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3D printing applied to health

Impressão 3D aplicada à saúde

Impresión 3D aplicada a la salud

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Abstract
3D printing, also known as additive manufacturing, is a technology that has existed since the 1980s. 3D printing can be applied to health in several ways: production of didactic material in the area of health, prostheses, surgical planning and with bioprinting of organs. There are several methodologies used for 3D printing applied to health, but basically they follow the process: idealization of the model, conversion of the file into STL, then G-Code and then printing and treatment of the printed object. The printers can use plastic, biodegradable material, powders, liquid or even living cells. The objective of this study is to show in a simplified way how 3D printing can be applied to health, addressing the main concepts of 3D printing. To carry out the article, a search was made for scientific articles from 2010-2023 with the theme 3D printing applied to health. This study showed that, since the 1980s, 3D printing has improved a lot, but challenges such as costs, production time and regulatory mechanisms still need to be overcome.
Keywords: 3D printing; Health; Prostheses; Surgical planning; Education; 3D bioprinting.

Resumo
A impressão 3D, conhecida também como manufatura aditiva, é uma tecnologia que existe desde a década de 80. A impressão 3D pode ser aplicada à saúde de diversas formas: produção de material didático na área da saúde, próteses, planejamento cirúrgico e com a bioimpressão de órgãos. Várias são as metodologias utilizadas para a impressão 3D aplicada à saúde, mas basicamente seguem o processo: idealização do modelo, conversão do arquivo em STL, depois G-Code e logo em seguida a impressão e tratamento do objeto impresso. As impressoras podem utilizar o material plástico, biodegradável, pós, líquido ou até mesmo células vivas. O objetivo deste estudo é mostrar de forma simplificada como a impressão 3D pode ser aplicada à saúde, abordando os principais conceitos de impressão 3D. Para a realização do artigo, foi feita uma busca de artigos científicos de 2010-2023 com o tema impressão 3D aplicada à saúde. Esse trabalho mostrou que, desde a década de 80, a impressão 3D se aperfeiçoou bastante, mas ainda é preciso vencer desafios como custos, tempo de produção e mecanismos regulatórios.
Palavras-chave: Impressão 3D; Saúde; Próteses; Planejamento cirúrgico; Educação; Bioimpressão 3D.

Resumen
La impresión 3D, también conocida como fabricación aditiva, es una tecnología que existe desde la década de 1980. La impresión 3D se puede aplicar a la salud de varias maneras: producción de material didáctico en el área de la salud,

prótesis, planificación quirúrgica y con bioimpresión de órganos Existen varias metodologías utilizadas para la impresión 3D aplicada a la salud, pero básicamente siguen el proceso: idealización del modelo, conversión del archivo a STL, luego G-Code y luego impresión y tratamiento del objeto impreso. Las impresoras pueden utilizar plástico, material biodegradable, polvos, líquidos o incluso células vivas. El objetivo de este estudio es mostrar de forma simplificada cómo se puede aplicar la impresión 3D a la salud, abordando los principales conceptos de la impresión 3D. Para la realización del artículo se realizó una búsqueda de artículos científicos del 2010-2023 con la temática impresión 3D aplicada a la salud. Este trabajo mostró que, desde la década de 1980, la impresión 3D ha mejorado mucho, pero aún deben superarse desafíos como los costos, el tiempo de producción y los mecanismos regulatorios.
Palabras clave: Impresión 3D; Salud; Prótesis; Planificación quirúrgica; Educación; Bioimpresión 3D.

1. Introduction

3D printing, also known as additive manufacturing, is a technology that allows the creation of three-dimensional objects layer by layer, from a digital model(Ventola, 2014). While initially widely used in the design and engineering industries, 3D printing is now revolutionizing the field of health (Shahrubudin et al., 2019).

The application of 3D printing in healthcare includes a wide range of fields, including educational, prosthetics, dentistry, surgery and regenerative medicine. One of the main advantages of 3D printing is the possibility of offering a personalized product to the patient (Awad et al.,2021).

In education, 3D printing can be used to create accurate anatomical models for educational purposes and training surgeons (Ford & Minshall, 2019). In the area of prostheses, surgery or dentistry, it is possible to build prostheses that fit perfectly to the patient and with customized modifications according to the need (Hao et al., 2020). In the area of regenerative medicine it is possible to build tissue and technology is developing to print organs (Chung et al.,2020) . And it is also being used for printing personalized medicine according to the dosage (Funk et al.,2022).

So it is clear that 3D printing is revolutionizing healthcare.The objective of this study is to bring the main technologies of 3D printing applied to health and discussions about the topic still little known by many people.

2. Methodology

To carry out this narrative review, a search was made for scientific articles from 2010-2023 with the theme 3D printing applied to health. The databases used were PubMed and Google Scholar, with no language restrictions. The keywords were "3D printing", "health", "prostheses", "surgical planning", "education" and "3D bioprinting".

3. Results and Discussion

3.1 Main 3D printing technologies used in healthcare

Some methodologies can be applied to 3D printing to health, from types of printing, strategies and materials. Fused Deposition Modeling (FDM), Stereolithography (SLA), Selective Laser Sintering (SLS) and 3D Bioprinting are some types of 3D printing that can be used in healthcare(Eshkalak et al., 2020).

FDM printing, deposition of thermoplastic material filaments, can be used to print models of organs, surgical instruments and some implants. This type of printing can use polylactic acid (PLA), bioplastic from renewable sources of sugar cane or corn starch, but also other materials such as Acrylonitrile Butadiene Styrene (ABS), Modified Polyethylene Glycol Terephthalate (PETG), Nylon and Polyvinyl alcohol (PVA), for example (Debnath et al.,2021; Haryńska et al., 2020).

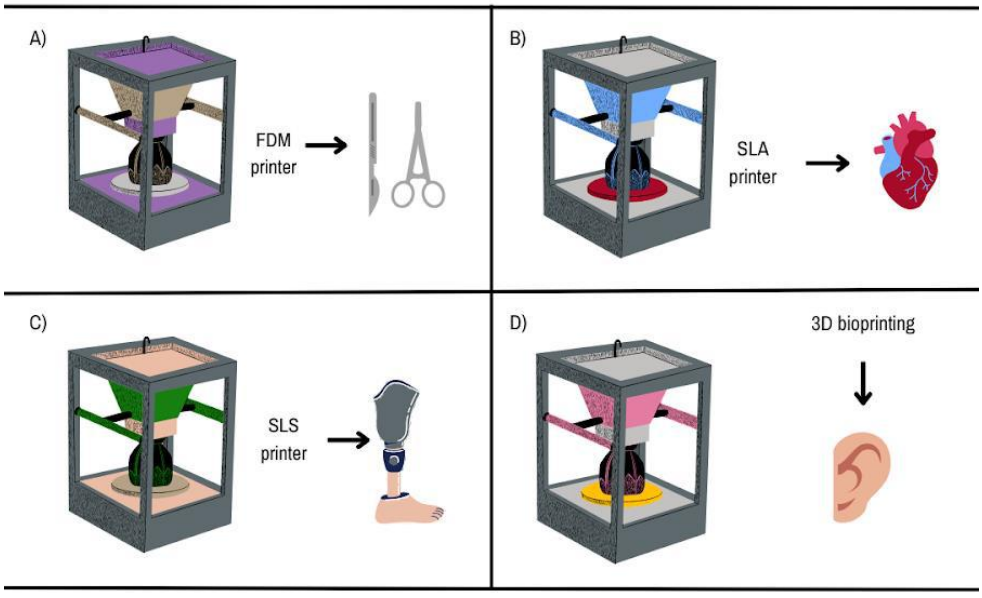
SLA printing, a laser beam solidifying a liquid resin, can be used to print anatomical models and precise emergency guides. The resin used can be biocompatible, transparent, resistant, flexible and even photosensitive with nanoparticles, in order to customize the medical product (Xu et al., 2021).

The SLS, a high power laser used to fuse particles of a material powder, is widely used in the area of custom medical prostheses or complex anatomical models. The material used as raw material can be Nylon, polypropylene, Polyether-ether-ketone (PEEK) and Thermoplastic Polyurethane (TPU), for example (Msallem et al., 2020).

Finally, 3D bioprinting can print living cells or biocompatible materials used in tissue engineering and in development to manufacture custom organs. The base material can be extracellular matrix, hydrogels, living cells and synthetic biomaterials (Ozbolat et al., 2016).

Other types of 3D printing are also used in healthcare, but use similar methodologies (Figure 1). All these processes basically follow the following order: idealization of the 3D model, conversion to the STL file, conversion from STL to G-code, file that the printer can read, 3D printing and image treatment after printing (Eshkalak et al., 2020).

Figure 1 - A) FDM 3D printing, it deposits filaments of thermoplastic material and can be used for the production of surgical instruments and some implants. B) SLA 3D printing, a laser beam solidifying a liquid resin, can be used to print anatomical models and precise emergency guides. C) The SLS, a high power laser used to fuse particles of a material powder, is widely used in the area of custom medical prostheses or complex anatomical models. D) 3D bioprinting can print living cells or biocompatible materials used in tissue engineering and in development to manufacture custom organs like ears.



Source: Authors.

Therefore, it is possible to observe in Figure 1 that different types and methodologies of printers practically follow the same steps, but with different materials, increasing the level of detail or not, according to needs.

3.2 Most applied cases in health

With the aid of computed tomography, or magnetic resonance imaging, it is possible to produce three-dimensional images. In an accident situation, for example, a patient who has lost some bone can have that part replaced according to the measurements of the original bone (De La Peña et al., 2018). With advanced tomography and 3D printing techniques, it is possible to design a personalized prosthesis for the region of the lost bone and guarantee a better quality of life for the patient (Liacouras et al., 2017; Park et al., 2019).

Another booming area is drug customization. Some medications have a geometry that makes them difficult to swallow or causes the active principle to be poorly or very absorbed (Elkasabgy et al., 2020). In addition, the drug dosage can vary greatly according to each patient and there are no specific dosages for each one on the market, since dividing the pill in half, for example, is not advisable (Goole & Amighi, 2016). With the help of 3D printing, it is possible to produce ultra-specific drugs in doses and sizes, according to the patient's needs (Tan et al., 2020).

It is also common, in surgical procedures, the lack of personalized instruments for each patient, since each person can have a different anatomy and not all instruments can be minimally invasive (Culmone, et al., 2020; George et al., 2017). Therefore, with the help of 3D printing, it is possible to produce specific surgical instruments for each patient, making surgery less invasive and with fewer sequelae for patients (Beitler et al., 2022).

In addition, the lack of anatomical models in disciplines in the health area is common (Ford & Minshall, 2019; Huang & Zhang, 2014). With 3D printing it is possible to produce several realistic materials for the educational process, or even for surgical planning (Sheha et al., 2019).

Another booming area that could revolutionize is 3D bioprinting (Gungor-Ozkerim, et al., 2018). Currently, skins, cartilages, blood vessels and even organs have already been produced (Murphy & Atala, 2014; Murphy et al., 2020). In the future, it is expected that organ donation queues will be smaller with the possibility of 3D printing of various organs.

3.3 Challenges and perspectives

One of the biggest challenges for 3D printing is the ability to print personalized organs for thousands of people in need, alleviating the shortage of organs, but which is still in development and still needs regulatory mechanisms (Kirillova et al., 2014; Ricles et al., 2018). In addition, creating personalized medical devices is also a big challenge. A doctor's office, for example, could have a 3D printer to print a medical device or medicine according to the patient's needs, increasing the effectiveness of treatments and reducing adverse effects. However, because it is an advanced technology, it is still necessary to train health personnel for these 3D printing processes for large-scale application.

Therefore, in general, it is still necessary to improve 3D printing technologies, invest in 3D printing training and solve regulatory legal mechanisms for these new Technologies (Morrison et al., 2015; Palo et al., 2017).

4. Conclusion

3D printing, a technology that has existed since the 1980s, is improving every day. Currently, it is already possible to produce didactic materials, surgical planning, replacement of prostheses and with the possibility of printing functional organs for transplants soon. However, it is important to highlight that there are challenges to be overcome so that the full potential of 3D printing is realized in the health area. These challenges include improving print speed, cost, and regulatory validation of printed devices. As these challenges are overcome, 3D printing could be widely available in doctors' offices and hospitals to treat and care for patients in a more individual and personalized way. One of the great challenges we must overcome to expand the practicality of 3D printing in healthcare.

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