Journal of Cranio-Maxillo-Facial Surgery 44 (2016) 229–241

Contents lists available at ScienceDirect

Journal of Cranio-Maxillo-Facial Surgery

journal homepage: www.jcmfs.com

Iterations of computer- and template assisted mandibular or maxillary reconstruction with free flaps containing the lateral scapular border – Evolution of a biplanar plug-on cutting guide

Carl-Peter Cornelius [a,*], Goetz Andreas Giessler [b], Frank Wilde [c], Marc Christian Metzger [d], Gerson Mast [a], Florian Andreas Probst [a]

[a] *Department of Oral and Maxillofacial Surgery, Ludwig-Maximilians-University, Munich, Germany*
[b] *Department of Plastic, Reconstructive, Esthetic and Hand Surgery, Klinikum Kassel, Kassel, Germany*
[c] *Department of Oral and Maxillofacial Surgery, Facial Plastic Surgery, German Armed Forces Hospital Ulm and Academic Hospital of Ulm University, Ulm, Germany*
[d] *Department of Oral and Maxillofacial Surgery, Albert-Ludwig-University, Freiburg i. Brsg., Germany*

ARTICLE INFO

Article history:
Paper received 23 September 2015
Accepted 10 November 2015
Available online 21 December 2015

Keywords:
Computer-assisted surgery
Bone flaps
Lateral scapular border
Mandibular reconstruction
Maxillary reconstruction
Cutting guide design

ABSTRACT

Background: Computer-assisted planning and intraoperative implementation using templates have become appreciated modalities in craniofacial reconstruction with fibula and DCIA flaps due to saving in operation time, improved accuracy of osteotomies and easy insetting. Up to now, a similar development for flaps from the subscapular vascular system, namely the lateral scapular border and tip, has not been addressed in the literature.
Patients/method: A cohort of 12 patients who underwent mandibular (n = 10) or maxillary (n = 2) reconstruction with free flaps containing the lateral scapular border and tip using computer-assisted planning, stereolithography (STL) models and selective laser sintered (SLS) templates for bone contouring and sub-segmentation osteotomies was reviewed focussing on iterations in the design of computer generated tools and templates.
Results: The technical evolution migrated from hybrid STL models over SLS templates for cut out as well as sub-segmentation with a uniplanar framework to plug-on tandem template assemblies providing a biplanar access for the in toto cut out from the posterior aspect in succession with contouring into subsegments from the medial side.
Conclusion: The latest design version is the proof of concept that virtual planning of bone flaps from the lateral scapular border can be successfully transferred into surgery by appropriate templates.

1. Introduction

The subscapular vascular system permits the elevation of a wide array of different flaps in almost every conceivable combination of skin, fat, fascia, muscle and bone (Swartz et al., 1986; Baker and Sullivan, 1988; Hallock, 1997; Moukarbel et al., 2010; Dabernig et al., 2007). Though the volume of vascularized bone from the lateral scapular border and inferior angle or tip is limited, the availability of extended soft tissue components at the same vascular pedicle offers worthwhile options in composite head and neck defects (Urken et al., 1991; Brown et al., 2010; Giessler et al., 2012). In contrast to virtual surgical planning (VSP) and computer-assisted-design and manufacturing (CAD/CAM) of cutting templates for fibula and DCIA flaps (Leiggener et al., 2009; Hanasono and Skoracki, 2013; Levine et al., 2013; Modabber et al., 2012a,b, 2013; 2014a,b; Shen et al., 2012a,b; Rodby et al., 2014) similar planning methods and supporting tools to contour the lateral or axillary scapular border are not particularly advanced. This may lie in the fact that a muscle cuff consisting of infraspinatus, teres minor/major and subscapularis portions must be preserved around the lateral scapular border to maintain the blood

* Corresponding author. Department of Oral and Maxillofacial Surgery, Ludwig-Maximilians-University, Munich, Germany, Lindwurmstr. 2a, 80337, Munich, Germany.
E-mail address: Peter.Cornelius@med.uni-muenchen.de (C.-P. Cornelius).

http://dx.doi.org/10.1016/j.jcms.2015.11.005
1010-5182/

supply provided by the branches from the circumflex scapular artery (Baker and Sullivan, 1988; Wagner and Bayles, 2008). This need for an intact muscle cuff interferes with an unimpaired application of cutting guides, which are conveniently affixed in DCIA or fibula flaps upon the bare bony surfaces at the outer iliac wing or the lateral aspect of the fibular shaft, respectively. The additional separate vascularization of the scapular tip by the angular vessels (Deraemaecker et al., 1988; Van Thienen and Deraemaecker, 1988; Seneviratne et al., 1999; Seitz et al., 1999; Wagner and Bayles, 2008; Dolderer et al., 2010) enables the straightforward isolation of a small separate segment on a long vascular pedicle which makes a broad-based muscular interconnection unnecessary (Coleman and Sultan, 1991).

VSP in conjunction with stereolithography (STL) models and templates for oncologic mandibular or maxillary resections and sub-segmentation of fibula and DCIA bone flaps have been shown to overcome the guesswork in freehand osseous contouring. Appropriate cutting guides offer unprecedented accuracy of wedge osteotomies, enable maximum contact of the angulated bone ends, a favourable condition for bone healing (Roser et al., 2010; Ciocca et al., 2015), and accelerate the surgical procedure (Modabber et al., 2012b; Hanosono and Skoracki, 2013; Seruya et al., 2013; Sieira Gil et al., 2015; Kääriäinen et al., 2015). The reduction of operating time and hence theatre costs has been shown to largely compensate for the additional expenditures in VSP procedures, what particularly matters in fixed budget health care reimbursement (Zweifel et al., 2015).

These characteristics are pressing issues in the use of free flaps of the subscapular vessel axis containing bone islands from the lateral scapular border, since in mandibular reconstruction the scapular bone segments are fraught with high rates of pseudarthrosis (Mitsimponas et al., 2014). Moreover the unfeasibility of a simultaneous two team approach and the need for turning the patient from a supine position into a lateral decubitus position for flap harvesting and backward is time consuming and asking for any conceivable savings during the operation.

The purpose of this survey is to show the gradual optimization of CAD/CAM applications in bone island flaps from the lateral scapular border and tip for mandibular or maxillary reconstruction from getting started with STL models over uniplanar to more sophisticated biplanar cutting guides.

2. Materials and methods

A consecutive series of 12 patients who underwent mandibular (n = 10) or maxillary (n = 2) reconstruction with free flaps containing the lateral scapular border in the time period between August 2011 and November 2013 was reviewed. The institutional ethics committee approved the retrospective study protocol and each patient provided informed consent. Demographic information including the surgery dates was collected and the location and size of the defects was determined and displayed (Table 1). Involvement of the anatomic regions within the mandibular arch and ascending ramus were recorded according to the classification of Urken and coworkers (Urken et al., 1991). The maxillary defects were classified according to Brown and coworker (Brown and Shaw, 2010).

The bony reconstructions were performed subsequent to preoperative VSP, manufacturing of hybrid STL models displaying the prospected or preexisting mandibular or maxillary defect as well as the planned segments of the bone graft and different types of SLS (selective laser sintered) – cutting guides for harvest and segmentation of the bone from the lateral scapular border.

Since the features of these cutting guides are the outcome of an evolutionary process, the iterations are comprehensively described in the results section.

Hardware was either hand-bent to the STL models (patients 1 to 3, 6, 7, 9 and 12) or a recent type of CNC (computerized numerically controlled) – milled patient specific mandibular reconstruction plates (Wilde et al., 2014, 2015; Cornelius et al., 2015) (patients 4, 5, 10 and 11) (Patient Specific Mandibular Plate – PSMP) DePuy Synthes Maxillofacial®, Paoli, USA) were used for osteosynthesis of the bone segments based on the commercial availability and speed of the production process. A two-piece patient specific selective laser melted titanium platform provided fixation into one of the maxillary defects (patient 8). The cornerstones of the preoperative preparations were the same in all cases. The workflow began with high-resolution-CT scans (slice increments $\leq$1.0 mm) of the craniofacial skeleton and the scapular region. The DICOM (Digital Imaging and Communications in Medicine) datasets were converted into virtual three dimensional mandibular and/or midface models and models of the left or right scapula using Synthes ProPlan CMF software (DePuy Synthes Maxillofacial®, Paoli, USA/ Materialise® Leuven, Belgium). In an interactive web session between clinical engineers and surgeons the resection lines (primary reconstruction) or the limits of the preexisting defects (secondary reconstruction) were determined and superimposed on a virtual model of the intact native mandible or the upper jaw. The osteotomies for segmentation of the scapular border were planned to restore the contours of the mandibular base or the alveolar crest of the maxillae. The length and angles of the neomandibular or neomaxillary segments were shaped to result in opening osteotomies initially or to accomplish a closing approximation of the bone ends by wedge-shaped ostectomies later in the series (Table 1). The design of the SLS cutting guides for the lateral scapular border varied depending on the overall extent of the segments, the number of subdivisions and the location of the osteotomies relative to the muscle cuff which is essential for the vascular supply of the infraglenoid margin or to the tip area through the angular branch.

A set of personalized templates (resection and cutting guides, etc.) and physical models was then fabricated using the above mentioned rapid prototype modelling (RPM) technologies for VSP transfer into surgery.

The intraoperative instrumentation for the osteotomies for segmentation and sub-segmentation of the scapula, either piezosurgery or reciprocating saw, varied (Table 1).

3. Results

The patient cohort under review had mean age of 55.7 years (range 12–72 years) and the gender ratio was 4 females to 8 males.

Diagnoses included squamous cell carcinoma (SCC) (n = 8), chondroblastic osteosarcoma (n = 1), ameloblastoma (n = 1), infected osteoradionecrosis (IORN) (n = 1) and a hyena bite defect (n = 1) (Table 1). In 9 of 12 patients the reconstruction with bone containing flaps from the subscapular vascular axis was a secondary procedure. In addition to the bone from the lateral scapular border 8 patients had soft tissue flaps on the same vascular pedicle (2-in-one flap with – scapular flap n = 1, parascapular n = 5, latissimus dorsi n = 2).

The extent of the defects and the number of scapular bone subsegments are detailed in Table 1. In 10 patients the defects were localized in the mandible, 2 patients had maxillary defects. The length of the defects ranged from 3.4 to 10 cm.

The harvested bone from the lateral scapula was osteotomized in 2 (n = 6) or 3 (n = 4) sub-segments. Two bone transplants remained uncut (n = 2).

With any single cut sub-segmentation the osteotomy site either lay within the infraglenoid lateral periscapular (= infraspinatus, teres minor and major, subscapularis) muscle cuff (n = 2) or ran along the frontier between the lateral scapular border and angle