4D printing and its applications in Orthopaedics

Dear Editor,

In Orthopaedic Surgery, customization challenge is undertaken effectively by different 3D printing technologies. However, the model manufactured by a 3D printing technique or even a conventional manufacturing technique is rigid, and there is no further possibility of a change of shape and size of the printed part.¹ In living beings part grows and change shape and colour with the passage of time. So there is an essential requirement to upgrade our technologies to a level where they can produce parts which grow and change shape with the passage of time.

During the up gradation of 3 D to 4 D, smart materials are used which are flexible and change its shape or size to time. A 3D printed time-dependent model has good potential in medical as well as in Orthopaedic Surgery. Because in Orthopaedic surgery, there may be a requirement to develop artificial bones and other Orthopaedic implants which need to grow in children, as per the patient's growth and requirements and 4D printing technology can effectively fulfill this significant requirement.

This 4D printing is an advanced, upgraded version of 3D printing, where with the existing machines a smart material is used, which can self-assemble and can change shape with time, here printed product reacts with parameters like temperature/humidity/pressure, etc. to change its form.² 4D printing uses programmable and advanced smart materials, which can perform various functions in a controlled fashion by external stimuli such as temperature, stress, and light. These materials remain in a patient, in vivo conditions.

The fundamental difference between 3D printing and 4D printing is that 3D printing produces a static output which does not have a time element. For this process, a variety of materials metals, powders, thermoplastic polymers, UV curable resins, etc. are used. On the other hand, this 4D printing only uses smart materials which are temperature or humidity responsive.

Table 1
Clinical uses of 4D printing.

1) Smart Orthopaedic 3D implant
This emerging technology is readily applicable for printing of various Orthopaedic models that change their shape and functionalities in the body. These are applicable in bones of the elbow, wrist, ankle, etc.
2) Smart multi-material printing of organ
Printing of customizable smart multi-material of a medical organ which can grow within the body. This technology is flexible and is also applicable for bioprinting of organs with precise and proper fit with a genetic match of the patient such as skin, liver, heart, kidney, etc.
3) Tissue printing
4D printing technology is applicable for printing of those tissues in which mechanical properties vary dynamically as the patient body gets active, such as muscle, cardiovascular tissues, etc.

Computer tomography (CT), Magnetic Resonance Imaging (MRI) scan are used to create 3D CAD models with the help of different software like a 3D slicer, OsiriX Imaging Software, Mimics, 3D doctor, Magics and InVesalius. This 3D virtual model is transformed to a printable file format by 4D printing technologies using the smart material. This technology can effectively be used for the development of 3D medical devices like the biomedical splint, stents, bioprinting of organs which are susceptible to human growth. Table 1 discusses the various clinical uses of 4D printing.

Doctors can now take advantage of these self-deforming component printed by this technology to treat any abnormality. It develops an Orthopaedic model whose property changes with a change in temperature. First, it prints object then it assembles itself or reshapes the object over time. This technology could have created a disruptive effect in Orthopaedics and other medical fields in next upcoming years.³

Now the printing of Orthopaedic parts is possible with greater flexibility which fits perfectly as per the genetic match. It could well be used for complicated surgery which was not possible by other manufacturing technologies even 3D printing technology.⁴ With the help of this technology, one can manufacture an accurate replica of the patient's part by using different types of smart material that also represents anatomical details accurately and precisely. In upcoming years, 4D printing will grow in the Orthopaedic field to fulfill various requirements and innovation.⁵ This technology provides excellent service and creates endless possibilities to give a better life to the patient.

Conflicts of interest

None.

Appendix A. Supplementary data

Supplementary data related to this article can be found at <https://doi.org/10.1016/j.jcot.2018.08.016>.

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