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Original Article

Study of medical education in 3D surgical modeling by surgeons with free open-source software: Example of mandibular reconstruction with fibula free flap and creation of its surgical guides

L. Ganry [a,*], B. Hersant [a], R. Bosc [a], P. Leyder [b], J. Quilichini [b], J.P. Meningaud [a]

[a] *Department of Maxillo-facial, Plastic, Reconstructive and Aesthetic Surgery, Henri-Mondor Hospital, 51, avenue du Maréchal-de-Lattre-de-Tassigny, 94010 Créteil, France*
[b] *Department of Plastic and Maxillo-facial Surgery, Robert-Ballanger Hospital, boulevard Robert-Ballanger, 93600 Aulnay-sous-Bois, France*

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A B S T R A C T

Introduction: Benefits of 3D printing techniques, biomodeling and surgical guides are well known in surgery, especially when the same surgeon who performed the surgery participated in the virtual surgical planning. Our objective was to evaluate the transfer of know how of a neutral 3D surgical modeling free open-source software protocol to surgeons with different surgical specialities.
Methods: A one-day training session was organised in 3D surgical modeling applied to one mandibular reconstruction case with fibula free flap and creation of its surgical guides. Surgeon satisfaction was analysed before and after the training.
Results: Of 22 surgeons, 59% assessed the training as excellent or very good and 68% considered changing their daily surgical routine and would try to apply our open-source software protocol in their department after a single training day. The mean capacity in using the software improved from 4.13 on 10 before to 6.59 on 10 after training for OsiriX® software, from 1.14 before to 5.05 after training for Meshlab®, from 0.45 before to 4.91 after training for Netfabb® and from 1.05 before and 4.41 after training for Blender®. According to surgeons, using the software Blender® became harder as the day went on.
Discussion: Despite improvement in the capacity in using software for all participants, more than a single training day is needed for the transfer of know how on 3D modeling with open-source software. Although the know-how transfer, overall satisfaction, actual learning outcomes and relevance of this training were appropriated, a longer training including different topics will be needed to improve training quality.

1. Introduction

In complex surgical procedures, the degree of precision and reduction of operating time constitutes major medical and economic issues [1–4]. Over the last decade, rapid prototyping (RP) technology progressed largely due to the help of professional engineers. Since surgeons depend on this technology to obtain precise reconstructive surgical outcomes, the development of the concept of "home staging" surgical 3D modeling and 3D printing technologies allows experienced surgeons to obtain these results by performing surgical pre-operative 3D planning themselves.

We developed a year ago a 4 software protocol using only open-source free software for 3D surgical modeling [5]. Our protocol description in the technical note explains every step needed to complete surgical modeling [5]. We also assess our outcomes in mandibular reconstruction by osteocutaneous fibula free flap after the creation of surgical guides [6]. In practice, protocols like the one presented in this paper, provides a free, rapid and flexible solution for complex cases. Transmission of the knowledge necessary to master this software is the principal difficulty encountered by surgeons who want to train in home staging. We found that the use of tutorial videos alone did not provide enough insight to master the complexity of home staging 3D modeling. The desire to create an educational seminar to train surgeons was the motivating factor for this study. Currently in

* Corresponding author.
E-mail addresses: laurentganry@hotmail.fr (L. Ganry), barbara.hersant@gmail.com (B. Hersant), romainbosc@gmail.com (R. Bosc), chir.max.plast@ch-aulnay.fr (P. Leyder), julien.quilichini@gmail.com (J. Quilichini), meningaud@mee.com (J.P. Meningaud).

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France, the learning curve of personal virtual surgical planning, even using professional software, is perceived as too time consuming so the majority of surgeons rely on engineers to perform a professional 3D surgical modeling. We believe the transmission of this free technology can be done quickly with a seminar, with the goal to incorporate this training in the initial and continuing education of surgeons worldwide in any surgical specialty.

The primary objective of this study was to evaluate whether surgeons from different backgrounds (OMFS, plastic surgery, ENT and orthopedic surgery) with various degrees of experience in surgery (residents and senior surgeons) could acquire, in a single day, a high score of what we called the software skills (SS). Using our 4 open-source software protocol, we evaluated if each surgeon could successfully plan clinical cases of mandibular reconstruction with fibula free flap, by extracting 3D objects of the skull and fibula from CT-scans, preparing these files for 3D surgical modelling and performing the virtual surgical planning with the creation of appropriate surgical guides.

2. Material and methods

We organized a single day of training for 7 hours in our Department of Maxillofacial and Plastic, Reconstructive and Aesthetic Surgery. The course provided training in the 3D surgical planning of a right hemi-mandibulectomy with fibula free flap reconstruction and the creation of the mandibular and fibular surgical guides. Surgeons in specialties of Maxillofacial, Plastic, ENT and Orthopedic Surgery were accepted from the public and private practice, from resident to attending physician. The majority of the participants were interested in the subject of 3D surgical modeling and had prior experience in mandibular reconstruction.

The details of the 4 software protocol were withheld from the participants prior to the training session. Each participant brought his own computer and downloaded the 4 open-source software: OsiriX®, Meshlab®, Netfabb® and Blender®. Each of these programs provides a precise role to complete a 3D surgical modeling and are used one after the other: Osirix® is a viewer for Digital Imaging and Communications in Medicine (DICOM) images from CT-scan and exports them in sterolithography (STL) format file, Meshlab® is used for the simplification and alignment of meshes derived from the STL files, Netfabb® repairs the meshes of the 3D object before any 3D printing process and Blender® is used for isolated 3D surgical modelling work on the 3D object. The principal instructor presented each stage of the 3D surgical modeling process, starting by Osirix®, then Meshlab®, Netfabb® and finally with Blender® via lecture while providing individual guidance for each step of the procedure.

One month before the course, we provided each participant with two videos. The first video presented the basic controls of Blender® in French: (http://www.youtube.com/watch?v=WlnUkQZizME) and the second reviewed the learning objectives for the course (http://www.youtube.com/watch?v=Q2iZpVzWX48).

At the start of the course, each participant was given a USB drive containing a guide and a checklist of all the stages of the 3D surgical modeling for the surgical case. This prevented the need for note taking and ensured that the participants left the course with the resources necessary to continue individual training at home. We recorded the candidates' characteristics:

- age;
- gender;
- surgical grade;
- private or public practice;
- surgical knowledge of fibula free flaps;
- experience with video games and computers;
- prior knowledge of software and surgical 3D modeling.

The primary assessment criterion for the study was the participants' actual learning gain. Assessment of the gain was determined using several statistical tools including the degree of heterogeneity of the group (η), the average gross gain (AGG) and the average relative gain (ARG):

- the degree of heterogeneity (η) is a tool, which enabled Hainaut [7] and Ouellet [8] to approximate the degree of agreement between the participants questioned. If it is $< 15\%$, the agreement (or homogeneity) is marked, but if it is $> 30\%$, there is marked disagreement (or heterogeneity). The formula is: $\eta = (\sigma/\mu) \times 100$, in which "$\sigma$" is the standard deviation and "μ" is the mean;
- AGG is the difference in what was actually gained in terms of learning expressed as the means for all the participants, for each software. The formula is: μ (pre-training) – μ (post-training);
- ARG is the ratio between what was gained by all of the participants and the maximum possible gain (SSmax) for each software. ARG is obtained by noting the participant with the best gain from 0 to 10. In the literature [7], it is generally accepted that there is a positive learning effect when the relative gain is > 30–40%. The formula is: [SS(pre)–SS(post)]/[SS(max)–SS(pre)] $\times$ 100.

The secondary assessment criteria were evaluated using an 8-point Likert qualitative non-metric scale [8] that assessed of: participant satisfaction rate, level of independence to conduct 3D surgical modeling using our protocol, weak points of the training course, whether prior history of intensive video gaming/computer use facilitated ease of learning during the course and whether prior knowledge of the 3D software used facilitated learning the protocol.

The learning evaluation tools consisted of 2 questionnaires administered pre- and post-training 9 [9,10]. The questionnaires were compiled following the recommendations of the French Health Agency: "Evaluation and improvement of practices: guide to good practices for healthcare simulation", December 2012. A self-assessment stage [10] was advantageous because it enabled the participant and instructor to identify the difficult stages to improve subsequent courses [11] and to determine whether the stages of the course had been truly mastered by the participants.

Link for questionnaires: https://drive.google.com/open?id=0B151YvzqKom4Q3h0TV9CN2JJd1k.

Our procedure was performed in this article in accordance with the Ethical Standards of the Institutional and National Research Committee and with the 1964 Helsinki Declaration and its later amendments.

3. Results

3.1. Characteristics of the series

We studied 22 surgeons from 7 French cities (Paris, Besançon, Lille, Lyon, Clermont-Ferrand, Bordeaux and Grenoble) and from a Belgian city (Brussels). There were 13 maxillofacial surgeons, 6 lastic surgeons, 2 ENT surgeons, and 1rthopedic surgeon.

There were 14 men and 8 women. Among them, 59% were residents, 32% had a M.D., one surgeon (5%) was a Professor of plastic surgery (M.D., PhD) and one surgeon (5%) had a private practice.

The participants' technical skills are summarized in Table 1.