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Breast

Enhanced Preoperative Deep Inferior Epigastric Artery Perforator Flap Planning with a 3D-Printed Perforasome Template: Technique and Case Report

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Summary: Optimizing preoperative planning is widely sought in deep inferior epigastric artery perforator (DIEP) flap surgery. One reason for this is that rates of fat necrosis remain relatively high (up to 35%), and that adjusting flap design by an improved understanding of individual perforasomes and perfusion characteristics may be useful in reducing the risk of fat necrosis. Imaging techniques have substantially improved over the past decade, and with recent advances in 3D printing, an improved demonstration of imaged anatomy has become available. We describe a 3D-printed template that can be used preoperatively to mark out a patient's individualized perforasome for flap planning in DIEP flap surgery. We describe this "perforasome template" technique in a case of a 46-year-old woman undergoing immediate unilateral breast reconstruction with a DIEP flap. Routine preoperative computed tomographic angiography was performed, with open-source software (3D Slicer, Autodesk MeshMixer and Cura) and a desktop 3D printer (Ultimaker 3E) used to create a template used to mark intra-flap, subcutaneous branches of deep inferior epigastric artery (DIEA) perforators on the abdomen. An individualized 3D printed template was used to estimate the size and boundaries of a perforasome and perfusion map. The information was used to aid flap design. We describe a new technique of 3D printing a patient-specific perforasome template that can be used preoperatively to infer perforasomes and aid flap design. *(Plast Reconstr Surg Glob Open 2018;6:e1644; doi: 10.1097/GOX.0000000000001644; Published online 23 January 2018.)*

INTRODUCTION

Autologous breast reconstruction using the deep inferior epigastric artery perforator (DIEP) flap has become an integral component of the holistic treatment of breast cancer patients.[1] However, to this day, perfusion of DIEP flaps remains a key difficulty with this flap, and the rate of fat necrosis remains relatively high (8.7–35%).[2] Fat necrosis is a frequent cause of secondary surgical refinements.[3] Using the classification of fat necrosis by Lie et al.,[3] grade III–IV necrosis, involving greater than 15% of the flap, can significantly compromise aesthetic outcome and inevitably requires revision with lipofilling, skin grafts, or an entirely new flap. Fat necrosis can be prevented, and is well described, by improving the flap design to improve perfusion that adequately captures perforasomes and flow of deep inferior epigastric artery (DIEA) perforators.[3–5]

Modern imaging technologies, such as computed tomographic angiography (CTA), has assisted in preoperative flap and perforator selection, leading to improved clinical outcomes. However, they are limited by being displayed on a 2-dimensional (2D) surface. In contrast, a 3D-printed model provides additional tactile feedback that facilitates superior spatial understanding.[6] Recently, we have developed an affordable, convenient method of 3D printing a patient-specific DIEP template that can be used to draw preoperatively the location of DIEA perforators, their intramuscular course, and the DIEA pedicle.[7] Using this new technique, we have fashioned a template

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that maps intra-flap course of DIEA perforators, thus defining their perforasomes.

METHODS

In this study, we describe our technique of 3D printing a DIEP perforasome template. Henceforth, we will call it the "perforasome template" to differentiate it from our previously reported DIEP template, which identifies the location of perforators and their intramuscular course.[7]

CTA was performed using standardized "single-volume" acquisition technique that ensured maximal image quality and minimal radiation exposure.

Case Report

A 46-year-old woman underwent immediate unilateral breast reconstruction with a DIEP flap. She was otherwise well, with no comorbidities and had a BMI of 20.

TECHNIQUE

Design of the Perforasome Template

Digital Imaging and Communications in Medicine files from CTA are processed using free, open-source software (Fig. 1): 3D Slicer (Surgical Planning Laboratory, Boston, Mass.), Autodesk MeshMixer (Autodesk, Inc., San Rafael, Calif.), and Cura (Ultimaker, Geldermalsen, The Netherlands).

In 3D Slicer, holes/lines are created into the 3D image of the patient's abdominal wall, where subcutaneous branches of each DIEA perforator are found. Similarly, a notch is created at the level of pubic symphysis, which will be used to orientate the template on the abdomen. The final 3D image is exported in Standard Tessellation Language (STL) format.

In Autodesk MeshMixer, the holes/lines within the STL file are enlarged to fit surgical marking pens, and the entire template is made thicker to enable manual handling. The final 3D image is again exported in STL format.

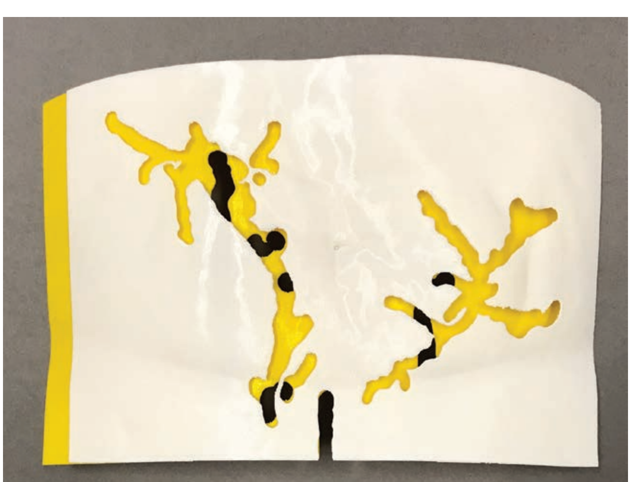

Fig. 1. 3D-printed perforasome template placed on top of 3D-printed DIEP template of the same patient demonstrating their accurate alignment.

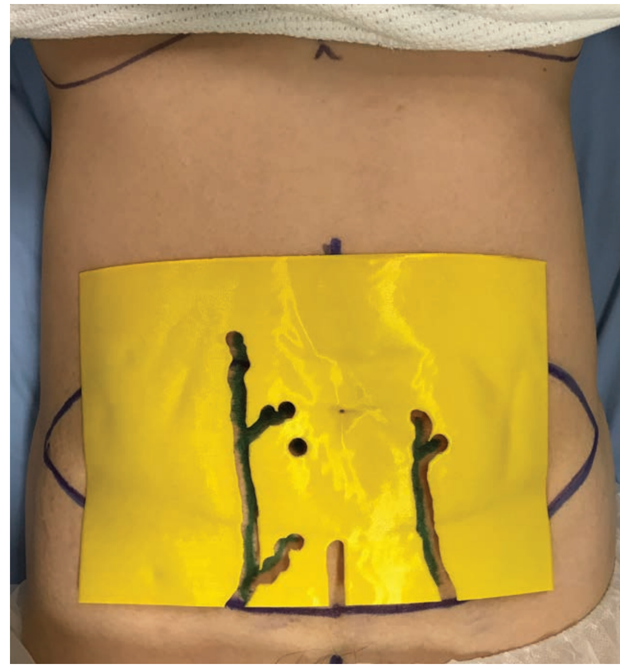

Fig. 2. 3D-printed DIEP template used to mark the location of DIEA perforators, their intramuscular course, and the DIEA pedicle.

In Cura, the STL file is converted into a 3D printer-compatible file and exported in G-code format.

3D Printing

Both the perforasome and the DIEP templates are 3D-printed for the case using polylactic acid filaments in Ultimaker 3E printer (Ultimaker, Geldermalsen, The Netherlands; Fig. 2). The DIEP template took 15.1 hours and 94 g of filament, whereas the perforasome template took 15.4 hours and 80 g, respectively (Fig. 3).

Clinical Outcome

Perforasomes were drawn using the template, providing the precise location of the relevant perforator exit point and intra-muscular course, which was useful for designing the final flap (Fig. 4). There were no immediate flap-related complications.

DISCUSSION

Fat necrosis transforms into disfiguring palpable lumps and is associated with significantly lower patient-reported aesthetic satisfaction.[8] In 2013, Lie et al.[3] have recommended a classification system to encourage consistent reporting of fat necrosis, ranging from grade I where < 5% of flap is involved resulting in minimal impact on the overall outcome to grade V or complete flap loss. In grade II fat necrosis involving 5–15% of the flap, lumpiness and discomfort may be subtle. However, in grade III involving 15–50%, aesthetic outcome is significantly compromised and may require substantial refinements with lipofilling or skin grafts. In grade IV involving > 50%, necrosectomy inevitably needs to be followed by reconstruction with an additional or an entirely new flap. Less frequently, fat

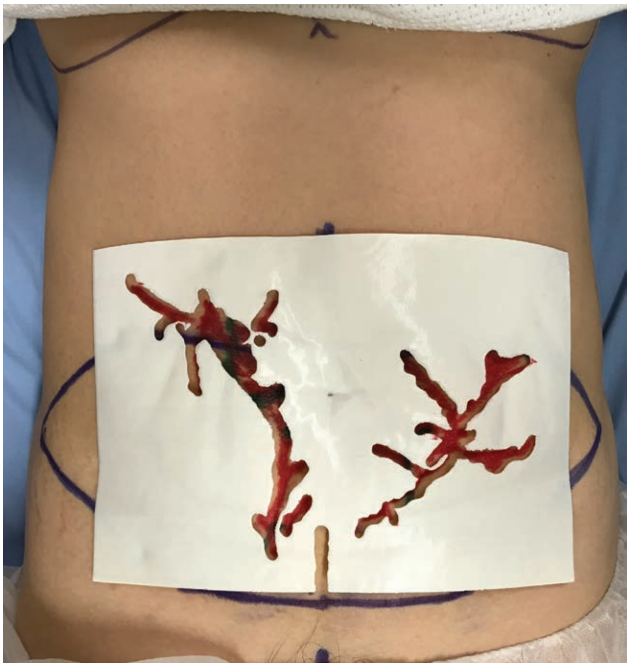

Fig. 3. 3D-printed perforasome template used to mark the subcutaneous branches of DIEA perforators and their linking vessels.

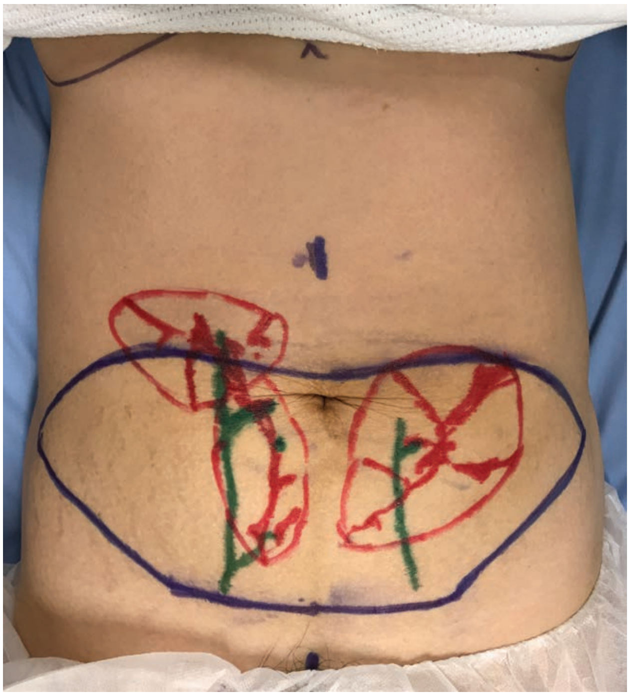

Fig. 4. The markings are used to estimate the size and shape of each perforasome to aide with flap design.

necrosis (2.8%) and partial flap necrosis (1.2%) may necessitate revision operation during the same admission of original reconstruction. One of the main reasons for grade I–IV fat necrosis is due to insufficient flap perfusion and its microvascular architecture stemming from a suboptimal flap design.

Understanding its vascular territory and perforator flow characteristics is critical for flap design and, to date, capturing dynamic vascularity of perforator flaps using imaging modalities has been challenging since routine CTA only provides static images. An ideal method remains to directly inject the perforator with contrast and use dynamic imaging modalities, such as 4D CTA, to demonstrate its axiality of flow, connection with subdermal plexus and outline its physiologic perforasome.[5] However, this is difficult to perform routinely for clinical application. CTA has largely been utilized in its arterial phase, as we have similarly done in the current study, although imaging (and 3D prints of such imaging) could equally be done for venous anatomy, should it be sought.

Encouragingly, when its parameters are optimized,[9] CTA can maximally opacify intra-flap, subcutaneous branches at minimal radiation exposure.[10] Phillips et al.[9] report the importance of supine positioning without compressive clothing, limiting the scan range to the flap area, triggering contrast bolus at the common femoral artery, scanning caudo-cranially in the direction of DIEA flow and setting acquisition time to 4 seconds.

CONCLUSIONS

We describe a new technique of 3D printing patient-specific perforasome template that illustrates intra-flap, subcutaneous branches of DIEA perforators. This can be used to derive perforasome anatomy and may help flap design preoperatively. A larger longitudinal study to assess the utility of these templates in improving clinical outcomes, such as rates of fat necrosis is underway.

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