Journal of Plastic, Reconstructive & Aesthetic Surgery (2014) 67, 1171—1185

JPRAS
An International Journal of Surgical Reconstruction
www.JPRASurg.com

REVIEW

Advances in oncologic head and neck reconstruction: Systematic review and future considerations of virtual surgical planning and computer aided design/ computer aided modeling

Katherine A. Rodby [a,c], Sergey Turin [a,c], Ryan J. Jacobs [a], Janet F. Cruz [a], Victor J. Hassid [a], Antonio Kolokythas [b], Anuja K. Antony [a,*]

[a] *Department of Surgery, Division of Plastic, Reconstructive and Cosmetic Surgery, University of Illinois at Chicago, Chicago, IL, USA*
[b] *Department of Oral and Maxillofacial Surgery, University of Illinois at Chicago, Chicago, IL, USA*

Received 17 December 2013; accepted 26 April 2014

KEYWORDS
Virtual surgical planning;
Computer aided design;
Maxillofacial reconstruction;
Mandibular reconstruction;
Oncologic reconstruction

Summary *Background:* Mastery of craniomaxillofacial reconstruction has been traditionally considered to be learning curve dependent, often with inconsistent results during the skill acquisition phase. Until recently, the overall success in bony oncologic reconstruction of the craniomaxillofacial skeleton has relied mainly on the use of 2D imaging modalities, as well as surgical trial-and-error. Virtual surgical planning (VSP) and computer aided design (CAD)/ computer aided modeling (CAM) are gaining traction in oncologic applications and offers opportunity for increased accuracy, improved efficiency, and enhanced outcomes. Its role in oncologic head and neck reconstruction has not been formally evaluated.
Methods: A systematic review of the current literature was conducted by three independent reviewers. Three separate search schemes were utilized to identify cases incorporating VSP-CAD/CAM technology in head and neck reconstruction for an oncologic indication. Inclusion and exclusion criteria were applied; articles that met criteria were evaluated for cohort demographics, osteocutaneous flap type and usage, oncologic indication, recipient bone reconstructed, flap survival, follow up, VSP technology usage, specific reported benefits of the technology, and qualitative and quantitative outcome assessments.

* Corresponding author. Division of Plastic and Reconstructive Surgery, University of Illinois at Chicago, Chicago, IL 60601, USA. Tel.: +1 312 996 9313; fax: +1 312 413 0496.
E-mail addresses: akantony@uic.edu, anuantony1@yahoo.com (A.K. Antony).

[c] Co-first authors.

http://dx.doi.org/10.1016/j.bjps.2014.04.038

Results: The systematic literature review yielded 87 articles; of these, 33 met inclusion criteria describing a total of 220 cases of oncologic head and neck reconstruction incorporating virtual planning technology. Numerous qualitative benefits of VSP were reported including increased accuracy of the reconstruction (93%), decreased intraoperative time (80%), and ease of use (24%) among others. However, quantitative results using survey data or preoperative/postoperative CT scan comparisons were given for only 33% (3%, 30% respectively) of cases.
Conclusion: VSP represents an evolving technology that ushers oncological craniomaxillofacial reconstruction into a modern era that holds potential to advance the field with increased reconstructive accuracy, expedition of the surgical phase, and improved outcomes. While qualitative improvements from the technology are delineated, specific quantifiable benefits and cost-benefit analysis are limited and need to be further investigated.

Introduction

Virtual surgical planning (VSP) in the area of reconstructive surgery is a new technology that is gaining acceptance due to its many perceived benefits including increased accuracy, improved operative efficiency and enhanced outcomes.[1,2] A number of authors have described using VSP in craniofacial reconstruction, with indications ranging from trauma to oncologic reconstruction.[1–36] Refinements in the use of computer aided design (CAD) and computer aided modeling (CAM) for preoperative planning now offers a more facile user interface lending itself to greater draw and adoption in reconstructive applications requiring precise planning and execution.[1,6,24,26] In particular, VSP has gained traction for use in reconstruction of the mandible and maxilla, as surgical accuracy is required to restore facial symmetry, appearance, and function; a task complicated by the irregular, unique shapes of the maxillomandibular construct and the relative lack of similarly-shaped graft donor sites.[11] VSP is an exciting new technology that warrants consideration for use in complex oncologic osseous head and neck reconstruction.

Multi-stage implementation of virtual surgical planning with use of cutting guides, stereolithographic models and pre-fabricated plates offers reconstructive accuracy previously reliant on surgeon experience and intraoperative trial-and-error using 2D imaging modalities. Cited reconstructive benefits of CAD/CAM implementation include increased bone-to-bone contact, better dental alignment, improved esthetic contour, and reduced complication rates.[11,37] As an increasing number of authors are reporting on VSP in oncologic craniomaxillofacial surgery, we sought to investigate the benefits of the technology by performing a systematic review of the literature to identify usage and assess advantages for an oncologic indication. Additionally, to determine the utility of VSP in reconstruction of the head and neck, a comparison of surgical outcomes against those of conventional craniomaxillofacial surgery will be included. This is the first and only systematic review-to-date regarding the utility of virtual surgical planning in oncologic head and neck reconstruction, with a focus on reconstruction of the maxilla and mandible. We will also present sample cases highlighting our experience with VSP in head and neck reconstruction.

Surgical technique

Computer assisted craniomaxillofacial surgery is based on four specific, well-described phases, which are all necessary in order to achieve predictable outcomes: planning, modeling, surgery, and evaluation.[3,17] These steps are detailed as follows:

The first phase, *planning*, beings with a high-resolution computed tomographic (CT) scan with thin cuts of the craniofacial skeleton and the possible donor sites, (e.g. lower extremities) if considered necessary. A 3D reconstruction of the CT images is performed and then forwarded to the desired modeling company. A web-based teleconference is then held between the surgical teams and a biomedical engineer to allow participation from remote locations. During this session, the resection and reconstruction is virtually planned, taking into account factors such as resection margins, osteotomies, and placement of the vascularized bone graft in oncologic reconstruction, accurate reduction of the fractured bony segments for traumatic injuries, or the staged virtual movement of the jaws in orthognatic procedures.

Based on the virtual surgical plan, the *modeling* phase begins. Stereolithographic models are manufactured of the area of the craniomaxillofacial skeleton of interest, along with specific cutting guides for both the resection and the vascularized bone graft that will be used for oncologic bony reconstruction (e.g. fibula). This also allows for manufacturing of a reconstruction plate or plate bending template; the specific guides and templates can be tailored to the surgeon's preference.[17,19]

These models, cutting guides, and plates are utilized during the *surgery* phase. Osteotomies are made in the mandible or maxilla based on the resection guides, typically after maxillo-mandibular fixation is achieved. The harvested osseous flap is also cut and osteotomized in-situ based on the cutting guides and typically fixed to the reconstruction plate before the composite unit is secured into the maxillofacial/mandibular defect. With the bony foundation restored, the soft tissue reconstruction ensues.

The *evaluation* phase continues in the postoperative period, where a repeat high-resolution CT can be performed, based on the same preoperative protocol.[17] While the method of evaluation varies between institutions, a