



Letter to the Editor

Future applications of five-dimensional printing in dentistry



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Dear Editor,

Five-dimensional (5D) printing is a new branch of additive manufacturing (AM), with extensive potential in solving problems of engineering, medical, dentistry and other associated fields. It is a latest technological advancement used to manufacture difficult and complex shaped products, implants and devices with much better physical properties than those obtained by three-dimensional (3D) printing.

The concept of 5D printing originated from American University by Mitsubishi Electric Research Laboratories (MERL) by William Yezuanis. In 5D printing, during the printing process, the print plate also moves along with the print head. In 3D printing technologies, printing is done in three axes, i.e., X, Y and Z axes. In addition to these three axes, 5D printing adds two more axes, i.e., moving of the printing head and moving of the print bed at defined angles, whereas four-dimensional (4D) printing is a concept of using smart material that can change the shape of the printed object with the change of temperature with respect to time.<sup>1</sup>

This technology is a new version of 3D printing which allows curved layers; therefore, it prints stronger complex design parts. One of the benefits of 5D printing is the 25% less usage of material than 3D printing. Fig. 1 shows a brief printing process of 5D printing.

In dentistry surgery, there is an essential requirement of complex and strong implants having curved surfaces. Five-dimensional printing applies to efficient manufacturing of this complex and curved structure requirement with maximum strength. This new technology will become an innovative manufacturing technique

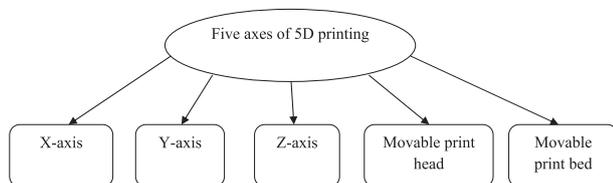


Fig. 1. The printing process of 5D printing. 5D, five-dimensional.

for manufacturing dental implants, orthodontic braces, crowns, aligners, bridges and tools with excellent strength using the input of computer-aided design (CAD) data. These CAD data are created by a dental 3D scanner/different designing software.<sup>2</sup> This technology can efficiently fulfil the complex challenge and create endless possibilities in dentistry. Fig. 2 shows the process to be used by 5D printing during printing of dentistry implants/tools.

Five-dimensional printing process follows almost the same steps as 3D printing technology. Here, a 3D image is created by using suitable dental 3D scanner/designing software, and the same is converted into standard triangulate language (STL) format or a printable format. This file is easily printed through the 5D printing and then tested and used for clinical applications in dentistry.

The main advantage of this technology is to produce curved shape products/implants with improved strength, and this technology creates parts with curved layers instead of flat layers. This curved layer, printed object prevents the weak point of products caused through of a flat layer. It is being investigated whether 5D printed objects are much stronger than a 3D printed object.<sup>3</sup> Therefore, we anticipate an improvement in the quality of patient life by creating any complex curved shape dental product with much improved strength and reliability for surgery.

Five-dimensional printing can easily take over different challenges that are not fulfilled by 3D printing technologies. Mostly,

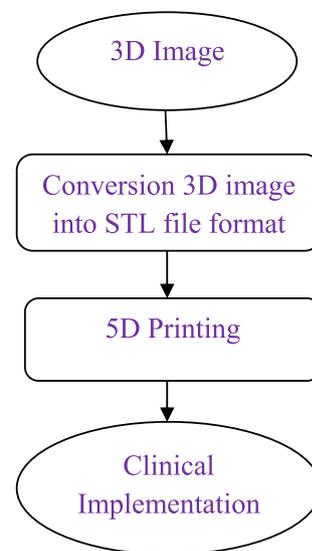


Fig. 2. Process chart of 5D printing in dentistry. 5D, five-dimensional.

the dental implants, dentures and other devices are not flat and have a curved shape. This technology could manufacture a complex curved shape with higher strength.<sup>2</sup> These can improve patient outcomes and reliability of implant after surgery. Missing tooth of a patient is easily manufactured with its required reliability and surface finish. Therefore, it provides dental surgical guides with a high degree of precision. Creating orthodontics models and aligners as per required strength is helpful. This technology will be applicable for complex shape manufacturing, planning, education and making reliable operation.

The main limitation of this technology is the extra cost for two more axes, for the movable print head and bed. There is also a requirement of highly skilled human resources in developing and maintaining the 5D printer.

In future, this technology will make a surgeon's job easier with much higher reliability and minimum side effects. It can be well applied to print dental implants made of multiple biocompatible materials. Five-dimensional printing technology will become the perfect solution for any curved shape products such as stents, bones, dentures and other dentistry tools and devices.

This technology helps to create digital dentistry by enhancing it to the level of mass customisation using digital data of the patient. To reduce the cost of implants, 5D printing is preferred over 3D printing technologies as the former has lesser wastage of material.<sup>4</sup> In the upcoming years, this technology has scope for successful use in dentistry and will be helpful for complicated cases. It has great potential to solve various problems in dentistry such as improvement in existing dental practices and customised complex shape requirements. The requirement is to undertake application-based research, development and customisation in dentistry.

#### Conflict of interest

None.

#### Appendix A. Supplementary data

Supplementary data to this article can be found online at <https://doi.org/10.1016/j.cmrp.2019.03.002>.

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