

## Commentary: 3D printed puzzles fit smoothly into ophthalmic pedagogy

Additive manufacturing, or 3D printing as it is commonly called, has been a boon for makers and innovators. This technology has made it easy for anyone to download and “print” a physical object. The authors of the accompanying article<sup>[1]</sup> found a lacuna in ophthalmic pedagogy in teaching about complex three-dimensional structures in human anatomy. They have tried to fix this by designing and 3D printing physical puzzles of anatomical structures.

### 3D printing and additive manufacturing in ophthalmology

There are several uses for 3D printing in ophthalmology,<sup>[2]</sup> such as puzzle toys for the blind,<sup>[3]</sup> designing surgical instruments, smartphone-based fundus cameras, adapters for slit-lamp imaging,<sup>[4]</sup> spectacles, lenses, modified gadgets, teaching tools, simulators, surgical planning, and bio-printed cornea. Quite different but in some ways reminiscent of the accompanying article is the Fittle Project<sup>[3]</sup> by LV Prasad Eye Institute Centre for Innovation, which is a set of Braille-guided puzzle objects

that have to be assembled by tactile sensations. This helps in teaching blind children with the fun of puzzles.

### Different types of 3D printing

The most commonly employed 3D printing technique is solid filament-based fused deposition modeling (FDM). This involves a spool of solid filament that is fed into the heated printer head which can move around and deposit molten polymer onto a heated bed. Examples of FDM printers that I have used would be the Ultimaker 3 (Ultimaker, Geldermalsen, Netherlands) at Aravind Eye Hospital Pondicherry and the Accucraft i250D (DivByZ, Mumbai, India) at Sri Ramachandra Medical College; these have the added advantage of dual print heads. This allows dual color or dual material printing on a single 3D design.

Another affordable 3D printing technology is the liquid resin-based liquid crystal display (LCD) stereolithography (SLA). This has the advantage of being able to print at high resolution with fine details while being relatively affordable. A monochrome LCD-based high-pixel-resolution printer would give the best results. An example would be the Creality LD-006 (Creality, Shenzhen, China) at Sri Ramachandra Institute of Higher Education and Research.

Other types of 3D printing include selective laser sintering (SLS), digital light processing (DLP)-based SLA, selective layer melting (SLM), laser metal deposition (LMD), bioprinting, and so on.<sup>[5]</sup>

### Getting started with your first print

There are several free 3d models available online on websites such as Thingiverse ([www.thingiverse.com](http://www.thingiverse.com)), GrabCAD ([grabcad.com](http://grabcad.com)), 3D warehouse ([3dwarehouse.sketchup.com](http://3dwarehouse.sketchup.com)) and many more. The files may be available in STL(Stereolithography) format or STP(Standard for the Exchange of Product Data) or 3MF files. If you are looking for an ophthalmology related print, I would suggest a 3D eye model, spectacles, 90D holder, or a smartphone fundus camera such as oDocs Fundus. Do check out the designs by Mr Ganesh Babu and Dr Anthony Vipin Das at LV Prasad Eye Institute Centre for Innovation (<https://www.thingiverse.com/ganant/designs>) GAN-ANT.<sup>[6]</sup>

There are also several 3D printed designs from Aravind Eye Hospital – Pondicherry by Dr Rajesh Vedachalam,<sup>[7]</sup> Dr Rengaraj Venkatesh, Dr John Davis Akkara, Dr Prithvi Chandrakanth, Dr Hirika Gosalia, Dr Megha Nair, Dr Shivraj Tagare, Dr Nikhil Jain, Dr Manavi Sindal, Dr Kanika Chhabra, Dr Vaibhav Khanna, Dr Kulharsh Jaiswal, Dr Nikita Soanawane, Dr Harsh Vardhan Singh and others. One of these innovations is the RetiSurge<sup>[8]</sup> model eye for laser and vitreoretinal surgical practice. Another is the iOpener,<sup>[9]</sup> an innovative instrument to safely and easily keep a patient's eye open for examination. Yet another one is the iVerter,<sup>[10]</sup> which helps to safely and easily evert the upper eyelid for examination. Please do check out the Thingiverse page of Dr John Davis (<https://www.thingiverse.com/drjohnnda/designs>) for innovative designs such as a 3D printed Glaucoma Drainage Device.

Once downloaded, the files can be taken to a 3D printing shop nearby to “print.” If you have access to a 3D printer, the next step would be to use a 3D slicer software such as Cura to generate the gcode file for the specific 3D printer. This is then sent to the printer in a pen drive or via WiFi if the printer supports it. Next, the print is started and it may take a few hours depending on the size and complexity of the print.

### Designing your first 3D printable model

Free 3D software such as TinkerCAD, FreeCAD, Sketchup, Shapr3d, Onshape 3D CAD, and Fusion 360 can be learned pretty quickly with the help of free tutorials on YouTube. You should be able to make simple objects by using 3D geometric shapes within a couple of hours. These do have to be designed with some of the principles of 3D printing in mind for a successful print.

### Future of 3D printing

3D printing is here to stay and is surely becoming more affordable and accessible. In fact, there is currently a 3D printer that uses fused filament fabrication (FFF) on the International Space Station. It can be used to 3D-print spare parts, instruments, and tools that they can download over their 600-MBps Internet connection. They also have a refabricator that recycles material to produce 3D printer filament. Makers and innovators should definitely try their hand at the amazing technology of additive manufacturing.

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