing allows the creation of grafts, autotransplates and tissue regeneration.
Objective: describe the contribution of 3D printing to the field of medicine.
Methods: a review of the literature was carried out in the month of November 2023 through access to the databases Scopus, PubMed, Dialnet, Scielo, and the search engine Google Scholar version 2022, with the strategies: ((print 3D) AND (medicine)), ((medicine) AND (technological advances)) and ((3D printing) AND (surgical sciences) AND (prosthetics) AND (orthoses) AND (surgical procedures)) and their translations into the English language , limited the search to the last 5 years -from 2019 to 2023-, in Spanish, English or Portuguese languages.
Development: in a general sense, 3D printing refers to the sequential accumulation of materials on a platform through different production methods, including: polarization, injection injection, binder injection, material extrusion, powder bed, lamination metal and metal tank. This creation process that consists of printing 3D objects by superimposed layers in ascending order.
Conclusions: 3D printing has allowed us to reduce the costs and manufacturing time of the structures used in medicine -implants, prostheses, grafts and surgical material- as well as a great advance in medical education from the creation of three-dimensional pieces that allow better preparation and maintenance of surgical skills.

Keywords: Surgery; 3d print; Medicine; Prosthesis.

RESUMEN

Introducción: la impresión 3D ha supuesto un avance tecnológico en la esfera de las ciencias salubristas. Esta manufactura aditiva permite la creación de injertos, autotransplates y regeneración de tejidos.
Objetivo: describir el aporte de la impresión en 3D al campo de la medicina.
Métodos: se realizó una revisión de la bibliografía en el mes de noviembre de 2023 a través del acceso a las bases de datos *Scopus*, *PubMed*, Dialnet, *Scielo*, y el gestor de búsquedas Google Scholar versión 2022, con las estrategias: ((impresión 3D) AND (medicina)), ((medicina) AND (avances tecnológicos)) e ((impresión 3D) AND (ciencias quirúrgicas) AND (prótesis) AND (órtesis) AND (procedimientos quirúrgicos)) y sus traducciones a la lengua inglesa, limitada la búsqueda a los últimos 5 años -desde 2019 hasta 2023-, en idiomas español, inglés o portugués.
Desarrollo: en sentido general la impresión 3D se refiere al cúmulo secuencial de materiales en una plataforma a través de distintos métodos de producción entre los que se encuentran: polarización, inyección de aporte, inyección de aglutinante, extrusión de material, cama de polvo, laminación de metal y depósito metálico. Este proceso de creación que consiste en la impresión de objetos 3D por capas superpuestas en orden ascendente.
Conclusiones: la impresión 3D ha permitido reducir los costos y el tiempo de fabricación de las estructuras

utilizadas en la medicina –implantes, prótesis, injertos y material quirúrgico– así como un magno avance en la educación médica desde la creación de piezas tridimensionadas que permitan una mejor preparación y conservación de habilidades quirúrgicas.

Palabras Clave: Cirugía; Impresión 3D; Medicina; Prótesis.

INTRODUCTION

3D printing machines are electronic equipment that can create three-dimensional objects from models sketched on computers through Computer Aided Design (CAD) programs. Its history dates back to 1984, when Charles Hull, a researcher who founded the company 3D Systems, was granted the patent entitled "Apparatus for production of three-dimensional objects by stereolithography" with a development based on inkjet printing, which was developed in 1976;[1] this became a milestone for science and technology in the current century.

In health, technologies play a transcendental role if a well-functioning system supports them. In particular, medical devices are considered indispensable for the effective diagnosis and treatment of diseases and their prevention and future rehabilitation once the problem has been solved. The global demand for these devices has experienced a considerable and sustained increase in the last period, stimulated by the aging population and technological advances.[2] For 3D printers, the result of the development of bioinks and the improvement in the application of their deposition techniques has been significant.

Bio inks are elaborated with a vast number of materials from different groups; in the case of equipment or devices developed for medical use, there are two fundamental primary groups for their manufacture: 1) module in which there are those that need cells to be made - mainly prostheses or orthoses - and 2) the module of those that do not need cells for their manufacture. Generally speaking, developing an attachment or medical device requires that the bio-inks have characteristics that allow them to be processed at room temperature, to print beads, and to control their microstructure.[2,3]

Transplanting organs or tissues is a technique that allows the solution and correction of problems that must be treated as a matter of urgency; however, despite the progress that has been made over time in these processes, there are still difficulties inherent to the expertise of the physician -immunological rejection and deficiency in the number of donors, to name a few-.

The technology of artificial organs and tissues has made it possible to improve patient's quality of life despite the need for manufacturing to develop complex structures. 3D provides an accurate response to these limitations since it allows the incorporation of cells to develop a biomaterial that regenerates biological structures, facilitating the acceptance of the affected person's immune system and making up for the lack of donors.[4] The objective of this research is to describe the contribution of 3D printing to the field of medicine.

METHODS

A literature review was conducted in November 2023 through access to the databases Scopus, PubMed, Dialnet, Scielo, and the search engine Google Scholar version 2022, with the strategies: ((3D printing) AND (medicine)), ((medicine) AND (technological advances)) and ((3D printing) AND (surgical sciences) AND (prosthetics) AND (orthotics) AND (surgical procedures)) and their translations into the English language, limiting the search to the last five years -from 2019 to 2023, in Spanish, English or Portuguese languages. Theoretical level methods were used, such as analysis-synthesis for the introduction and development and deduction-induction for structuring the conclusions. The articles selected were those that allowed open access, had the entire length of the manuscript, and were relevant to the topic addressed in the authors' opinion, resulting in 21 investigations distributed in original articles, case presentations, literature reviews, and theses.

DEVELOPMENT

3D Technology

3D printing has become one of the most revolutionary technologies of the 21st century. Authors such as Joiner, quoted by Hervás-Gómez et al.[5], define this printing technique as a style of manufacturing solid substances in a third dimension from a file in digital format, which he calls an additive process.

Generally, 3D printing refers to the sequential accumulation of materials on a platform through different production methods, including polarization, filler injection, binder injection, material extrusion, powder bedding, metal lamination, and metal deposition.[5]

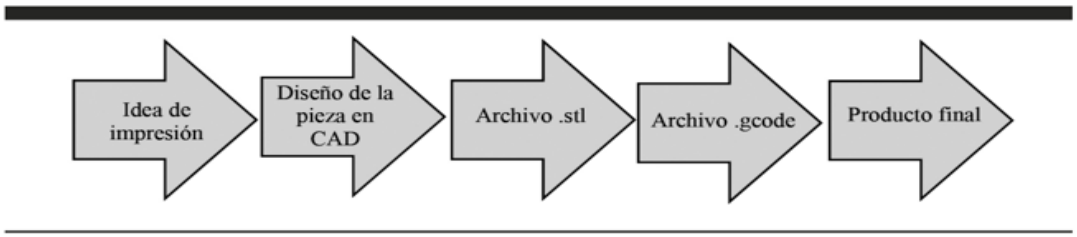
Despite being an emerging technology that allows the creation of materials through the transformation of other less complex ones following a process of accumulation of layers, for the authors of this research, 3D printing involves a series of events that result in the creation of the final three-dimensional entity, which has its origin in CAD software. With the technological progress the present century has meant for humanity, this

knowledge is becoming a low-cost and accessible tool. CAD applications with open codes for the daily use of different users and the different formats of this printing equipment allow its broad reach within society.

Novak[6], in his exposition of the 3D printing process or additive manufacturing as a layer-by-layer aggregate of high precision from a digital model through the manipulation of biodegradable or non-biodegradable materials, concludes in his definition that it is a group of manufacturing technologies.

This creation process, which consists of printing 3D objects by superimposed layers in ascending order, follows several inviolable steps for its correct operation, of which there are two main ones, especially in fused deposition printing (Figure 1): [6]

1. Division of the software in a 3D graphic in layers as exquisite as the diameter of the nozzle present in the printer (they vary from 0.10 to 1.10 mm, where the 0.4 mm measure is the most commonly used).
2. Then the printer moves on the plane to eject the material used in the creation of the three-dimensional article with the coordinates entered in the CAD application.



Source: Cano Vicent et al.[7]

Figure 1. General scheme of 3D manufacturing by fused deposition (main stages)

In this way and with the fundamental fulfillment of these steps, the 3D object is obtained. It will have structural conditions that allow its use in specific target fields according to the material used. This tool -printer- is a numerical control machine with three axes and an extruder.

History of 3D technology

As mentioned in the introduction of this research, the origin of this technology dates back to 1976 with the creation of the company 3D Systems,[1] with the invention of the inkjet printer; its evolution has been diverse, from the format of the machinery to the improvement, refinement, and functionality of the techniques, as well as the transition from ink printing to printing with materials; the needs of different industries have promoted this progress.[5,6]

In 1984, a series of events began that triggered the birth of 3D printing as an industry; during this half of the 1980s, the first patents and companies were created. 3D technologies begin to gain power: the oldest of these is Stereo LithogrAphy (SLA), a printing pattern that through the use of a laser converts a photo-polymer from a liquid state to solid plastic - a process called stereolithography - since it uses UV-sensitive resins, the machinery needs to be protected by orange, green, red or yellow colored foils; Another printing pattern is Selective Laser Sintering (SLS), which substitutes laser solidification for sintering with the use of laser powder of plastic, nylon, polyamide or glass-fiber-filled polyamide; Digital Light Processing (DLP) are the type of printer that with the use of UV rays in a projector solidify the material -SLA and DLP use a resin that hardens under the administration of UV rays, which makes them photosensitive-; and the most widespread type of printing is Fused Deposition Modelling (FDM) that uses the way of deposition of molten filaments by layers on a platform that can be heated or not, this filament is extruded by a nozzle.[5]

The first printing kit that reached the market allowed the user to assemble and calibrate it cheaply. This happened in 2009, and by 2010, a milestone in the history of printers occurred when it reached homes, and from that moment on, it has continued to evolve and become part of daily social action.[5]

Application of 3D Printing in Biomedicine

The development of 3D printing has attracted considerable interest in various areas of life. According to the principle of the constitution of the filaments by polymers that often have characteristics that make them biocompatible, 3D printing in biomedicine has enormous viability; in addition to its biocompatible character, there is its mechanical and structural behavior.[7]

The properties of the materials that allow the development of 3D printing make them ideal for the manufacture of scaffolds that act as an extracellular matrix in artificial tissue engineering.[8]

In the case mentioned above, biomaterials provide cellular support that recognizes and guides localized tissue regeneration after creating micro-controllable environments similar to in vivo designs. Scaffolds are used to grow other structures of the human anatomy: bone tissue, cartilage, ligaments, skin, blood vessels, nerves, and muscle. Given the biodegradability of scaffolds, they allow the material to disintegrate, but, in turn, new

tissue is generated, which favors the manufacture of complete organs through bioengineering.[9]

Traditional applied sciences need to experience incorporating scaffolds' internal architecture and control. However, with FDM, control of pore dimensions and distribution is possible.[8]

To fabricate scaffolds, it is necessary to mix different biomaterials to get the best out of each of them; for example, creating a scaffold by FDM of hydroxyapatite and polycaprolactone favors bone regeneration.[9]

Depending on the application of the scaffold, the design may require specific physicochemical properties, such as biodegradability, or specific mechanical or morphological properties, such as surface topology and pore dimensions, among others, to achieve the creation of an in vivo cellular microenvironment according to the specific tissue to be regenerated.

3D printing has also been a breakthrough in the pharmacological industry since using biomaterials allows the release of biomolecules such as antimicrobials, biometals, or growth factors. This has become an advantage because the continuous controlled release of drugs is adequate for their administration.[9,10] The development of implantable devices that allow drug-dosed release has allowed the creation of even triple therapies -captopril, nifedipine glipizide-.[10]

Three-dimensional biomimpression has reached such complex levels as neuron, kidney, skeletal muscle, and liver tissue creation. The future focus of this printing method lies in cellular viability for composites of bone and soft tissues that are lacking.[11] It is a goal to realize these manufacturing techniques faster and with more excellent compatibility in terms of biological materials.

Application of 3D Printing in Medicine and Medical Education

Since the last ten years, there has been an increased interest in surgical training areas, especially those focused on repetition of tasks and pre-exist with objectives of previous identification in controlled scenarios. At this point, the tools created with 3D printing for Medical Education become useful since they favor the teaching of residents, the improvement of specialists, and even the biomedical development of students with the creation of pieces that provide expertise to those interested since they would have faithful portraits that would allow the improvement, maintenance or birth of surgical skills.[12,13]

In the surgical development of medicine, 3D printing has allowed the joint use of radiological equipment, the manufacture of instruments that are customized to perform simplified controlled interventions that allow the reduction of the cost up to 10 times its price in the current market with traditional technology, which achieves that the underdeveloped countries, obtain benefits with this industry.[8,9,10]

In Orthopedics and Traumatology, printed models have shown a remarkable superiority in using images, even with the three-dimensional format, which has allowed planning the resection of tumors or the treatment of conditions of the osteoarticular system. [14]

The most recent use of this technology has involved the manufacture of patient-specific implants; these aim to improve the fit for the anatomical restoration and ensure that the relationship function can be balanced through previous planning based on radiological images of three-dimensional reconstruction.[15]

In the creation of implants, 3D printing has allowed not only the structural functioning of an anatomical structure in a biological way but has also contributed to the attractiveness of these implants, as craniofacial implants are an example since they allow their total customization according to the anatomical demand.[16,17,18]

Regarding prostheses, the conventional way of creation has been transformed using the principle of personalization and the low cost of production added to the capacity of rapid manufacturing that 3D modeling printing provides, which has given rise to prosthetic limbs that have broad anatomical adaptations capabilities and even allow the release of drugs. The authors consider that thanks to 3D printing, it has been possible to create tubular implants -stents- efficiently and with less possibility of rejection since their manufacture is through biological materials.

The establishment of drug delivery systems has had a favorable acceptance in the international medical field; these arise from the union of 3D printing and coating techniques through adjustments in the pore sizes, the matrix that the device has, and the thickness of the layer that covers it, it is possible to control the release time at nano and microscale, this technology allows the elimination of side effects that often arise from the use of chemotherapy or surgical interventions for tumor resection.[19]

In current times, due to the shortage of organ and tissue donors, 3D printing has become a boom in this field since this additive manufacturing has allowed researchers to develop and customize tissues and organs, in addition to the placement of cells in the printing biomaterials that allow the creation of a kind of autograft, thus reducing the possibility of rejection to almost 0%; With these techniques, bone, cartilage and diaphragmatic defects have been corrected, corneal substitutes and brain structures have been developed, while the incorporation of blood vessels has yet to be overcome for the survival of this development. 3D bioprinting with angiogenic tissues similar to in vivo structures will approve blood circulation within the tissue constructs, although proangiogenic factors are necessary.[20,21]

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CONCLUSIONS

3D printing has made it possible to reduce the costs and manufacturing time of structures used in medicine -implants, prostheses, grafts, and surgical material- as well as a significant advance in medical education through the creation of three-dimensional parts that allow for better preparation and preservation of surgical skills.

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