ROLE OF 3D PRINTING TECHNOLOGY IN VETERINARY EDUCATION

Abstract

3D printing is a rapidly emerging technology successfully utilized in different fields of medical science and in recent years 3D printed specimens have been used in veterinary education. With the invention of affordable 3D printers, the application of superior quality 3D printed models of anatomical specimen is expanding as an effective teaching tool in veterinary anatomy education. The use of this technology has also in surgical planning, creating prosthetics, orthopedic implants, anatomical models, etc. In this technology, the 3D solid models are produced through a process of adding layer upon layer of materials from a computer aided design (CAD) model. In this chapter, the principle of 3D printing technology is reviewed including steps, materials, and techniques to be used for creating the anatomical models in veterinary education. The chapter emphasizes that successful use of this technology in veterinary anatomy education and surgery practice. This technology shows promising results in learning and understanding of 3D structures and their relationships, teaching and training purposes, guide surgical procedures, improve confidence of surgeons to perform complex surgical procedures and investigate new therapeutic approaches.

Keywords: Cadaver, Anatomical models, 3D printing, Veterinary education

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I. INTRODUCTION

Cadavers have been used in veterinary and medical education for teaching and training purposes as the main instruction tools for hundreds of years and it has proven that it is one of the most effective tools for studying anatomy of human and animal body. There is different view between the anatomists that in a modern education curriculum full cadaver dissection is still suitable. Using cadavers for dissection is time consuming and also to procure cadaver has been challenging with ethical issue. In recent years, many medical institutions limited the use of dissection based training and favour alternative methods to enhance the learning experience. Among these methods plastination, corrosion casts, medical imaging, computer assisted learning and 3D printing have gained considerable popularity [1]. 3D printing technology is used to creation of 3D anatomical specimens for the purpose of teaching and surgical training [2]. This technique allows for the creation of realistic and accurate 3D anatomical models that can be used an effective teaching tool in anatomy education [3]. 3D anatomical models help students to identify anatomical structures in a better way as compared to anatomy books or digital sources of teaching [4]. 3D printing has been successfully introduced in different medical fields and teaching of anatomy in the last two decades bringing several benefits includes accuracy, personalized study and easy handling [5]. The medical scanners like MRI and CT scan are used to digitization of anatomical specimens and this data set stored virtually as 3D images utilized for 3D printing [2]. With the invention and advancement of software, hardware and printing materials, it has been possible to create more accurate anatomical specimens and reduce the cost and time. It is beneficial to enhance visual experience and understanding of 3D structures and their relationships [6]. In medical field, this technology has application in surgical practice and research, reduction in the period of anesthesia, the risks of infection, creating implantable prosthetics, biological tissue engineering, regenerative medicine etc. [7-9]. In veterinary science, anatomical models have been used since beginning of veterinary anatomy teaching, therefore 3D printed models can be useful as an effective teaching aid for demonstration in practical classes. With the invention of 3D printing technology and demand of veterinary anatomy models, the use of 3D anatomical specimens is expanding; hence, in this chapter we will be reviewed the basic principle of 3D printing, various methods and tools for creating the anatomical models in veterinary education.

II. 3D PRINTING TECHNOLOGY

3D printing is a method of creating three dimensional models through a process of adding layer upon layer of materials from a digital file [10-12]. The printing materials used in 3D printers are thermoplastics such as acrylonitrile butadiene styrene (ABS), metals, resins, ceramics, composites, smart materials and special materials like food, lunar dust and textile [13].

With the invention of first technology, Stereolithography (SLA) in the late 1970s, the history of 3D printing starts. Dr. Hideo Kodama published a paper on Rapid Prototyping (RP) system in 1981. He proposed a system in which layers of a model were printed on a platform and the final product was created layer by layer [14]. Later, in the year 1983, Charles Hull, an American engineer created the Stereolithography Apparatus (SLA), the part of first 3D printer and filed first patent the technology in 1984. Stereolithography is the first 3D printing process which was involved ultraviolet laser beam lights that solidify the resins contained in a vat [15]. He received the patent for Stereolithography in 1986 and co-founded 3D systems.

The world's first commercial 3D printer, the SLA-1 was advented in the year 1987 and following years many 3D printing systems were developed. In 1993, Z Corp invented the Binder jetting 3D printing technology. In coming years this technology was continued to grow and show its true potential in the year 2000 when the first 3D printed organ was implanted in a human body. In following years research was going on and in the year 2006, first commercially viable SLS printer was manufactured that received global demand from industries. During the year 2011 to 2020, this technology was form an important part of the history of 3D printing. 3D printer was available at affordable rate, accuracy getting better and its application have in multiple fields such as manufacturing plastic products, body organs, automobile industry, aviation industries, locomotive industry, in healthcare, in the field of agriculture etc. [13]. In the present scenario, 3D printing technology is uprising in different medical and allied fields [16].

1. **Steps of 3D Printing:** The first step of 3D printing includes scanning of anatomical specimens/structures by using medical scanners like CT scanning, MRI etc. or to create models by computer aided design (CAD) software. In the second step, 3D images are converted to STL file format which is commonly used for 3D printers [12]. In this step, editing of the scanned image is performed, so that the final digital image looks as possible close to the original specimen. The third step is modeling in which slicing the 3D digital object into layers. The next step is 3D printing. It is carry out by the additive process performed by equipment called 3D printers. The final step is post processing where the final touches are made on the printed object [12, 17].

2. **Types of 3D Printing:** The three main types of 3D printing techniques are used for making 3D plastic products *viz*., stereolithography (SLA), selective laser sintering (SLS), and fused deposition modeling (FDM). Among these, stereolithography is the oldest technique based on photopolymerization. In this type of technique ultraviolet (UV) light source is used to interact with the resin (liquid photopolymer) in a selective manner to cure and solidify a cross section of the objects in thin layers [12]. The large parts can be built easily with high accuracy by use of this technology. It has been used effectively in the field of orthodontics. In addition, the other application is in the treatment of cardiovascular diseases, neurosurgery, spine surgery and traumatology [18]. Selective laser sintering produces solid structure by solidifying powder like material layer by layer by use a high power laser. The product manufactured by this process is high strength and resolution. Fused deposition modeling is the most popular and affordable type of 3D printing method used at the consumer level today. The material used in this process is mainly thermoplastic polymer. FDM process is based on extruding the heated thermoplastic filament onto a platform and forms product layer by layer from a digital file [19]. This technique has been used successfully to build distal tibia model for preoperative planning [20]. In recent years, 3D printing technology has improved and according to ASTM, it is categorized into seven groups such as Binder Jetting, Direct Energy Deposition, Material Extrusion, Material Jetting, Powder Bed Fusion, Sheet Lamination and Vat Photopolymerization [21]. The choice of the technology selection is based on the nature of required output.

III. APPLICATION OF 3D PRINTING IN VETERINARY EDUCATION

In veterinary anatomy, the application of 3D printed models is increasing since past few years due to advancement of current technology and cost effectiveness. In last few years, 3D models of organs and bones are created for practical classes of veterinary anatomy teaching. The result shows that 3D models have good accuracy and looks like an original specimen. It can also overcome the existing formalin embalmed preservation method having various health hazards. The 3D anatomical models of tongue of domestic animals were created by using filamentous thermoplastic material and FDM technology [3]. The 3D printed models of sheep brain were produced recently using SLA and FDM technology. The efficacy of printed brain models of sheep were compared with real specimens. The result shows that brain models can be used to teaching the brain anatomy as like the real specimen [22]. A 3D printed model of different hyoid bones of domestic animals was produced for anatomy teaching [23]. These models were durable, realistic and cost effective. The 3D replicas and digital images of hyoid bone have good teaching aids for anatomy teaching [23]. A comparative study was conducted among students by using 3D printed dog skulls and real skulls. No significant difference was found in the test scores of the students using the real skulls and those using 3D printed skulls [24]. These findings suggest that digitalized and printed skull models can be used for teaching the gross anatomy of dog skull in the practical classroom [24]. The 3D modeling technology could use to facilitate surgical planning and correction. It increases the success of operations in regions with complex anatomical structures as the cardiovascular system. Use of 3D printing technology was carried out to facilitate surgical planning and correction of a complex cardiovascular anomaly in a dog [25]. For this purpose, 3D model of the dog heart and its vasculature was produced [25]. A variety of biomaterials and biomedical devices to be implanted in the body of human and animals are produced through the 3D printing technology and it has becoming a standard manufacturing practice [26]. The development of 3D bioprinting has crucial role in the advancement of tissue engineering and biomedical research [27]. 3D printing technology has advantages in small animal orthopedics. Generate 3D printed implants, anatomical models and orthopedic instruments have benefited to complex orthopedic procedures in small animals [28]. In orthopedic field, it provides more accurate diagnosis, preoperative planning, selecting appropriate implant type and performing precise surgery [28]. In neurosurgery field, this technology also shows significant advancement. In this field, 3D models are used to facilitate surgical procedures, intraoperative guidance and positioning in neurosurgery [29]. This technology can also be used to investigate new therapeutic approaches and understanding of tumor biology [30]. It is also applied to increase learning skills, improve confidence of neurosurgeons to perform complex surgical procedures and surgical skills [31-32]. The 3D printing technology is an emerging tool that has been found efficient in veterinary education and can be multiple application in veterinary field. There is some limitation of 3D printing technology. 3D printed parts have low strength that is created by traditional manufacturing techniques. The size of the model to be print in a printer has limitation. Production in large scale is also more expensive. The software tool chain is more complex and required a lot of 3D printing modeling training to manufacturing the complex parts. The accuracy of 3D printed models depends on process and type of machine used. This technique required post processing to create good quality of 3D printed parts. In conclusion, 3D printing is an emerging technology in the area of development of veterinary science. With the improvement of software, hardware and 3D printing materials, the use of this technology is continue to grow in veterinary education and veterinary surgical practices.

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