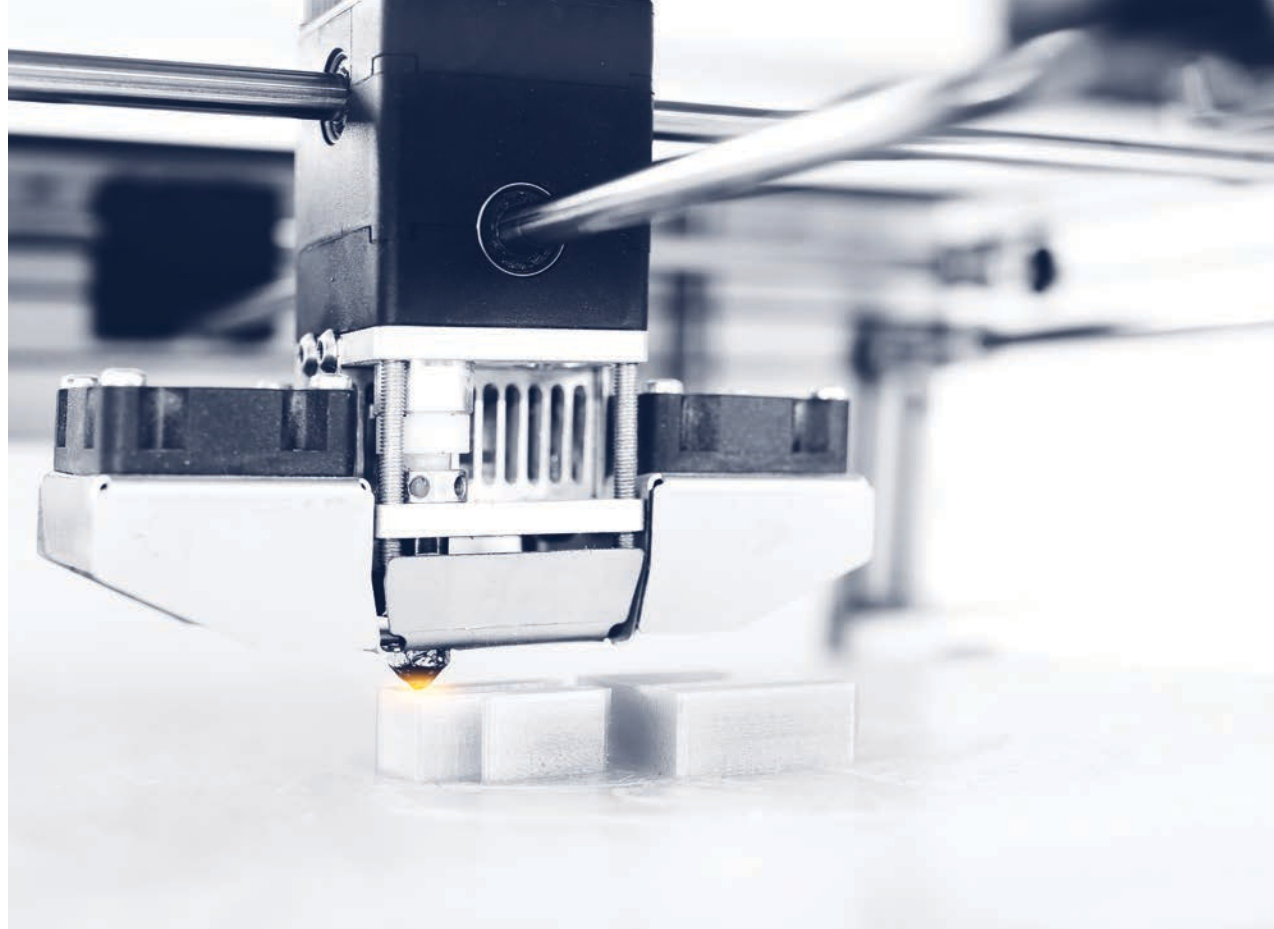




3D Printing: A New Dimension for Veterinary Medicine

Customizable printing technology offers value for surgical planning, prosthetics and even more in the future

BY FRED WININGER, VMD, MS, DACVIM (NEUROLOGY)

Innovation has always been a cornerstone of veterinary medicine, fueling a constant search for solutions that cater to the diverse needs of animal patients. Often regarded as the “MacGyver of the medical world,” veterinarians have a rich history of crafting bespoke tools and techniques to navigate the intricacies of animal anatomy. With the advent of 3D printing technology, this tradition of ingenuity has found a powerful ally, advancing the way veterinary care is delivered.

Unlike human medicine, veterinary medicine confronts myriad

anatomical variations across different species, rendering one-size-fits-all, mass-produced solutions impractical. Additionally, fewer cases and relatively less financial investment in veterinary care encourage practitioners to explore individualized, customized options. The shorter lifespans of animal patients alleviate concerns about long-term implant decay or failure, granting freedom in the constitution of materials used and how they’re integrated.

How 3D Printing Works

Creating a 3D print begins with

acquiring cross-sectional anatomic data, often facilitated by advanced imaging techniques such as computed tomography (CT) scans. In veterinary medicine, the availability of CT scanners proves particularly advantageous, as they can delineate tissues based on density with remarkable precision, especially for skin and bone (the tissues of primary interest for modeling). Other modalities, such as ultrasonography and magnetic resonance imaging (MRI), have value, but their current poorer resolution of bone limits the accuracy of 3D prints.

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Once the data is acquired, unwanted tissues are carefully removed based on their density (thresholding) and location (subtraction), resulting in a scaled, digital representation of that patient’s anatomy. The model can be printed at that point or digitally manipulated to meet the practitioner’s needs, such as aligning anatomy.

Fused Deposition Modeling

The most common printing technique is fused deposition modeling (FDM), where a plastic filament is melted and layered repeatedly to form the print. FDM is relatively fast, inexpensive and error-free but is less resolved than other techniques and limited by the plastics’ properties. For example, most of these plastics cannot be steam autoclaved.

Stereolithography

Stereolithography is similar in principle but uses a photoactivated resin that hardens when exposed to a particular wavelength. It is more resolved than FDM and has sterilizable material, but it is more cumbersome and has limited long-term biocompatibility. Newer techniques, such as selective laser sintering, have a vast material toolbox, including titanium and nylon. However, they require greater expertise, have different biomechanical properties compared to traditional milling and are only recently becoming affordable to the consumer.

Applications in Action

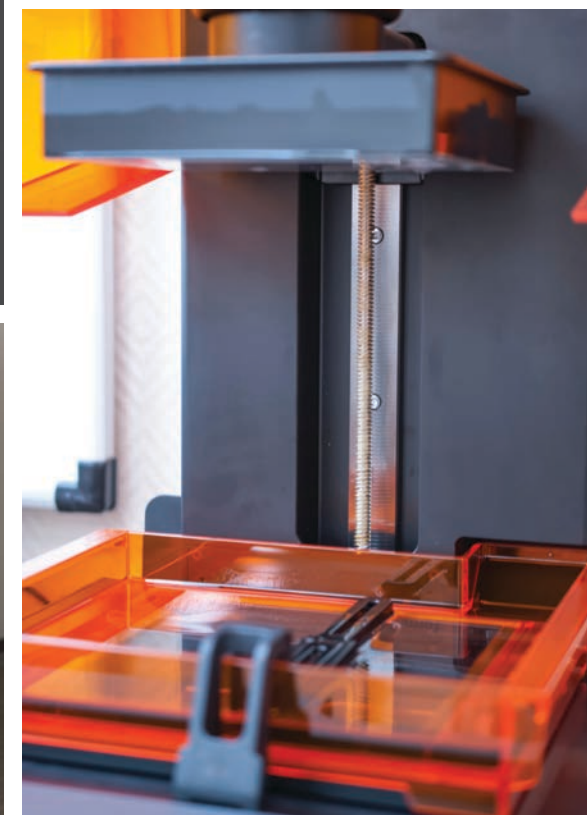
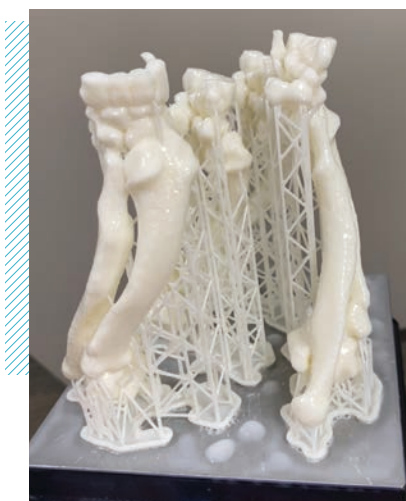
The applications of 3D printing in veterinary medicine are as diverse as the patients they serve. Initially, the technology was applied solely to anatomic models. Utility included spatial surgical planning, student education, improved client communications and biomechanical testing of standardized implants. Since then, the technology has expanded to

encompass many functions. Patient-specific guides interdigitate with novel points on the individual patient’s bones, facilitating the ideal osteotomy cuts for an angular limb deformity or safe and effective screw placement in a vertebral pedicle for an unstable spine. There is an exponential increase in the evidence-based support that these “jigs” increase accuracy and improve outcomes. These guides are becoming commonplace and are considered a standard of care in many facilities. Anatomic models can be virtually manipulated to align anatomy, such as in an atlantoaxial malformation, before guide fabrication, ensuring optimal virtual results before even entering the operating theater.

Creativity is the only limit of the technology, and inventive veterinarians are now fabricating orthotics for joint instability, prosthetics for broken beaks or shattered shells, and even implants for large cranioplasty or conformal bone plates. Imagine a tibial plateau leveling osteotomy guide and plate specifically made for your dog, facilitating the perfect cut and stabilizing it in the most biomechanically sound way. Or for the patient that can’t undergo stifle surgery, albeit for anesthetic risk or financial limitations, an external brace molded for that dog can be used indefinitely. The technology is not limited to CT, and with fusion techniques, ultrasonography or MRI can be combined to align hard and



A computed tomography scan of the antebrachium of a dog with an angular limb deformity (top left). A 3D model of the bones is printed via stereolithography (right), with liquid resin hardened by a laser (bottom left).





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soft tissue for best results, such as bone removal over a brain tumor. 3D printing has transformed the landscape of veterinary care.

Additive modeling has been referenced as the third industrial revolution, as invention returns to the at-home creator, or in our case, the clinical desktop. For those looking to dip their toes into the world of 3D printing, the barriers to entry have never been lower. Affordable FDM printers (under \$200) and user-friendly freeware programs abound (e.g., Tinkercad, tinkercad.com), and practitioners can be empowered to experiment with relative ease. Many national veterinary meetings now coordinate 3D printing labs where experts provide on-site tutorials. For those interested in reaping the rewards of 3D printing but need more interest in their development, several companies will convert a CT scan of your patient to a valuable print with rapid turnover and reasonable cost.

Unlimited Opportunities

The future of 3D printing in veterinary medicine holds tremendous promise. Integrations with artificial intelligence are poised to revolutionize the field, leveraging vast datasets to optimize print designs for enhanced efficacy and fit without high expertise in modeling. Moreover, advancements in bioprinting hold the exciting prospect of organic tissue replacement with endless applications. "Bio-ink" has



3D model implant guide for the cervical spine. The guides are composed of a footplate that interdigitates with a novel surface of the bone for accurate placement.

already been applied to basic tissue replacement, such as an external ear replacement in a human, and it is realistic to envision whole organs being produced.

3D printing has emerged as a game-changer in veterinary medicine, offering a level of precision and customization that was once unimaginable. From surgical planning to prosthetics and beyond, the applications are limited only by the bounds of imagination. As veterinarians continue pushing the boundaries, imagining what comes next is exciting. □

Dr. Wininger began his veterinary career researching neurology and developing treatments of neurodegenerative diseases that affect both young dogs and children. He has a special interest in neuroimaging and spent time on faculty at the University of Missouri as a collaborator in the Comparative Neurology Laboratory before going on to work in private practice. Among his many clinical and research interests, Dr. Wininger is the owner and operator of 3D Veterinary Printing LLC, where he creates models and customized surgical tools to aid veterinary surgeons and neurosurgeons.



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