Innovations and Future Directions in Head and Neck Microsurgical Reconstruction

Marissa Suchyta, BA, Samir Mardini, MD*

KEYWORDS

• Craniofacial reconstruction • Innovation • Face transplant • Regenerative medicine • Virtual surgical planning • 3D printing • Perfusion monitoring

KEY POINTS

- Integration of virtual surgical planning and three-dimensional printing has enabled improved surgical accuracy, efficiency, and dealing with more complex reconstructions.
- Novel intraoperative navigation, imaging, and perfusion assessment have led to ease of flap design, avoidance of vital structures, and innovative flap monitoring.
- The development of minimally invasive reconstructive microsurgery has advanced oncological head and neck reconstruction.
- The integration of regenerative medicine, tissue engineering, and stem cell biology presents novel methods of osteogenic flap prefabrication as well as research in ex vivo generation of patient-specific craniofacial bone and tissue.
- Facial composite tissue allotransplant is an innovation in craniofacial surgery for patients who have exhausted the traditional reconstructive plastic surgery armamentarium.

INTRODUCTION

"Pourquoi pas?" Paul Tessier, known as the father of modern craniofacial surgery, would often answer questions about his innovative procedures with this response of "Why not?"[1] This expression, which eventually became the motto of the International Society of Craniofacial Surgery, should continue to drive this field of innovation and multidisciplinary advances, encouraging craniofacial and head and neck reconstructive surgeons to think creatively and outside the confines of the discipline. In few other surgical fields do advances in science, technology, and surgical ingenuity combine to better patient outcomes in such dramatic and visible ways.

Large-scale innovations often occur when there is a convergence of knowledge across disciplines, leading to new ideas or the coalescence of ideas to make advances. The development of microsurgery is an example of this. The combination of a series of advances in different fields in the early twentieth century led to the innovation of clinical microsurgery. This innovation includes advancement in surgical technique, with the reporting of the triangulation method of end-to-end anastomosis in 1902.[2] However, advances in basic science were also needed to aid in

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Division of Plastic and Reconstructive Surgery, Mayo Clinic, MA1244W, 200 First Street Southwest, Rochester, MN 55905, USA
* Corresponding author.
E-mail address: Mardini.samir@mayo.edu

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anticoagulation, and the 1916 discovery of heparin thus enabled the patency of microvascular anastomoses.[3] Perhaps most vitally, in the early 1920s, the introduction of the operating microscope as well as fine microsurgical suture and instruments provided necessary bioengineering advances.[4] These multidisciplinary innovations led to the first successful microvascular anastomosis in 1960, thus dramatically changing reconstructive surgery.

In the current era of head and neck microsurgical reconstruction, clinicians again have embraced the coalescence of multidisciplinary fields leading to innovation and future advances, including the integration of virtual surgical planning and three-dimensional (3D) printing technologies in craniofacial surgery, enabling planning of complex procedures before entering the operating room as well as the creation of patient-specific surgical guides and implants. Novel imaging methods enable assessment of flap design and immediate perfusion outcomes intraoperatively. Innovations in postoperative perfusion monitoring incorporate technological advances, including infrared thermography and oxygenation. In addition, smartphone capabilities have also led to dramatic advances in early detection of flap problems, thereby decreasing flap failure rates. Innovation in surgical technique has led to minimally invasive reconstructive procedures, including transoral reconstructive capabilities for oropharyngeal cancer and endoscopic skull base reconstruction. Advances in regenerative medicine and tissue engineering show the potential of merging stem cell biology with reconstructive craniofacial microsurgery, which has already shown advances in prefabrication techniques. In addition, face transplant provides an ideal example of disruptive innovation in craniofacial surgery for patients who have exhausted the armamentarium of plastic surgery options.

THE INTEGRATION OF VIRTUAL SURGICAL PLANNING AND THREE-DIMENSIONAL PRINTING WITH CRANIOFACIAL RECONSTRUCTION

The ability to plan and virtually execute complex craniofacial surgical procedures has revolutionized head and neck reconstruction. Virtual surgical planning starts with a high-resolution computed tomography (CT) scan with thin cuts; the potential for virtual surgical planning depends on the ability to obtain such scans (**Fig. 1**).[5] The 3D reconstruction is then performed in one of the US Food and Drug Administration (FDA)–approved computer-aided design or computer-aided modeling software environments. A Web conference is conducted between the surgeon and biomedical engineers to virtually plan the surgery, including osteotomy placement, resection margins (in the case of oncological surgery), bone graft placement, and positional alignment. This virtual conference allows the surgeon to plan the procedure in a less time-sensitive environment before surgery rather than relying on intraoperative judgement as the main method of deciding on osteotomies. Virtual surgical planning also requires the declaration of surgical intention, allowing a lower-stress environment in which to decide on recipient vessel choice as well as osteotomy placement. Furthermore, in the case of oncological head and neck reconstruction, virtual surgical planning can avoid any potential conflicts between the resection and reconstruction teams caused by uncertainty or change of plans in the operating room. Most importantly, virtual surgical planning enables surgeons to attempt multiple approaches and reconstructive options in a virtual environment, thereby determining the optimal surgical outcome before entering the operating room.

The integration of virtual surgical planning with 3D printing furthers the frontier of craniofacial

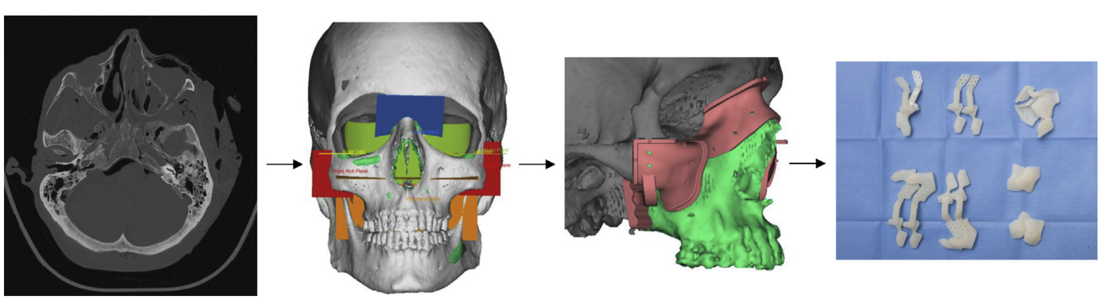

Fig. 1. The process of planning a Le Fort III–based face transplant. The process of virtual surgical planning begins with a high-resolution CT scan. This scan is then 3D reconstructed and, in a virtual planning session between engineers and the surgeon, osteotomy locations are planned. Then 3D printed guides are designed to guide these osteotomies, which are then printed, sterilized, and used in the surgery.