Rebuilding faces and lives with the help of 3D printing

Project report to The Alborada Trust

"The 3D printing service is a valuable extension to our surgical service. Being able to fully appreciate the unique anatomy of each patient helps us plan treatment more accurately as well as inform patients appropriately – we can deliver better quality in less time."

Mr Malcolm Cameron, Consultant Maxillofacial Surgeon at Addenbrooke's Hospital

Gemma Downham, Head of Development, Addenbrooke's Charitable Trust (ACT)
Tel. (direct): 01223 596434
gemma.downham@act4addenbrookes.org.uk

Rebuilding faces and lives with the help of 3D printing

Summary

In January 2015, the Trustees of the Alborada Trust awarded Addenbrooke's Charitable Trust a very generous grant of £80,775 to set-up an in-house 3D printing service at Addenbrooke's Hospital in Cambridge.

This report shows what your grant has helped to achieve.

Project background

Medical 3D printing is a quick and cost-effective way of producing models of organs or anatomic structures that accurately represent a patient's anatomy. Models derived from MRI, X-ray or CT scans that depict the unique and intricate details of a patient's condition, enable surgeons to take planning for surgery to another level. Previously, off-the-shelf surgical implants had to be bent into place during surgery while the patient was under anaesthetic. Thanks to 3D printing, bespoke implants can be custom-tailored before surgery. This, together with the surgeons' improved understanding about what to expect, ensures that patients benefit from better results and less time spent in the operating theatre.

Project description

The creation of an in-house 3D printing service was first proposed by Mr Malcolm Cameron, Consultant Maxillofacial Surgeon, and Dr Karen Eley, Academic Radiology Fellow.

The Alborada Trust's generous grant paid for the set-up costs of the service, including the purchase of two 3D printers and refurbishing space to create a laboratory. An application was made to ACT's Innovation Fund to cover the cost of employing a technician to run the service.

Media Studio, the hospital's central graphic design and print studio, was chosen to accommodate the 3D printing laboratory, because of its established role as a central service for the hospital.

The laboratory

An old personnel files store room, which was no longer in use after the hospital's transition to electronic filing, was chosen to accommodate the 3D printing laboratory. Making the room fit-for-purpose required extensive refurbishment, including fitting out the room with new floors, ceilings, plumbing, electrics and lights as well as safe asbestos removal.

The old personnel files store room

The room was fitted with furniture recycled from hospital stores and other hospital departments.

Equipment

The equipment was purchased following a thorough review of current technologies and a competitive tendering process. Originally, the plan was to purchase a second-hand 3D printer for £45,000, which seemed to be good value for a machine that cost £70,000 new. However, 3D printing technology is coming down in price and, with an educational discount, we were able to purchase a new machine for £43,000, with some starter materials included. This meant that we could also purchase a fused deposition modelling (FDM) machine for functional prototypes for Clinical Engineering and laboratory use, at a cost of £2,161.

- 3D Systems Projet 6000 Pro printer – produces full colour 3D models
- Ultimaker 2 Extended FDM printer – prints smaller objects in transparent, flexible and hard plastics

Processing the CT scans and creating virtual 3D models suitable for 3D printing requires significant processing power. Two computers with software to access and process the scans and run the printers were installed.

The finished laboratory – equipped with the full colour 3D printer, the FDM printer, two computers, a sink, an air conditioning unit and a ceiling extractor

Staffing

To run the service, we recruited a 3D printing technician, Geoffrey Oliver, funded for 20 months through ACT's Innovation Fund. Geoffrey has a background in technology, having worked for a local electronic engineering firm. He is used to working with a range of software and, in particular, segmentation techniques for creating 3D files from CT scans. Two days of training for the main printer and the software were provided by the vendor, EMCO Education.

Since Geoffrey had not worked in medicine before, we have enrolled him on a medical terminology course with Cambridge Regional College. The 3D printing laboratory has also been equipped with a set of anatomy books, software guides, radiology and terminology textbooks for Geoffrey's reference when working with clinicians and surgeons. The laboratory has its own full-size replica skeleton to refer to when segmenting and printing bone models. Project lead Karen Eley, who has extensive experience of using 3D printing for clinical purposes, has provided additional coaching and training for Geoffrey.

In December 2015, Media Studio hosted an official launch event to introduce the service to an audience from across the Cambridge Biomedical Campus and other potential collaborators, some of them coming from as far afield as Sheffield.

Dr Karen Eley, Mr Malcolm Cameron and Mr Jeremy Nayler speaking at the launch event

Project outcomes

Improving patient care through 3D printing

A model of a patient with scoliosis requiring complex surgery using fixation devices on each vertebra

The 3D printing laboratory was set up as a centralised service to ensure all hospital departments can take advantage of 3D printing to improve their care for patients.

While the maxillofacial surgeons were the driving force behind the project, the 3D printing team is working hard to promote the service throughout the hospital. The hospital's 26 Consultant Orthopaedic Surgeons were introduced to the 3D printing service at their monthly audit meeting.

As a result, we have now produced a number of knee, hip, shoulder joint, elbow and spine models. As with maxillofacial surgery, these bone replicas are extremely valuable in surgical planning and can save both time and resources in the operating theatre. Patients benefit from reduced time under anaesthetic, reduced infection risk and potentially improved outcomes as a result of more precise planning of surgical implants.

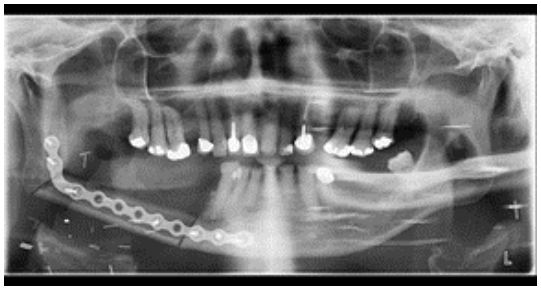
Case study: Nigel's story

After a dramatic skiing accident, Nigel was treated by Consultant Maxillofacial Surgeon Mr Malcolm Cameron, who reconstructed his right eye socket to restore full 3D vision and cure his permanent double vision. Having an accurate model of Nigel's injured skull allowed the surgical technicians to produce a custom-made titanium plate, modelled on Nigel's healthy left eye socket, to replace the smashed bone. The surgery was amazingly successful. Nigel now has normal vision. He drives again and is confident that he will even be back on the tennis court in no time.

Case study: Tim's story

Ten years ago, Tim was diagnosed with mouth cancer. His treatment; surgery and radiotherapy, was successful, but the radiotherapy caused Tim to develop osteoradionecrosis, a rare side effect leading to bone death. This year, Tim presented with an infected wound, caused by a piece of dead bone in his lower jaw. Pus was constantly leaking out of his face and he was at risk of developing serious complications. Tim had to undergo surgery to remove and reconstruct the dead jaw bone. To plan and prepare for the surgery, a 3D-model of Tim's

jaw was produced. The model allowed the surgical team to create an exact template for the bone transplant as well as to pre-bend the titanium fixation plate (see picture of x-ray). During surgery the template allowed the surgeons to quickly and precisely shape the bone, transplanted from his leg, to neatly replace the dead bone and fix it with the pre-bent fixation plate. Having a 3D model of Tim's jaw allowed a level of preparation that rendered the complicated procedure very straightforward and successful.



X-ray of Tim's jaw after surgery with the bone transplant and fixation plate on the left.

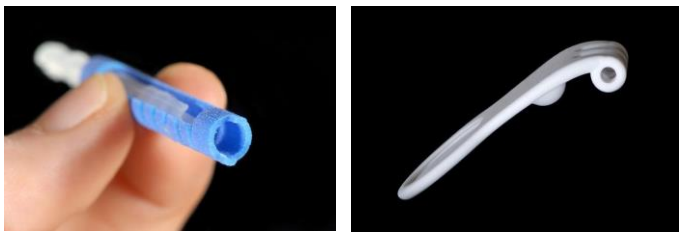
Alex's story

Alex was referred with an extensive facial tumour which needed urgent surgery. The tumour had invaded Alex' eye socket and his cheek, putting his eye in an abnormal position and causing him pain and difficulties when opening his mouth. A 3D model of his skull and the tumour was produced to enable the surgical team to plan the procedure, to reconstruct the eye socket which had been dissolved by the tumour. To produce a custom-made titanium plate to replace the eye socket, the team produced another 3D model of the eye socket without the tumour. Thanks to the detailed planning and preparation, the surgeon was able to preserve Alex's eye and facial nerve, so that despite a ten centimetre tumour removed from his face, Alex still has full eyesight and can move his face.

3D model of Alex's skull and the tumour in his left cheek protruding into his eye socket

Other users of the 3D printing service throughout the hospital

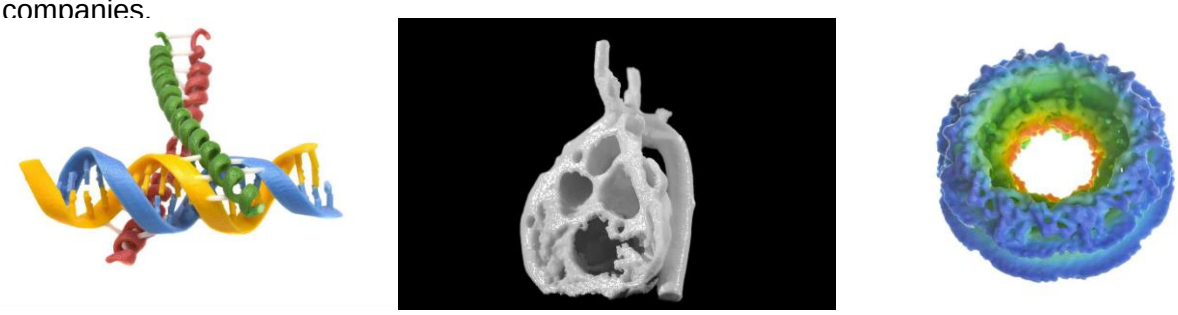
The range of applications has already surpassed initial expectations. In addition to providing planning models for surgeons, Media Studio has worked with the Clinical Engineering Department to evaluate whether they can provide them with prototypes from design software to aid their design work.



Engineering prototypes from CAD files

Collaborations across the Cambridge Biomedical Campus and beyond

The team has showcased the 3D printing service at a number of innovation and technology networking events establishing good relationships with a broad range of health care and biotechnology institutions. These included the University College Suffolk, Cancer Research UK, MRC Laboratory of Molecular Biology, Adam, Rouilly - the medical teaching model company, Fripp Engineering - the design and research consultancy, and some local biotech companies.



3D models from left to right: DNA complex Escherichia Coli; heart with a congenital heart defect (Totralogy of Fallot); Cryo-electron microscopy – a human nuclear pore complex)

The team is working with its sister department in the Norfolk and Norwich University Hospital (NNUH) to offer 3D printing services.

Peterborough City Hospital maxillofacial surgeons have placed orders for models and we are exploring the possibility of directly accessing x-rays and scan images on their system. This will shorten the turnaround time for surgeons to receive 3D models in NHS hospitals in the region.

Extending our remit beyond human health, we have printed surgical guides for Matthew Allen, Professor of Small Animal Surgery at the University's Department of Veterinary Medicine. Building on the long-lasting cooperation between Cambridge's museums and Addenbrooke's Hospital, the team has also produced 3D models of specimens from the Sedgwick Museum using CT scans of fossils that are encased in rock.

Media Studio has produced replica models of a number of specimens from an ancient collection housed at the Sedgwick Museum in Cambridge. Left: The original shark-toothed dolphin's jaw fossil embedded in rock. Right: 3 printed model of the dolphin jaw

Thank you!

On behalf of patients and staff, ACT would like to thank you once more for helping to keep Cambridge University Hospitals at the forefront of clinical developments by bringing this innovative and versatile technology to our hospital so that patients across the East of England can benefit from improved outcomes.