



Revolutionizing Facial Reconstruction Using 3D Printing and 3D Haptic Design

- Geomagic Freeform enables rapid iteration of implant design and surgical planning
- 3D Systems' ProJet, SLA and MultiJet 3D printing technology used for prototypes, surgical practices and surgical guides

Maxillofacial reconstructive surgery reportedly began as far back as the American Civil War, (1861 – 1865) where doctors began treating facial fractures in soldiers. In the 150 years since, it has come a long way. But even as recently as a few years ago, successfully reconstructing a damaged face or head was notoriously difficult, with surgeons often having to be highly reactive to unforeseen complications during surgery.

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The CARTIS team combines industrial designers and surgeons. From left: Dominic Eggbeer, Dr. Adrian Sugar, Sean Peel.

The Centre for Applied Reconstructive Technologies in Surgery (CARTIS), an innovative partnership between surgeons and design engineering experts in Wales, is leading the way in revolutionizing this kind of surgery by researching and developing new ways, technology and processes to prepare for successful surgery. This unique combination of skills and talents has successfully developed new approaches and solutions that are changing the way facial reconstructions are carried out.

“This is groundbreaking work,” said Adrian Sugar, Consultant Cleft and Maxillofacial Surgeon at Morriston Hospital. “The combination of being able to use the patient’s own data from CT scans, being able to ‘feel’ bone fragments in the virtual world, model implants, and manufacture custom-designed devices and implants is changing the way we approach surgery and is significantly reducing surgery times.” It is also allowing us to introduce a degree of pre-surgical planning and more accurate outcomes for the patient which was previously not achievable.





Combining technologies, skills and best practices, CARTIS was formed in 2006 to research and innovate ways to streamline facial reconstruction surgery, make it less intense on the patient and improve outcomes. The Centre aspires to be a world leader in maxillofacial reconstructive surgery, is an alliance between the Maxillofacial Unit at Morriston Hospital in Swansea, Wales, and the National Centre for Product Design and Development Research (PDR) at Cardiff Metropolitan University. This combined Welsh team uses many 3D software packages as well as “haptic” design software, which gives a sensation of touch during the design process, and 3D printing technology, which enables the creation of perfect physical representations of the patient and implant data.



Image right, the surgical guides and implants. Image left: the implants remaining after the surgical guides have been removed.

The team has, since early 2012, worked with increasing efficiency on the most complex mid-facial reconstruction projects. One particular project that has been receiving international media attention is the planned reconstruction of a patient’s face after it was crushed in a motorcycle accident. The team has a number of similar complex projects lined up for which they are designing surgical guides, creating practice environments, and 3D printing prototype bone models and actual implants.

“As part of most projects, the specialist design engineers sit with the surgeons and prosthetist, and view the patient’s CT scan data in 3D on Geomagic Freeform,” said Dr. Dominic Eggbeer, Unit Manager, Surgical and Prosthetic Design, PDR.

Geomagic Freeform is a 3D design and sculpting software that uniquely works with a haptic or “force-feedback” device. Reading in the pre-processed CT scan data model, Freeform includes tools to design organic and unusually shaped objects that are not able to be created using CAD software. The software also has tools for removing undercuts and other fabrication preparation capabilities, so implants can be quickly produced. PDR and the Maxillofacial Unit at Morriston Hospital have been using Geomagic Freeform since 2001, and CARTIS has been using it since it was founded in 2006.

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The team works quickly with the surgeons to assess and touch the 3D data, plan what bones need to be cut and moved to adjust the skull, and design a solution for the required implants.





As importantly, they also start design on the surgical positioning guides. These are templates, custom built to the patient's data, that inform the surgeon exactly where to place screws, drill into bone, and cut into tissue during the surgery. The surgical guides are regarded as critical tools for the surgery to be a success, and they are removed at the completion of the surgery, leaving the implants and bones exactly where they were planned to be.

"Viewing the patient's data in Freeform, we can immediately see where displaced or damaged bone needs to be moved to match the uninjured areas, and where screws for the implants can be seated correctly for a successful outcome," said Sean Peel, Design Engineer, PDR. "We can quickly design the perfect bespoke surgical guides, custom implants, and set up virtual scenarios for practice sessions with the surgeons."

With some practice, the combined team can now create implant and surgical guide designs within a few hours, and be ready to start 3D printing within the day.

The team uses a suite of 3D Systems technology to fabricate prototypes of the devices and replica models of the anatomy within a few hours. This includes using ProJet®ColorJet 3D printers, SLA systems and MultiJet printing. "The full-color prints from the ProJet are especially useful in practice sessions," commented Peel. "We give bone fragments different colors in Freeform, and this is printed in full color on the 3D printer. The surgeons then have a very easy-to-translate reference for practice sessions." SLA and MultiJet technologies are used to fabricate models and implant prototypes that can be cut, drilled and practiced on.

As soon as the surgeons feel that the design is going to have a successful outcome, the implants and surgical guide data is sent for fabrication - sometimes in-house (in SLA Accura ClearVue resin), sometimes externally (in titanium or cobalt chrome).

"SLA ClearVue materials are perfect since the models can be cleaned extremely well before being sterilized ready for surgery," said Eggbeer.

The team has learned so much of the process, and built the skills to optimize the technology, that they can go from CT data to complete, printed implants with prototypes, practice models and surgical guides all in place within seven days.

"The way we are approaching this type of reconstructive facial surgery means that we can perfectly translate the surgical plan from start to finish, having already anticipated many of the problems that would need to be tackled," said Eggbeer.

