3D Printing in Orthopaedic Surgery

AAHKS Digital Health Committee

3D Printing is an exciting innovation that is quickly integrating into orthopaedic practices. Although 3D printing is not a new concept, the evolution of technology has unlocked the potential, which has broad applications to the medical field. Many applications are being utilized in orthopaedics, such as customized prosthetics, fracture-specific casting and precision bone grafting. Applications also extend to pre-operative planning and modeling technically difficult cases, as well as enhancing resident education through prototyping and creation of physical models. Orthopaedics has only breached the surface of the potential that this technology has to offer.

What exactly is 3D printing?

3D printing utilizes a unique manufacturing process to bring concept to real-world design. The principle is an additive manufacturing process, engineering a product de novo using a wide array of materials. To build a 3D printed model, first a concept must be developed through drafting. Typically, computer aided design (CAD) software is utilized to create a 3D geometric model. Next, the material(s) must then be selected based on availability, workability, and cost. Additionally, several different types of 3D printers exist, and the application dictates which type of printer should be utilized. Fused deposition modeling (FDM), stereolithography and other additive manufacturing techniques represent the major workhorses of current 3D printing medical applications.

FDM is one of the earliest and the most basic 3D printing technologies. Simply put, this methodology involves the melting of thermoplastics through a heated nozzle, analogous to glue gun technology. The nozzle deposits the material layer by layer; and no curing process is required as the newly layered thermoplastic hardens and integrates itself into the previous material or scaffold. Other popular examples of 3D printers include additive manufacturing that require a curing process with energy sources such as UV light, laser or electron beams. Additive manufacturing 3D printers are also able to be adapted to print biomaterial; thus, these types of printers can accept a wide array of materials anywhere from implants made of cobalt/chromium, steel and titanium to live bone and hydrogels.

Orthopaedic Applications of 3D printing: Now and the Future

There are numerous examples of how orthopaedic surgery currently employs 3D printing technology. Some of the earliest uses of the 3D printer were large scale designs and extra-corporeal products, such as fracture specific casts and custom fitted prosthetics. Fracture specific casts are fabricated based on the patient-specific fracture pattern and are fitted to a specific mold that offers optimum stabilization. Additionally, fully customized 3D printed prosthetics have been popularized for amputees.

3D printing has gained robust utility in the pre-operative and surgical planning of orthopaedic operative cases. A highly accurate, anatomic model can be constructed from a patient's existing radiographic studies. Highly customized implants, including fracture-specific plates are currently in their early stages of development. Patient specific joint reconstruction is now receiving a resurgence in interest due to the advantages and evolved capabilities of modern 3D printing. How clinical outcomes may be affected remains to be seen, however even in the result of non-inferiority, the cost savings and the increase in operating room efficiency may be enough rationale to employ this technology to total joint arthroplasty.

3D printing can potentially benefit complex revision total joint arthroplasty cases as well; highly customized augments and reconstructive acetabular cages can be fabricated in the setting of extreme osteolysis and bone loss to provide an “exact” fit to fill the defect with an osteo-inductive material designed to further stimulate bony union.

As technology and creativity continue to evolve, 3D bio-printing is a new concept that is beginning to have clinical applications including examples of both bone and cartilaginous reconstruction and “skin” printing. It is envisioned that a myocutaneous flap could be simply “printed” onto a surgical wound, easing the burden of a complicated closure, advancement or turndown.

Conclusion/Summary

3D printing technology has revolutionized prototypical design engineering with applications to orthopaedic surgery. The investment in 3D printing technology can improve an institution’s ability to improve pre-operative planning of complex cases, increase development of implant design, and enhance trainee education. With technology evolving in nearly every aspect of medicine, 3D printing continues to improve and integrate with the field of orthopaedic surgery. Highly challenging problems, both clinical and academic, can be addressed with low cost and fast turn over while offering a whole new perspective of solutions.