Figure 2 All the central area and the majority of the flap is fluorescent which translate its autonomisation.

extended soft tissue contusion, and no comorbidities. Patient 2 was 52 years old, had grade III open fracture of the right tibia and associated comorbidities: hypertension, hypercholesterolemia and type 2 diabetes. Patient 3 was 50 years old, had a chronic wound seven month after the excision of merkel carcinoma of the posterior part of the ankle, followed by complementary radiotherapy complicated by radiodermitis, and associated comorbidities were: hypercholesterolemia and smoking. The skin paddle of the neurofasciocutaneous flap was of respectively 9 cm and the width of 6 cm, 9 cm and the width of 9 cm and 5 cm and the width of 4 cm.

In all 3 cases, the ICG camera allowed a precise study of the perfusion of the flap authorizing an early division of the pedicle at 2 weeks (most investigators advocate a period of 3 weeks before the division of the pedicle) thus a shorter hospitalization stay, and an earlier start of the physical therapy. For Patient 2, the clinical evaluation at 10 days was in favor of an extended peripheral necrosis. At day 15, it was decided to do a flap revision in the OR, the ICG camera facilitated intraoperative decision making regarding to how much tissue to excise.

Several studies appraised the contribution of the ICG to assess vascular perfusion of pedicled flaps[4] and free flaps intraoperatively during the harvesting but to our knowledge there are no studies analyzing its utility postoperatively in the autonomization of pedicled flaps. In this study, we established its contribution to increase the safety and reliability of the reconstruction of soft tissue defects of the lower leg by distally based neurocutaneous sural flap especially in cases with high risk for complications.[5] It gives an accurate and reliable assessment of tissue perfusion in the intraoperative setting minimizing complications du to an excessive debridement and allows an early division of the pedicle decreasing the hospitalization stay. The accuracy of the ICG camera in the analysis of perfusion and the viability of pedicled flaps, eliminates the question of flap survival based on clinical judgment alone. It is a new tool available to surgeons and based in these observations we would recommend the systematic use of the ICG camera in the post-operative evaluation of the perfusion of local flaps with high risk of failure.

Conflict of interest statement

The authors declare that they have no conflict of interest.

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P. Aguilar
J. Niddam
L. Vidal
B. Hersant
J. Bouhassira
R. Bosc
J.-P. Meningaud
Department of Plastic, Reconstructive and Aesthetic Surgery, Henri Mondor Hospital, 51 avenue du Maréchal de Lattre de Tassigny, Créteil 94010, France

E-mail address: af_pao@hotmail.com

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http://dx.doi.org/10.1016/j.bjps.2015.12.014

3D printing provides unrivalled bespoke teaching tools for autologous free flap breast reconstruction

Dear sir,

Recent advances in CT angiography (CTA) have enhanced the pre-operative planning of autologous breast reconstruction by identifying suitable perforator vessels. Many breast reconstruction centres now have the ability to create computer generated three dimensional reconstructions of the CTA scans to locate the surface anatomy of suitable perforator vessels. Whilst these images can

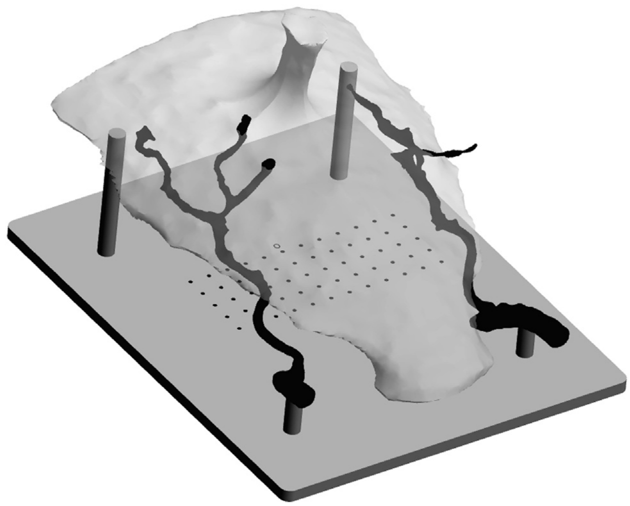

Figure 1 Segmented computerised model of the DIEP flap for 3D printing.

be helpful to the experienced surgeon, they can be difficult to conceptualise for the novice.

The application of 3D printing is becoming increasingly popular in surgery to aid pre-operative planning of complex procedures. Certain surgical specialties have made 3D printing common place. For example, Neurosurgeons have printed 3D models of cerebral aneurysms to aid pre-operative planning.[1] Indeed, 3D printed models have also been used in Neurosurgery to create sophisticated educational tools for teaching complex surgical procedures.[2] Cardiothoracic surgeons have used models to appreciate the complex morphologies of congenital heart disease, and help plan the complex procedures these require.[3]

In Plastic Surgery, 3D printing has been used to help with craniofacial pre-operative planning and implant design.[4] As far as we are aware, 3D printing has not been applied to breast reconstruction to date.

One of the most challenging steps of raising DIEP free flaps is dissecting the intramuscular course of the perforator artery. Meticulous pre-operative planning with the aid of imaging has helped reduce the dissection time required for this crucial step in the procedure. Further, with increasing reliance on surgical simulation and wet lab training, plastic surgery trainees can benefit from highly advanced educational tools.

In this study, we applied 3D printing to autologous reconstructive breast surgery to create a patient specific model to help plan and teach DIEP flap breast reconstruction.

Method

The preoperative abdominal CT angiogram of a healthy, middle aged female patient undergoing bilateral prophylactic mastectomy and DIEP flap breast reconstruction was used to create a 3D image for printing. The rectus abdominal muscle, umbilicus and relevant vascular structures were segmented using a combination of thresholding, region growing and then manual editing tools.

Figure 2 State of the art Objet500 Connex1 3D printer.

The software used for segmentation was Mimics Research v17.0, written by Materialise NV, Leuven, Belgium. Different thresholds were applied for the enhanced blood and muscle signals. Intramuscular sections of the perforator, for which the vessel diameter approached the pixel size of the scan data, were manually segmented directly by an expert radiologist.

The segmentation geometries were exported as STL (standard triangulation language) files using the program 3-matic Research v9.0 (Materialise NV, Leuven, Belgium) (Figure 1). A physical 3D model was printed in-house using an Objet500 Connex1 3D printer (Figure 2). This is a true 3D printer using polyjet technology to create layers of liquid resin photopolymer which are then cured under UV light. A black, flexible photopolymer (TangoBlackPlus FullCure980) was used to print the perforator vessels. A transparent, rigid photopolymer (VeroClear FullCure810) was used to print the rectus abdominus muscle and umbilicus. In addition, a white, durable photopolymer (Endur RGD450) was used to print the stand and scale grid to help measure and locate the perforator vessels in relation to the umbilicus.

The model was shown to surgeons pre-operatively and compared with the CTA scans. The model was also available during surgery to act as a point of reference to trace and follow the intramuscular course of the perforator.

Results

A bespoke, life size model of the patient's abdominal wall, DIEP vessels and their intramuscular course was successfully printed in just under 15-h (Figure 3). The model was used by trainee surgeons both pre- and intra-operatively to visualise the intramuscular course of the deep inferior epigastric perforator vessels.

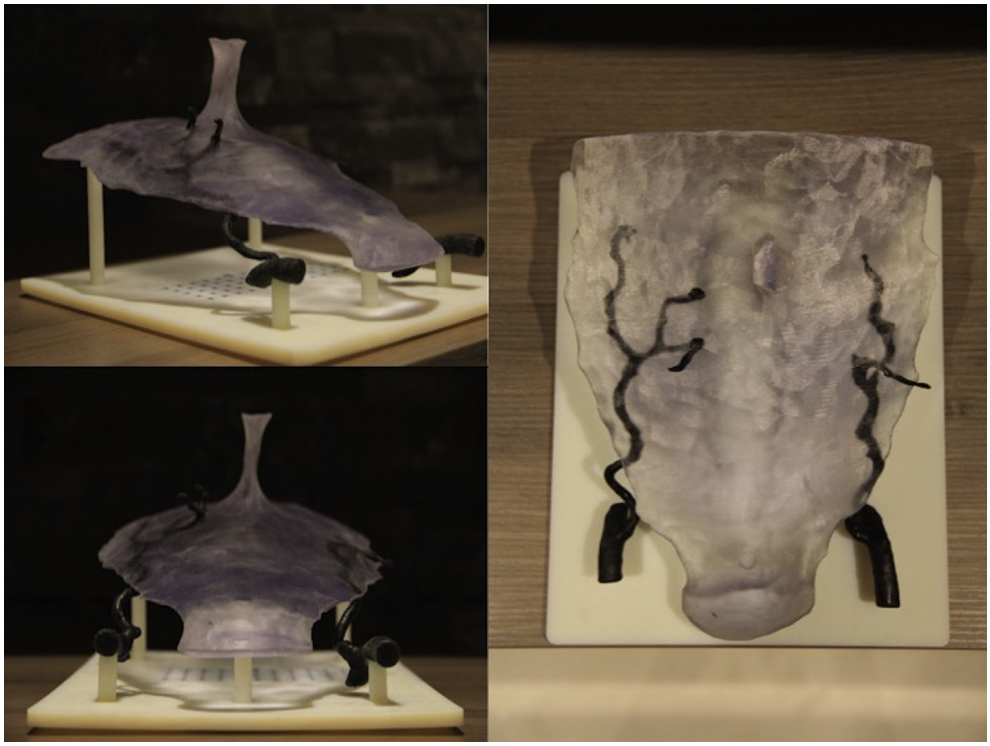

Figure 3 The final 3D print. The DIEP perforator vessels are represented in black. The rectus sheath is represented in translucent material.

Discussion

We believe that this is the first application of 3D printing in breast reconstruction. Sophisticated educational tools in surgical training are needed and this project is such an example. Anecdotal reports from the surgical trainees were that the model helped visualise the intramuscular course of the perforator which made the dissection more straightforward. The model was so detailed that even the depth of the perforator could be better understood which is something that 3-dimensional CTA reconstructions viewed on a 2-dimensional computer screen cannot provide. Future projects could include running a series of 3D printed models to evaluate if any operative time is saved due to improved pre-operative planning.

Conflicts of interest

None to declare.

Funding

None.

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Saahil Mehta
Plastic Surgery, Guy's & St Thomas' NHS Foundation Trust, London, UK

E-mail address: saahil47@gmail.com

Nicholas Byrne
Division of Imaging Sciences and Biomedical Engineering, King's College London, London, UK

Narayan Karunanithy
Radiology, Guy's & St Thomas' NHS Foundation Trust, London, UK

Jian Farhadi
Plastic Surgery, Guy's & St Thomas' NHS Foundation Trust, London, UK

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http://dx.doi.org/10.1016/j.bjps.2015.12.026