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Editorial

Current Role of 3-D Printing in Orthopaedics

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Introduction

Three-dimensional (3d) printing is a technical revolution that might significantly change the way we treat patients in Orthopaedics. Off the shelf implants and prosthesis are available for the majority of Orthopaedic procedures. For a small number of procedures no implantable prosthesis may be available.

3D printed implants and prosthesis are revolutionising the reconstruction of complex bony defects encountered during revision hip and knee surgery. Even larger defects are encountered during excision of bone tumours and 3D printed prosthesis have a major role in these difficult scenarios. This manufacturing method is based on 3D computer models for the reconstruction of a 3D object by the addition of material layers such as plaster, metal, plastic, etc [1]. The concept of 3D printing actually began as "stereolithography" in the early 1980s. Charles W. Hull started commercial production of the first 3D printers for Commercial applications in 1988 [2]. Stereolithography enables the creation of an object, usually by curing a photoreactive resin with a ultraviolet laser in a layer-by-layer fashion. Since then, different 3D printing processes have been developed for many applications; in the field of medicine, the numbers of applications has seen an exponential rise since the last two decades [3].

3D printing techniques can be used in indications, such as preoperative planning, implant designing, training, and to produce educational models. In surgical applications, these techniques have been described to provide a better understanding of complex anatomy/morphology or the possibility to create customized implants or surgical guides. The required time of printing and cost of the techniques are seen as the most important limitations. Although techniques of 3D printing are used increasingly in surgery, the advantages and disadvantages of their use remain to be investigated. Indeed, in view of the remarkable development of 3D printing over the last decade, close attention must now be devoted to specific requirements especially in surgery. Such information would help surgical teams intending to develop 3D printing for in-house production.

Techniques

Three 3D printing processes- selective laser sintering (SLS), fused deposition modelling, and inkjet printing have emerged and have overtaken stereolithography in terms of frequency of use. The first of these, SLS, uses a laser to selectively fuse together particles of powdered material within a powder bed. Lowering of the powder bed by 1 layer thickness allows the sequential building of an object layer by layer. Fused deposition modelling deposits small beads of thermoplastic material in layers to form the print. Inkjet printing uses a printhead that deposits thermally or mechanically droplets of material layer by layer to form the object. As the printing is of high resolution, inkjet printing is currently the most suitable technique for bioprinting of tissues and organs which have applications in regenerative medicine to enable the reconstruction of anatomic defects and the replacement of complex organs [4].

Figure 1: *Da-Vinci 1.0 printer 86pro 3D system.*

Advantages

The most important advantage of 3D printing is that it opens new possibilities in planning the surgical procedure. The position of the implants, its contouring, the trajectory of lag screws and the length of appropriate screws can all be easily decided. 3D printing allows the generation of precise implant shapes that fit perfectly to the anatomic site. These are major advantages in fracture fixation of pelvis, acetabulum, proximal tibia, facio-maxillary reconstructions and distal tibial plafond. It is often difficult to achieve satisfactory reduction and fixation of both-column acetabular fractures owing to the complexity of the regional anatomy of the pelvis and the fracture configuration, which is commonly associated with a high degree of comminution.

The consequential lack of implant recontouring requirement decreases soft tissue trauma [5]. The decreased duration of correction usually required before its definitive implantation in turn facilitates the surgical procedure and decrease the time patients were exposed to anaesthesia and increases time-efficiency of the surgical procedures [6] (Figure 2).

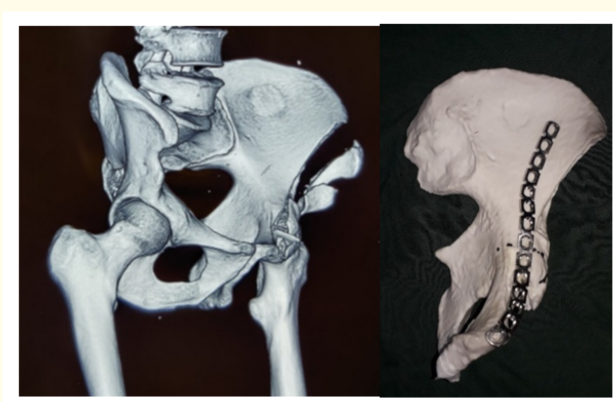

Figure 2: *3D Model of a hemipelvis of the Ipsilateral side being used to mould a pelvic econstruction plate before surgery for an Anterior column and anterior wall fracture acetabulum.*

Even modest decreases in operating time are helpful in decreasing post-operative infections. Observational studies have demonstrated reduction in operative time varying from 25 - 45 minutes [7]. Direct visualization of malformations in complex reconstructions, better anticipation of anatomic difficulties, precise implant shapes, ability to produce accurate guides and templates are all reported advantages [8]. Decreased radiologic exposure of patients and the operating team during the surgical procedure is a small but definitive advantage. Positioning improvement results in better surgical results, minimal posttreatment discomfort and better aesthetic results due to reduction of the size of operating incisions.

A 3D printed custom made porous tantalum prosthesis can be used to reconstruct bony defects in patients with aseptic loosening of the femoral and tibial prosthesis following total knee arthroplasty. For revision Total knee replacement with severe bone defects, 3D printed prostheses have advantages in precise reconstruction of bony defects and standard implantation of prosthesis over the reconstructed surface [9].

3D printed implants for large acetabular defects commonly encountered in revision total hip surgery are a revolution. 3D printing provides a collaborative plan, stable construct in the best host bone, optimized screw placement, relatively smaller operating time, anatomical cup placement, restoration of center of rotation and excellent clinical outcomes. Preoperatively, design of the custom prosthesis began with a thin-cut CT scan of the patient's pelvis. The raw data generated from the CT scan then was sent to the implant manufacturer, where a 3-D reconstruction of the CT image is created. Computer-aided design are used to create a digital implant proposal based on the 3-D reconstruction of the patient's hemipelvis, and a physical one-to-one replication of the involved hemipelvis is created using rapid prototyping technology. From the CT reconstruction of the hemipelvis, a design is fabricated on the computer and forwarded to the rapid prototyping machine for production of the model custom acetabular component. Component flanges are designed with optimal geometry and orientation to provide an intimate fit against the host bone and bridge existing bone defects to facilitate initial fixation. The hip center and cup abduction and anteversion angles are determined based on pelvic landmarks and anatomic planes [10].

A prospective randomized controlled trial was conducted by Cai., *et al.* on 120 patients with unilateral tibial fractures. Patients were enrolled to assess tibial malrotation between traditional minimally invasive plate osteosynthesis (MIPO) and three-dimensional printing-assisted MIPO (3D-MIPO) for different types of tibial fractures. The results suggest that 3D printed MIPO has the same anti-malrotation effect as traditional MIPO for type A tibial fracture, but for types B and C tibial fractures, the anti-malrotation effect of 3D printed -MIPO is significantly better than that of traditional MIPO. The more complex the fracture type is, the more significant this advantage [11].

3D printing in spinal disorders has various applications like patient education, medical education and training, presurgical planning, insertion guide templates for pedicles, lateral mass and trans-articular screws. 3D custom made implants have been used as Interbody fusion cages, bio-degradable cages and vertebral body replacement implants [12].

Disadvantages and difficulties

The accuracy of objects obtained with the 3D printing technique is not always satisfactory [13]. 3D prints of CT images do not print the cartilage and cause problems in paediatric applications. Several studies have concluded that the time to plan and produce the 3D-printed objects is in days and this technique may be unsuitable for use in emergency care [14].

The time required for both virtual plan design and printing of an anatomic model varied with a range from 10 hours to 2 weeks depending on the complexity of the model. The costs of the required equipment, such as computer-aided design software, the 3D printing machine, are enormous and advantages must be able to justify them. The prints are often not autoclavable and are thus not available on the sterile field limiting their usefulness. The prints are often brittle and can easily break if handled carelessly [15].

Conclusion

3D printing in Orthopaedics is a promising technique which can be extremely useful in difficult bony reconstructions, safe guidance of implants and designing custom made implants for Orthopaedics. Research on 3D printing in Orthopaedic surgery is relatively nascent, and the areas of 3D printing application are still evolving. Areas such as patient-specific implantation are rapidly emerging, though there is paucity of mid to long-term data. Conversely, some uses, such as patient education, appear to have clear advantages over conventional imaging methods. More research is required to identify which uses provide the best value for both patients and health-care systems. As the technology continues to improve and become more accessible and affordable - 3D printing can be the game changer in Orthopaedics.

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