

THE APPLICATIONS OF RAPID PROTOTYPING (ARTICLE REVIEW)

Raed H. Ogaili¹, and Lames H. Almansee²

^{1,2} Basic Medical Sciences, College of Dentistry, Iraq

E. Mail raedogaili@uokerbala.edu.iq

ABSTRACT

A new and incredibly promising technology is 3-Dimensional (3D) printing, which first emerged in the 1980s and has been continuously advancing since then. It is a distinct way of layer-by-layer material deposition that sets itself apart from other conventional modelling techniques through material molding and removal. Modelling by adding material, 3D printing can produce things with incredibly intricate geometries and even with previously unheard-of accuracy. It may be applied in a variety of fields, including aviation, the automobile industry, production, science, education, and medicine. Printing by adding material is a significant breakthrough for several writers in these latter domains of application. The spectrum of potential applications for 3D printing is enormous and highly promising, including modelling learning and training prototypes, producing tailored prostheses, and printing biological and functioning organs. In General, this article will focusing on the Major applications of 3D printers in education and medicine

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INTRODUCTION

3D printing (rapid prototyping or additive manufacturing) is creating solid, 3D objects from a collection of images in the form of a digital file. The printer deposits layers of a material (such as plastic, resin, or metal) in a volumetric manner such that an exact replica of the object is obtained. This innovative technology is likely to revolutionise our knowledge and understanding of structural heart disease and may have therapeutic applications as well [1]

The principle of three-dimensional printing represents a revolution in the manufacture of objects. Thanks to the addition of material layer by layer, this process makes it possible to obtain geometries that are much more complex and new than before. Imagination is almost the only limit to what can be produced with a three-dimensional printer [2,3].

Since three-dimensional printing is expensive and hence not available to a larger audience, technology was initially employed in the industrial sector, namely for prototyping. Then, as technology advanced, it became more accessible, and its use was widened. It has drawn an increasing amount of interest from archaeologists, then from medical professionals and educators. Three-dimensional printing is today employed in various industries, whether it is for printing antique things, implants, prosthetics, and live tissues or even potent educational aids. A presentation of the many uses of this technology in veterinary medicine will be made to carry out this study and in accordance with the context stated above, highlighting the significant contribution of this technology in the medical area. [4,5,6].

In this article, we discuss the third industrial revolution technology known as three-dimensional printing.

How does a 3D printer work?

It is a technique that creates 3-dimensional models one layer at a time using a device called a 3D printer. One thin layer of material is applied, and this layer connects with another. A model is gradually constructed from the ground up. An electronic design serves as the model's foundation.

Computer software is used to develop the model, which is then submitted to the printer and printed gradually. Gypsum powder, liquid resin, plastic, or even laser-melted metal can all be used in the printer[7-10].

3D Printing and Education

Despite not being widely used in medicine, this technology is becoming more popular due to its benefits. It makes it possible to create educational materials that are often reusable, unlike certain anatomical parts that they imitate [11-13].

Figure (1) 3D printing in education (source retrieved from <https://blog.grabcad.com/blog/2016/09/22/3d-printing-target-education/>)



➤ Studying general surgical techniques

• Silicone models

The teaching of general surgery is advancing rapidly with 3D printing, which has allowed the development of silicone models. The latter serves to provide a learning tool close to the texture of living models, available and reusable for training students and the maintenance of their clinical skills. This has the advantage of the ability to create educational models with pre-inserted incisions that the students apply to close according to different suture techniques to be mastered and which will make it possible to differentiate the levels of competence between users [14].

More specific applications for this technology include recurring postpartum laceration treatment using inexpensive, verified, standardised, and anatomically accurate silicone perineum models. They are utilised, for instance, by Memorial University of Newfoundland's Department of Obstetrics and Gynecology to organise clinical training seminars. [15].

Earlier training techniques that used simpler foams or animal corpses—materials that are more realistic but more elusive and perishable—were judged to be inferior to silicone models. The fact that they exhibit relatively minimal symptoms of wear after usage, allowing for reuse, has also been found to make them extremely durable and affordable to produce learning tools [14,15].

• Reality simulation of intravenous injection

Repeated practice is crucial to mastering the IV injection technique, but veterinary education programs do not always allow sufficient practice for all students. In addition, repeated attempts in a dog are impossible due to vascular damage, and the use of corpses, in this case, is of no interest because, after death, openings are formed in the wall of blood vessels, and the blood then escapes from the vessels, and suddenly, they will lose their conformation.

Augmented reality is the superposition of reality and elements (sounds, 2D, 3D images, videos). The user can see the real world, with virtual objects superimposed or composed with it. Using this technology, the user can see the 3D graphics of the vein and the syringe overlapping with the 3D silicone model and the syringe. 3D graphics move as the user moves the actual syringe and silicone model. After inserting the needle into the 3D container, he can press the button on the syringe for the simulator to determine the success of the injection.

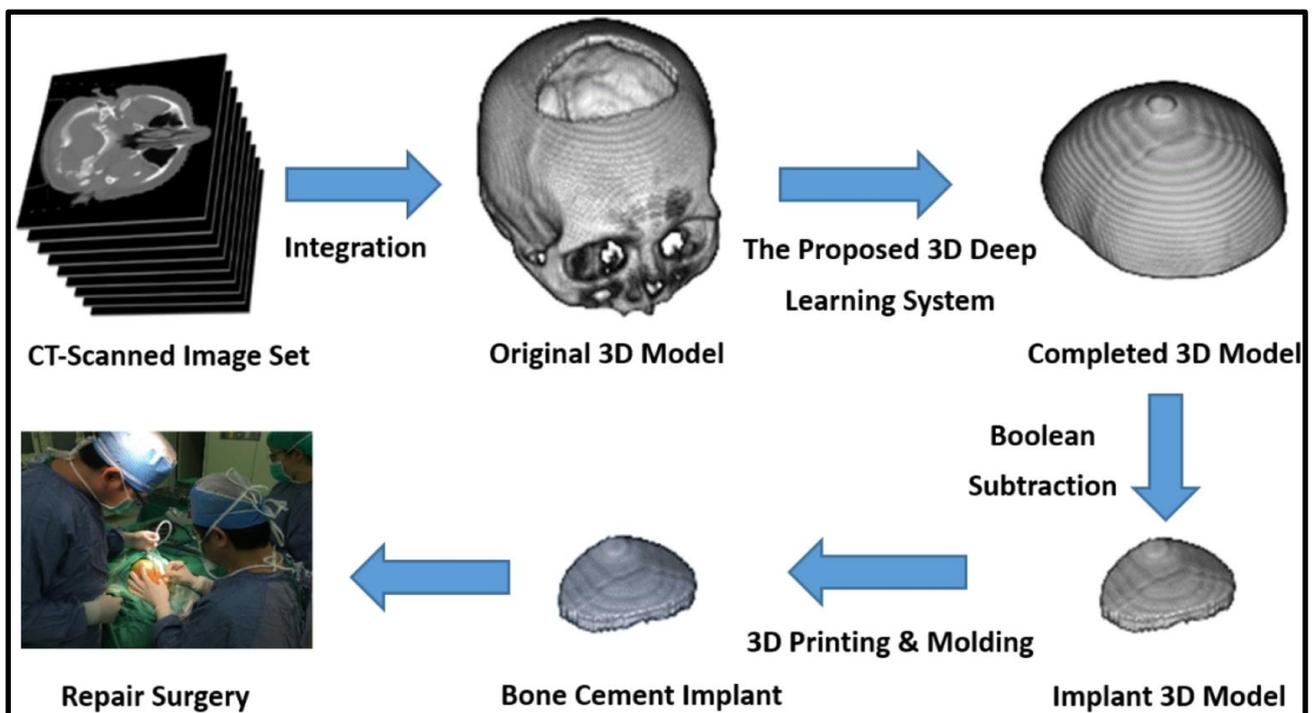
Currently, simulation-based medical education offers a viable alternative to live animals as part of the training of veterinary medicine students and plays an effective role in reducing the use of these animals [16,17].

- **Sold models**

How to create models?

It is first necessary to select an imaging modality, such as CT or MRI, to generate a model of the heart or any other bodily component. A volumetric data collection is created from a series of several photographs. A data set consists of a stack of photos that may be assembled seamlessly. The segmented anatomy from the photos is then transmitted to another software for processing. Any model noise would be eliminated in this stage, and any enhancements might be planned. Furthermore, the model may also be validated by overlaying the completed section back onto the original pictures to confirm that it matches the patient's anatomy. Once a necessary model (composed of a number of photos) has been chosen, it may be submitted for printing. The entire process can take a few seconds to several hours or even days. [9,18-20].

Figure (2) Process of preparing 3d models(source Ref. No. 47)



- **Models for learning anatomy**

Anatomy is a descriptive field that places a lot of emphasis on real-world applications. Students can have a greater understanding of animal physiology, pathology, and clinical problem resolution through anatomical instruction. Live animals and specimens have traditionally been used extensively to educate and learn about animal architecture, but most animal specimens need to be preserved in formaldehyde solutions, which may be dangerous and difficult for technicians, students, and educators. It is clean, dry, odourless, and durable so that samples can be handled without gloves and do not need special storage conditions. However, the patination of biological samples—a method for preserving biological tissues by replacing various body fluids with silicone—remains a protracted, expensive process. Dissection is frequently seen in veterinary medicine as the gold standard for learning anatomy. Over the past few decades, the use of animal specimens in the teaching of veterinary anatomy has decreased due to a variety of pedagogical, ethical, and financial restrictions, while new resources and teaching techniques requiring less use of animals have grown. [21, 22].

In cases where cadaveric dissections are limited, students often rely heavily on written and oral explanations, as well as on 2D visual representations. This teaching has been strongly associated with a detrimental increase in cognitive load, resulting in decreased cognitive performances, knowledge acquisition and retention [23,24].

Some studies have shown that students believe that the 3D printed model helped them to better understand and that it improved their interest in learning.

The acquisition of anatomical resources appears to have some potential uses for contemporary technological processes. 3D printing is a new innovation that has been adopted in a variety of biomedical sectors, including research, teaching, and practice. It allows for the speedy and precise production of products from computer-generated models. For instructional reasons in the realm of anatomy, highly realistic 3D-printed replicas have been created. Digital models may be examined and changed before manufacture. Following the scanning of biological samples, the scale models may be 3D printed using filamentous thermoplastic, plaster-like powder, or polylactic acid (PLA) filament.

These printed models provide an added benefit: it becomes possible to create truly larger-than-life models, enlarging the bones to make details easier to see and enhancing student learning. A sphenoidal bone printed in the United States at Purdue University has caught the attention of educators to replace the bone kits (skeletons that can be dismantled into several bones) used by students in their general anatomy classes because the Conventional bone kits are expensive to purchase and create and are also easily damaged in use [25].

3D-printed skeleton models have been used in laboratory training for learning anatomy. Samples of adult cattle skeletons: The femur, the fifth rib and the sixth cervical vertebra (C6) from the collections of the College of Animal Science and Veterinary Medicine of Qingdao Agricultural University and others from a horse: the scapula, humerus, radius and ulna, carpus and phalanges, were selected for scanning to create the 3D models.

The skeletal samples were scanned using the 3D surface scanner. The digital models were processed in STL files and then transferred to the 3D printer. The dimensions of the specimen and the 3D printed models were measured and compared; there was no significant difference between them.

Anatomical features of bone samples, digital models, and 3D printed models were also analysed according to the Manual of Veterinary Anatomy of Domestic Mammals [26].

A survey was distributed to assess the opinions of students regarding the use of 3D printed models in teaching anatomy. The results of the survey showed that the students felt that the 3D printed model helped them to better understand the material and that the anatomical characteristics of the 3D printed models were not different from those of the real models (Bone specimens). Regarding safety and convenience, the students found that the 3D printed model was odourless and

lasting and improved their interest in learning.

Data show that 3D printed models can be a reliable alternative to bone samples in the teaching of veterinary anatomy [21,22].

Figure (3) Three-dimensional-printed model of frontal sinus anatomy. Cells are colour-coded according to anatomic structure: yellow, frontal sinuses and outflow tracts; reds, anteriorly based cells; and blues, posteriorly based cells (source ref. No. 46)



- **Models for learning orthopaedic**

For owners of small animals suffering from bone damage to receive a good and sufficient diagnosis and treatment, a thorough understanding of normal skeletal architecture and the capacity to recognise the existence of fractures is necessary. Therefore, it would be quite interesting to design and adopt new teaching strategies that make it easier to teach diseased anatomy to veterinary students. In contrast to traditional methods of diagnosis, 3D printed models have effectively helped students identify and characterise bone fractures and learn about normal skeletal architecture. In fact, it is a straightforward, affordable teaching strategy that enables the representation of the bone devoid of its musculature envelopes, allowing for unrestricted manipulation of the different bone ends in the three spatial planes and enhancing student comprehension. With training, the future practitioner will be able to better understand the interpretation of these images for the cases with which he will be presented in his future practice to the ability to associate a fractured image obtained by CT, MRI, or X-ray with direct observation of the corresponding 3D model [26,27].

- **3D Printing and Medicine**

The majority of medical applications fall into one of the following categories: organ bioprinting, which is currently restricted to research, prosthetic limbs and tissue, personalised implants, surgical planning, educational tools (anatomical models for medical education), and surgical planning tools [2, 28-31].

- **Surgical planning**

The surgeon often makes the major decisions regarding surgical planning during the operation based on a visual evaluation. This might be challenging, particularly if there are abnormalities in the bone structure. It is also obvious that this process is substantially facilitated by the capacity to examine and adjust an osteotomy from any angle without the presence of soft tissue. Case studies and series of cases make up the majority of the literature on 3D printing in the surgical sector [32-35].

In many situations of corrective osteotomies in oral and maxillofacial surgery, as well as in cases of congenital bone defects, 3D printed bone models can be utilised in veterinary orthopaedics to create a precise surgical plan and carry out a successful corrective osteotomy. The interpretation

of medical pictures (such as CT and MRI) cannot be replaced by 3D printing an anatomical model, but it is a supplement to these images. Orthopaedic surgeons have identified an additional benefit, particularly in cases of problems with bone and joint alignment, since it offers a better grasp of how to repair the alignment [36].

- **Prosthetic limbs**

A developing technology that tries to assist those who have lost a limb is prosthetic limbs. Animals all throughout the world must have their limbs removed or are born with malformations, so it's not just humans who suffer from limb loss. Because prostheses are expensive and take a long time to make, many of these animals may never have the chance to regain the use of their limbs. As technology develops, methods of production that are quicker and less expensive are being investigated, such as additive manufacturing. Production of an exterior prosthetic limb or even wheelchairs occurs on a case-by-case basis, and the goods are adapted to a single user through precise leg modelling and several testing [37,38].

A stent, an exterior element of the prosthesis known as an endoprosthesis, and a portion of the prosthesis placed within the limb make up a novel method. The stent, an intraosseous prosthesis, is placed into the bone of the residual limb and is constructed of an inert substance. This is where the implant and bone meet, allowing the prosthesis to be surgically linked to the bone. A portion of the intraosseous prosthesis not submerged in the bone is where the endoprosthesis, also referred to as the transcutaneous prosthesis, is attached. Contrary to external prosthetic limbs, this interaction between the intraosseous and transcutaneous prosthesis transmits the mechanical strain from the bone to the prosthetic limb.

This is more evidence that 3D printing will transform medicine by streamlining production and bringing down the price of both human and animal prosthetics. [39].

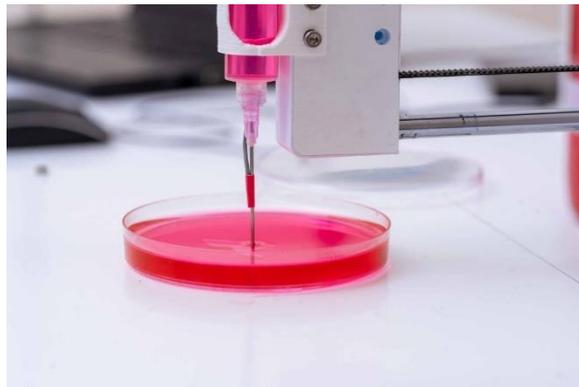
Figure (4) Examples of 3D-printed upper limb prostheses (a) Andrianesis' Hand: an externally powered forearm prosthesis. (b) Gosselin's hand: a body-powered forearm prosthesis. (c) Cyborg beast: a body-powered hand prosthesis. Published with permission of Zuniga. (d) Handiii COYOTE: an externally powered forearm prosthesis. ©exiii, Inc. (e) IVIANA 2.0: a passive forearm prosthesis. (f) Scand: a passive adjustable forearm prosthesis. (Source Ref. No. 38)



- **Bioprinting**

Bioprinting is a very complicated biomedical application that requires the intervention of experienced and highly qualified experts in the field of medicine and technology. In order to create accurate living tissue, this application is based on the spatial structuring of live cells and other biological products utilising computer-driven bio-printers. For the production and transplantation of a variety of tissues, including skin, bones, vascular and tracheal grafts, heart tissue, cartilage structures, and essential organs, it is used in regenerative medicine. The standard procedure for creating a portion of a tissue entails collecting autologous stem cells from the patient in the most sterile environment possible, then putting them in culture for laboratory cell multiplication while applying growth hormones to acquire the necessary number of cells. [40].

Figure (5) 3D Bioprinting Tissues (retrieved from <https://www.azom.com/news.aspx?newsID=59410>)



- **Artificial skin**

The skin is the body's outermost layer of defence, and since it comes into close touch with the outside world, it is extremely vulnerable to damage. This skin barrier can be seriously compromised by wounds and skin loss brought on by physical or chemical assault, which also affects the physiological functioning of the skin. In particular, the creation of skin replacements for transplantation to treat skin lesions requires the use of bioprinting technology. To create the piece of skin that will replace the lost substance, the skin is bio-imprinted layer by layer using a mix of biocompatible materials, dermal cell components, such as fibroblasts and keratinocytes, and a biomaterial matrix, such as a silicone-based sheet and a collagen scaffold. [41].

Figure (6) Artificial skin-like systems (Source: retrieved from <http://biomat.net/site/silk-composite-helps-artificial-skin-last-longer/>)



- **Bioprinting of cartilage and bone**

Bioprinting of cartilage is possible thanks to a 3D printer which is able to deposit cells and polymerise the support on which the cells are attached. Chondrocytes suspended in polyethylene

glycol diacrylate are placed on printed support in specific locations to reproduce the organisation of natural cartilage. The support is printed with a biocompatible and biodegradable material that will be degraded (digested by the body) over time and leave space that will be colonised by neo-cartilage. A piece of functional and biocompatible cartilage could therefore be produced by 3-dimensional printing with the same mechanical properties as natural cartilage. These bio-prostheses are used, for example, in the filling of osteochondrosis lesions of the elbow.

By the same principle but with different osteoblasts and different supports, bone tissue can be printed.

The bone tissue obtained is combined with a bioprinted cartilage tissue which will result in an osteochondral autograft of a specified shape. This type of autograft is used in osteoarthritis to compensate for the loss of bone and cartilage in the affected joint [42].

- **Bioprinting of organs**

For now, organ bioprinting remains theoretical because of the multitude of cells, the complex vascularisation, and the close links between cells allowing organ function that remain challenges that 3D printing has not yet succeeded in overcoming. However, there is one exception which is the liver. The latter has a powerful capability for regeneration. After the activity and functionality of primary hepatocytes are cultured and hepatocytes produced from stem cells are validated by biomimetic system, primary hepatocytes and "canaliculi" structures are grown together in a collagen matrix. They serve as bio linkages for the 3D printer to utilise when creating liver tissue. The precise size and form required by individuals who have had their livers removed are provided by this technology. Bio-printed livers can be utilized for simulated liver investigations in vitro as well as after liver resection in patients and other liver surgeries. As a result, they can be utilized as a liver equivalent for various medical and scientific investigations as well as for identifying medication toxicity. [2, 43-45].

CONCLUSIONS

We can see that this revolutionary process merits attention and constitutes an interesting area of research for the future after studying the major technologies currently available in the field of three-dimensional printing as well as the various applications of these technologies in the different sectors of education and the general world of health.

More specifically, the benefits of 3D printing can be enormous in the field of veterinary medicine, not only for the preparation of difficult surgical procedures or for the students of the osteology program but also as a tool for customer communication and the production of implants and prosthetic limbs.

However, great efforts still need to be made, particularly in bioprinting and the production of living tissues and organs. In the field of health, the most promising aim of three-dimensional printing would indeed be to succeed in producing living organs, but it is still far from being achieved due to the complexity of building such an object. Bioprinting remains a very interesting and very encouraging field of research because of the medical revolution it could bring. It is also necessary that this technology has a legal

framework more determined to avoid any drift of ethics or concerning the security of people and ideas because almost everything can be copied and printed by three-dimensional printing.

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