*Int. J. Oral Maxillofac. Surg. 2017; 46: 946–957*
http://dx.doi.org/10.1016/j.ijom.2017.02.1276, available online at http://www.sciencedirect.com

International Journal of Oral & Maxillofacial Surgery

Clinical Paper
Reconstructive surgery

# Three-dimensional surgical modelling with an open-source software protocol: study of precision and reproducibility in mandibular reconstruction with the fibula free flap

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*L. Ganry, J. Quilichini, C. M. Bandini, P. Leyder, B. Hersant, J. P. Meningaud: Three-dimensional surgical modelling with an open-source software protocol: study of precision and reproducibility in mandibular reconstruction with the fibula free flap. Int. J. Oral Maxillofac. Surg. 2017; 46: 946–957.* 

*Abstract.* Very few surgical teams currently use totally independent and free solutions to perform three-dimensional (3D) surgical modelling for osseous free flaps in reconstructive surgery. This study assessed the precision and technical reproducibility of a 3D surgical modelling protocol using free open-source software in mandibular reconstruction with fibula free flaps and surgical guides. Precision was assessed through comparisons of the 3D surgical guide to the sterilized 3D-printed guide, determining accuracy to the millimetre level. Reproducibility was assessed in three surgical cases by volumetric comparison to the millimetre level. For the 3D surgical modelling, a difference of less than 0.1 mm was observed. Almost no deformations (<0.2 mm) were observed post-autoclave sterilization of the 3D-printed surgical guides. In the three surgical cases, the average precision of fibula free flap modelling was between 0.1 mm and 0.4 mm, and the average precision of the complete reconstructed mandible was less than 1 mm. The open-source software protocol demonstrated high accuracy without complications. However, the precision of the surgical case depends on the surgeon's 3D surgical modelling. Therefore, surgeons need training on the use of this protocol before applying it to surgical cases; this constitutes a limitation. Further studies should address the transfer of expertise.

Key words: 3D modelling; 3D printing; surgical guide; mandibular reconstruction; fibula free flap; CAD–CAS.

Accepted for publication 28 February 2017
Available online 19 April 2017

 

The surgical gold standard for mandibular bone reconstruction is the fibula free flap[1]. Extensive mandibular bone resection in oncological surgery or traumatic mandibular tissue loss constitutes an indication for reconstructive surgery. The main technical difficulty in such cases is related to the three-dimensional (3D) conformation of the fibula free flap and gaining the most anatomical position possible[2].

Rapid prototyping (RP) consists of the technology enabling the design, through 3D printing, of objects or models derived from a computed tomography (CT) scan, magnetic resonance imaging (MRI), or optical scan, after a computer-aided 3D modelling stage. RP undoubtedly represents an advance with regard to the various stages of craniomaxillofacial reconstructive surgery planning, but also in the production of prototype surgical instruments, Maxillofacial protheses, and surgical guides[3]. With recent progress made in this technology, it appears to be a particularly pertinent solution with respect to 3D conformation of a fibula free flap in the context of mandibular reconstruction[4].

Surgeons are now able to finalize the treatment planning using computer-aided 3D modelling and then take the 3D-printed sterilized object into the operating room, thereby improving the precision, control, and duration of the surgical procedure relative to standard techniques[5]. This technology is markedly more precise than that based on pre-moulded patient plaster cast models[6]. However, computer-aided surgical 3D modelling remains the essential preliminary stage for the creation of 3D-printed objects. Since the modelling is complex, it is still mainly implemented by computer engineers and only rarely by surgeons, and is always done using onerous professional software packages. Thus, the main drawbacks are the high cost, most frequently incumbent on the patient, and the long production lead times, usually 10 days to several weeks.

The workflow for this technology in a healthcare organization involves radiologists, surgeons, prosthesis specialists, and the RP department (particularly 3D printing); thus, enhanced organization would enable optimization of the time frame[3].

Cost reductions and improvements in healthcare quality constitute a surgical challenge. This article reports a technique that would make the technology accessible to all. The technology enables the implementation of surgical 3D modelling by the surgeon through the use of an open-source software protocol[7] and the selection of professional-assistance solutions, with a view to enhancing the timeframe and trimming

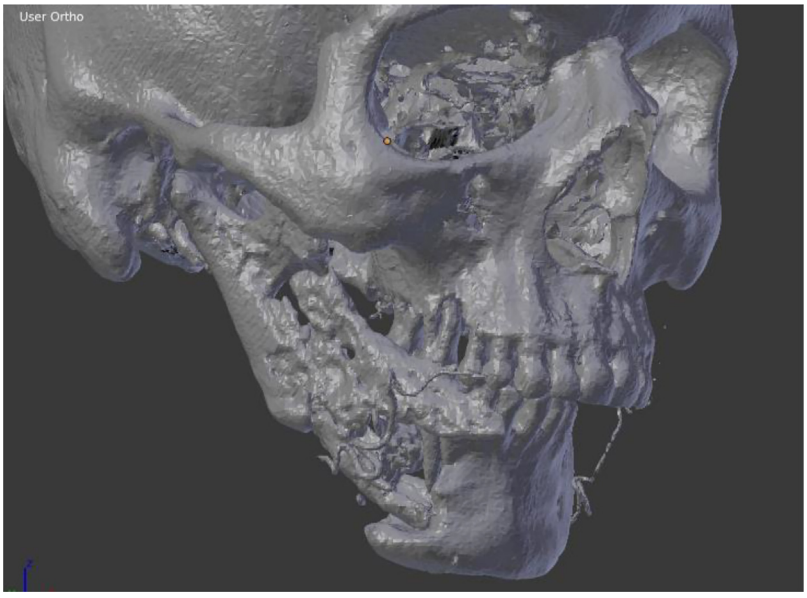


*Fig. 1.* Patient 1: skull with extensive osteoradionecrosis.

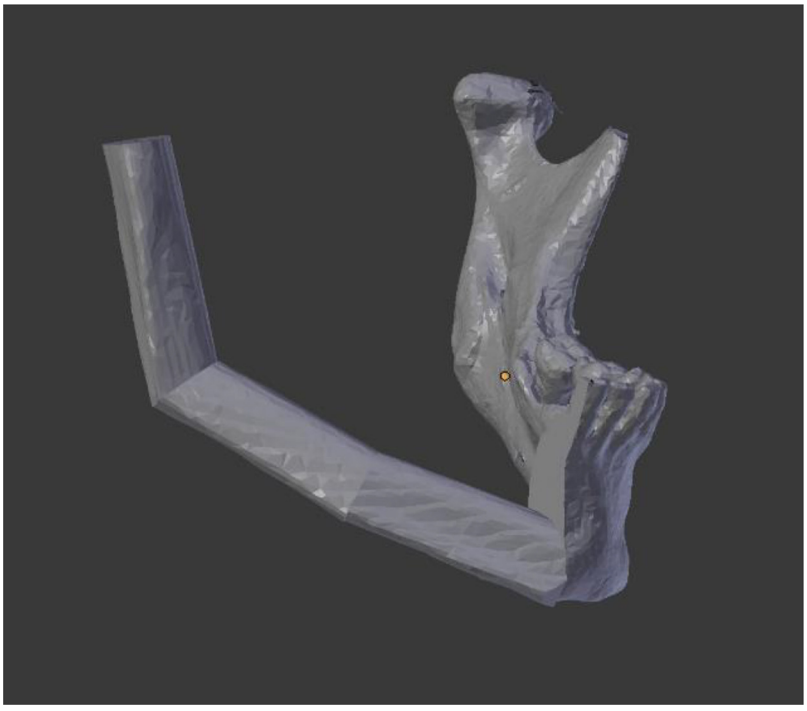

*Fig. 2.* Patient 1: mandibular reconstruction with a fibula free flap.

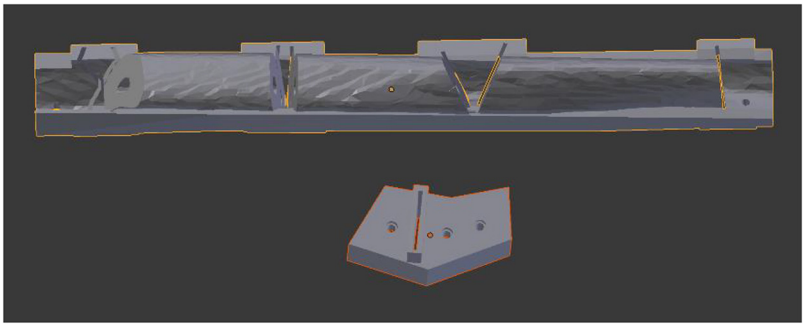

*Fig. 3.* Patient 1: surgical mandibular and fibular guides.