Mapping three-dimensional digital model to surgical site in facial surgery

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ABSTRACT

Reconstructive surgery in the facial and oral sites requires high levels of precision. Intraoperative guidance can enhance surgical precision with three-dimensional (3D) image model. Here, case report was our endeavor of creating a 3D digital image model to guide plastic procedure is performed on the soft tissue of a patient's cheek. 3D facial structure was taken preoperatively by scanning the contours of the patient's head. The defect on patient's left cheek due to an aneurysm was identified and virtually corrected by mirroring image from the healthy right side of the cheek. Once the 3D virtual model was created, we displayed the 3D model onto the surgical site during the operation to guide surgical procedure. Digital technology is developing rapidly and is unavoidable to merge with surgical care. Clinical judgment and intraoperative performance will be improved by our efforts of integrating digital technology into the operating room.

Keywords: Image registration, image-guided surgery, patient safety, plastic surgery, three-dimensional modeling

INTRODUCTION

Reconstructive surgery in the facial and oral sites requires high levels of precision as patients often undergo this type of surgery as a cosmetic procedure.[1] For years, surgeons have performed this type of plastic surgery with great caution. Nevertheless, clinical outcomes may diverge as surgeons' clinic experiences are varied which affects the surgeon's clinical judgment at the critical moment during the operation. In the era of digital technology, we believe advancement in intelligent technology can bring new solutions to improve surgical quality in facial reconstructive operations.[1-3] Specifically, the clinical judgment can be enhanced by integrating digitized three-dimensional (3D) models into the surgical site.

Digital medical images, mainly used for making diagnosis in current practice, should have an important role for improving the quality of surgery when mediated into the operating room. According to Zawartka *et al.*, three steps are involved when we make the effort of integrating image model to a surgical procedure: acquiring digital images from patients, creating 3D anatomy for presurgical planning, and mapping the image to surgical site to guide on-going surgical procedures in the operating room.[4] In many ways, oral and maxillofacial surgeons (OMFS) are leading the innovation for integrating digital technology into their surgical practice.[1-3] However, most innovative effects were previously performed on the skeletal structures on the oral and maxillofacial site. Image-guided procedures designed for improving the quality of facial

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plastic surgery involving only soft tissues were seldom seen in the reports. One significant challenge which lies ahead for applying image-guided techniques to soft tissue based-facial surgery is how to project an image onto the surgical site and to create a mechanism which allows the image and surgical site to map perfectly during movement or rotation.

In this paper, we report a case of integrating a 3D digital model to the surgical site as virtual guidance where a plastic procedure is performed on the soft tissue of a patient's cheek. We discuss the potential impact of this novel technology in improving operation outcomes in the soft-tissue-based facial surgery. We are aware that digital technology is still under development and challenges are unavoidable as it begins to merge into surgical care. For each achievement we mention, we will discuss the limitations and barriers that it needs to overcome.

CASE REPORT

Differing from most surgeries that require a series of 2D digital images from computed tomography or magnetic resonance imaging to reconstruct virtual models, surgeons can create a 3D modal of the patient's facial structure by directly scanning the contours of the head.[5,6] In this case, multiple optic cameras were used for taking images of the subject [Figure 1a].

The images taken by the 3DMD system (3DMD LLC, Atlanta, USA) measure complex geometries to create point clouds, which are then merged together to produce the final 3D digital representation. 3D photography is a newly developed area in medical imaging, which allows high-quality analysis of the facial surface and soft tissue.[6] This is a fast and low-cost step for creating a 3D facial model for each individual patient. It can estimate distances of specific landmarks on the face and assess and monitor pre- and post-operative changes.[6]

In medical imaging, the process of creating 3D models from a set of images is called 3D reconstruction.[7] In OMFS, reconstructing facial structure from photo images is not as complex as one would think. We can achieve this goal with the commercially available programs as shown in Figure 1b. Using these techniques can help determine the size and border of a soft-tissue defect for appropriate excision or expansion.

In OMFS, reconstruction is performed to correct altered anatomy or to rebuild a structure that is missing from the face due to various reasons. In the case, we present in this paper, a defect on patient's left cheek due to an aneurysm was identified. The ultimate shape of the left cheek was virtually created by copying image data from the healthy right side of the cheek. Using the mirror image is helpful for guiding the facial surgery, as long as the anatomy is symmetrical.

Figure 1: Three-dimensional photograph of the subject was taken at the Shanghai 9th Hospital by the 3DMD system (a); Three-dimensional virtual model was created (b)

3D virtual models allow surgeons to visualize and manipulate images on screen even before mapping a 3D model to the surgical site. The surgeon can rotate the 3D composite to identify landmarks, visualize unique anatomy, and define optimal cutting area for surgical planning. Having this ability to manipulate and appreciate 3D structures to learn a patient's anatomy has aided in precision for planning surgical steps. With the dramatic evolution of presurgical planning, the duration of operations has decreased, which has improved surgical patient safety.

Once we create the 3D virtual model, we will need to work on mapping the 3D model to patient anatomy during surgical phases to complete the last step of image-surgery integration. Instant display of the image on top of surgical anatomy can be a useful technique but encounters two major challenges. First, we need to translate data into a more usable format, so that the image can easily be displayed. In collaboration with scientists at the Surgical Simulation Research Lab (SSRL) at the University of Alberta, we output 3D model data to the Wavefront (.obj) format. This is a common format which can be used by most 3D graphics programs. An Aaxa Pocket Projector (Aaxa Technologies, Tustin, CA, USA) can be used to project the 3D image on top of the surgical

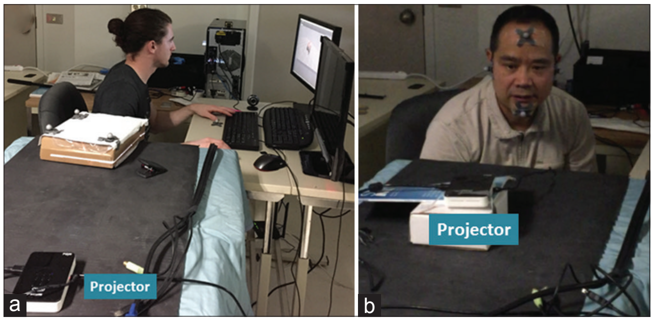

Figure 2: Three-dimensional virtual model was translated to projector (a) and displayed on top of the subject; motion of the subject's head was detected by three infrared markers (b)

site. The second challenge is to ensure the images map to the correct size of the human anatomy and move with the patient during surgery. At the SSRL, the mapping and tracking problem was solved by adding three infrared markers on the head of the patients [Figure 2]. Position data from these three markers were captured by the OptiTrack 3D Motion Tracking System (NaturalPoint, Inc., Corvallis, Oregon, USA) and used to adjust the 3D virtual model when the movement of the patient is detected [Figure 3]. The motion is captured at 120 Hz, so updates to the image appear nearly in real-time. The field of view of the projector is measured so that it corresponds with the display of the virtual objects. Since the projector has been calibrated, and the 3D image is accurate to the real size of the patient, no adjustment to the size of the virtual model is needed.

Mapping 3D images to the real surgical site can significantly improve patient safety as we can provide instant guidance to the facial surgery. This process could also be used to evaluate the success of a procedure by providing a clear comparison of images from before, after, and the target used during the procedure. Other researchers also try to track the instrument positions which we believe can be merged with our virtual image model for safe manipulation.[8,9] For example, when performing surgery at the base of the skull for a pituitary tumor, the global positioning system Suretrack (Medtronic, Minneapolis, MN, USA) can track the movement of instruments and monitoring the precision of surgical manipulation.[8]

DISCUSSION

Digital technology is developing rapidly and is unavoidable to merge with surgical care. OMFS has pioneered the use of digital technologies in their surgeries and has made excellent strides in improving accuracy and functionality of reconstructed implants for oral and facial defects. It has improved treatment for patients by creating individually

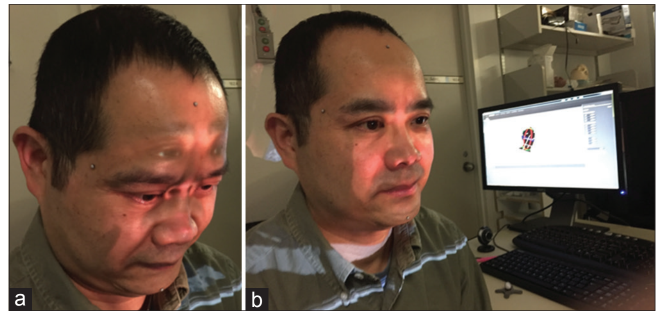

Figure 3: Motion markers were reduced in size in the later phase of the experiments (a); mismatch of virtual model was corrected (b)

customized implants. It shows promising techniques and technology for the future. It will also encourage the development of smaller, faster, and inexpensive imaging equipment. Creation and manipulation on the 3D model require skills and training beyond that of a health-care provider. It is important to have multidisciplinary teams consisting of engineers, information technology personnel, and health-care workers in collaboration to obtain the final result.

Declaration of patient consent

The authors certify that they have obtained all appropriate patient consent forms. In the form the patient(s) has/have given his/her/their consent for his/her/their images and other clinical information to be reported in the journal. The patients understand that their names and initials will not be published and due efforts will be made to conceal their identity, but anonymity cannot be guaranteed.

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Conflicts of interest

There are no conflicts of interest.

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