Journal of Veterinary Science & Technology

ISSN: 2157-7579

Quinn-Gorham and Khan, J Vet Sci Technol 2016, 7:5
DOI: 10.4172/2157-7579.1000360

Short Communication Open Access

Thinking Outside of the Box: The Potential of 3D Printing in Veterinary Medicine

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Abstract

The purpose of this project was to gain a better perspective of how 3D printing technology works by getting a first-hand look at this process and then strategize ways that this technology can potentially be used in veterinary medicine. A metal orthopedic plate and a humerus from a dog were obtained from the Veterinary Teaching Hospital at Tuskegee University College of Veterinary Medicine. A 3D Computer Aided Design (CAD) model of the metal orthopedic plate was made and printed using a plastic Polylactic Acid (PLA) filament. 3D CAD models of the metal plate and the humerus were also generated using a 3D Laser Scanning process. Using the CAD images from laser scanning, the metal plate was printed using aluminum material and the humerus was printed using nylon material. The 3D printed objects were very accurate in comparison to the original objects. In conclusion, this project demonstrated the value and potential in having the technology to duplicate anatomical structures and surgical instruments, which can lead to a variety of useful and unique applications in the academic and clinical realm of veterinary medicine.

Keywords: 3D printing veterinary medicine; 3D laser scanning dog bone; 3D CAD model veterinary medicine

Introduction

From food to cars, prosthetics and dental implants, architectural and fashion designs, 3D printing is revolutionizing the use of technology. When used in combination with 3D printing techniques, 3D laser scanning makes it possible to scan a human subject and print out a life-sized replica or a small figurine in an array of materials and colors that bear an accurate likeness to the individual [1,3].

3D printing has been around since the 1980s and was mostly used by large companies and organizations such as the military for prototyping. Since the advancement of 3D printing technology over the years, it is now available to the general public sector as well [2]. 3D printing has found multiple uses and applications, and there are various ways that this scientific advancement can be utilized in veterinary medicine.

What is 3D Printing and How does it Work?

The mechanics of 3D printing can be challenging to understand. A digital 3D image of an object is created with 3D Computer Aided Design (CAD) modeling software and saved in a file format that is compatible with a 3D printer. Similar to printing from an inkjet printer connected to a desktop computer, when the user selects the print button, information from the 3D CAD image file is sent to the printer, and the printer uses the digital image as a template. The 3D printer, in lieu of using ink, uses a material that is combined with a form of heat and/or a binding substance and prints out the first layer of the 3D model's pattern in a liquid or powdered form.

The printer then repeatedly adds more and more layers of the material over the first pattern layer until all angles, shapes, and features from the digital 3D CAD model have been fully captured and completed in the printed form. Thus a perfect replica of the original object is produced from the CAD model file. This process of building an object through the addition of layers on top of layers is known as Additive Manufacturing [3]. After printing is completed, the object is allowed to cure (i.e., cool, harden). Depending on the material and the amount of detail that is required, the finished product may undergo a cleaning and/or polishing process as well. 3D printers can print in a variety of colors and materials including plastics, metals, tissue and organ cells (also known as bioprinting), food/edible contents, concrete, etc. [3,4].

Exploring the Possibilities of 3D Printing in Veterinary Medicine

The project consisted of two phases and involved the reproduction of a metal orthopedic plate and a humerus bone from a dog. The humerus, which showed pathological changes, and the metal plate (Figures 1 and 2) were acquired from a colleague, a small animal surgeon, who had expressed an interest in using 3D printing as way to reproduce and pre-operatively evaluate abnormal structures on surgical patients.

Phase I of the Project involved printing a 3D model from a Computer-Generated CAD Model. Once the bone and metal plate were acquired, arrangements were made through Tuskegee University's Department of Aerospace Science Engineering, to see a demonstration of a 3D printer in action. At the time, this technology was demonstrated using a printer that was part of an in-house 3D printer construction project. Measurements were made of the original metal plate and, using a rectangular shape in the CAD modeling program, the measurements were applied to the rectangle and used to model and create a similar, smaller scale CAD model of the original metal plate. The model was then saved in a file format, compatible with the 3D printer that was

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Received June 22, 2016; **Accepted** July 14, 2016; **Published** July 18, 2016

Citation: Quinn-Gorham DM, Khan JM (2016) Thinking Outside of the Box: The Potential of 3D Printing in Veterinary Medicine. J Vet Sci Technol 7: 360. doi:10.4172/2157-7579.1000360

Figure 1: Abnormal Canine Humerus (Original) (Photo courtesy of Mr. Thomas Martin, TU College of Veterinary Medicine Media Center).

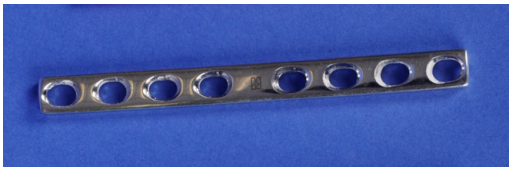

Figure 2: Metal plate used for orthopedic surgical Repair (Original) (Photo courtesy of Mr. Thomas Martin, TU College of Veterinary Medicine Media Center).

built in-house, and printed. The material that the printer used was a pink-colored Polylactic Acid (PLA) filament, which is a plastic-type of material that usually comes on a spool (Figure 3). As it passes through the printer, the PLA filament is heated into a liquid form to facilitate its dispensation through and from the printer and onto the printing surface. Using the CAD model as a template, the printer traced out the design in layers until the sample plate was produced (Figure 4).

Phase II of the project involved printing a 3D model from a laser-scanned object. 3D laser scanning involves the use of a laser beam to capture all sides, angles, and physical features of an object. This results in the creation of a 3D digital image that is the exact size and shape of the original object [2,5]. 3D laser scanners come in a variety of forms and can range from handheld devices to stationary devices that are large enough to perform a full body scan [1,6].

For this phase of this project, it was necessary to ship the bone and metal plate specimen off-campus to Direct Dimensions (Owings Mills, Maryland), a company that sells and provides 3D laser scanning products and services [6]. The samples were scanned, and 3D CAD models were produced (Figures 5 and 6). After scanning, the images were saved in a 3D printer-compatible format and then e-mailed to Xometry Industrial 3D Printing & CNC Machining Services (Gaithersburg, Maryland) for printing [7].

The bone model was printed using a plastic nylon material, and the metal plate was printed using aluminum material (Figures 7 and 8). After this phase of the project was completed, side-by-side comparisons of the original objects and the 3D printed objects were made, and the 3D printed models were very accurate in details (Figures 9 and 10).

Conclusion

Currently, there are at least 8 Colleges of Veterinary Medicine that are incorporating this technology into their programs: Auburn University, Cornell University, Mississippi State University, North Carolina State University, Ohio State University, University of California-Davis, University of Missouri, and the University of Pennsylvania. Private practices, such as South Paws Specialty Surgery for Animals and the Equine Podiatry and Lameness Centre (both in Australia) are also utilizing 3D scanning and printing as well.

Tuskegee University College of Veterinary Medicine (TUCVM) will soon be among the list of those veterinary schools that are incorporating and using 3D printing. Since the completion of the initial project, the Department of Aerospace Science Engineering has acquired a state-of-the-art 3D Printer and access to a high-tech 3D laser scanner, which is a part of a new Additive Manufacturing Lab within the College of Engineering.

Figure 3: Polylactic Acid Filament, used in 3D printers, comes in a variety of colors (Photo courtesy of MakerBot.com).

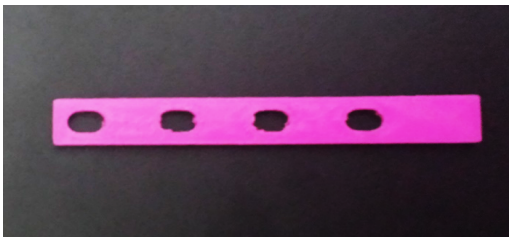

Figure 4: 3D printed sample of smaller version of orthopedic metal plate printed using Polylactic Acid (PLA), a plastic-type filament (Photo courtesy of Dr. D. Quinn-Gorham, TU College of Veterinary Medicine).

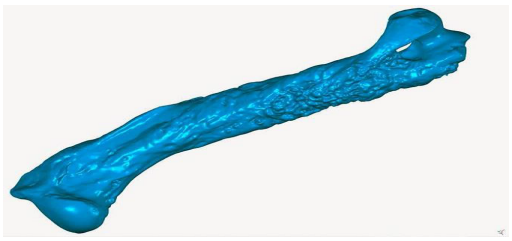

Figure 5: 3D CAD Model of Abnormal Canine Humerus created from laser scanning (Laser Scanning and CAD Model images provided by Direct Dimensions, Inc.).

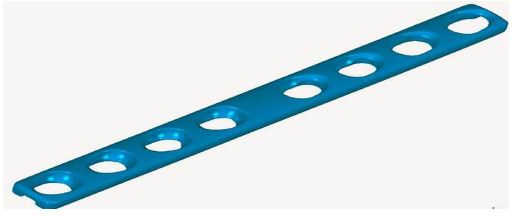

Figure 6: 3D CAD Model of Orthopedic Metal Plate created from laser scanning (Laser Scanning and CAD Model images provided by Direct Dimensions, Inc.).

Currently, Tuskegee University's Department of Aerospace Science Engineering and the College of Veterinary Medicine are working together to form 3D Printing initiative and partnership between the two schools. The partnership is currently in the pilot phase, in which sample specimen are being scanned, printed, and assessed. This partnership will be pivotal in providing a means for the veterinary college to further explore and develop uses for this technology in its curriculum. This will also provide opportunities for more interdisciplinary collaborations, particularly towards funded projects.

There are many benefits of 3D printing and having access to this technology. From an engineering perspective, students are able to design and manufacture the prototype, a process which provides them experience with concepts such as tolerancing (i.e., determining the physical limits of a material), form, fit and function. It also is a great tool to understand the concepts of usability or human-product interaction. Veterinary Medical students can be provided 3D printed replicas of bone specimens thereby preserving original samples. Such multi-disciplinary collaboration also has potential for bio-medical engineering research and development activities.

Figure 7: 3D Print (from CAD Model) of Abnormal Canine Humerus (Printing provided by Xometry Industrial 3D Printing & CNC Machining Services / photo courtesy of Mr. Thomas Martin, TU College of Veterinary Medicine Media Center).

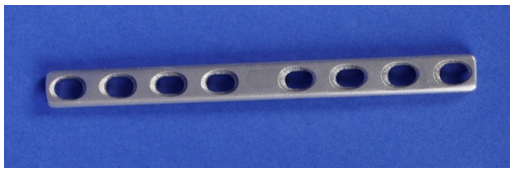

Figure 8: 3D Print (from CAD Model) of Orthopedic Metal Plate (Printing provided by Xometry Industrial 3D Printing & CNC Machining Services / Photo courtesy of Mr. Thomas Martin, TU College of Veterinary Medicine Media Center).

Figure 9: Comparison of 3D printed samples with originals. 3D printed bone (left side) and Original bone (right side) (Photos courtesy of Mr. Thomas Martin, TU College of Veterinary Medicine Media Center).

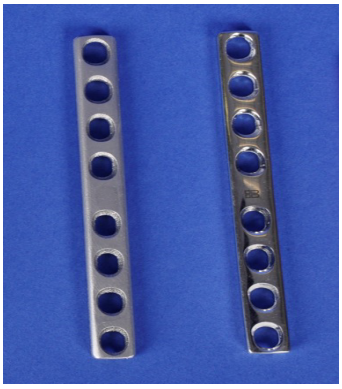

Figure 10: Comparison of 3D printed samples with originals. 3D printed metal plate (left side) and Original metal plate (right side) (Photo courtesy of Mr. Thomas Martin, TU College of Veterinary Medicine Media Center).

Some of the possibilities for veterinary colleges and private practices include the following:

- An opportunity for collaboration with Colleges of Engineering to develop educational programs to extend the exploration and utilization of 3D printing,
- In-house production of surgical instruments and supplies (i.e., metal plates, scalpel handles, containers, etc.) [8],
- In combination with 3D Laser Scanning and other imaging technology, such as CT Scanning, pre-operative assessment of surgical approaches and techniques [9-12],
- A means to do research on the production of customized 3D-printed prosthetics and implants, as well as tissue and organ production through bioprinting [13-16],
- Production and preservation of structures (normal and pathological) for study in Anatomy and Pathology courses, client education, and surgical training [17],
- Production and preservation of anatomical structures and organ systems using materials and processes that is less toxic and more resistant to degradation.

The costs of 3D printers, printing materials, and laser scanners vary and can range from the low end to the high end of the price market. However, this technology may prove to be worth the investment as it will bring many creative possibilities for educational enhancement, research, professional development, and for thinking outside of the box.

Acknowledgements

Special thanks to the following individuals who made this project possible. At Tuskegee University: Dr. M. Javed Khan (Department Head, Aerospace Science Engineering), and Mr. Bruce Heath (Instructor, Aerospace Science Engineering), and Dr. Howard A. King (Small Animal Surgeon). At Xometry Industrial 3D Printing and CNC Machining: Gregory Paulsen (Business Development Manager) and Luke Hendrix (Sales Engineer), At Direct Dimensions, Inc.: Michael Raphael (President and CEO), and Jeff Mechlinski.

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