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3-D biomodelling technology for maxillofacial reconstruction

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Abstract

Biomodel is a product of rapid prototyping process that represents a new approach for surgical planning and simulation. Biomodels were found to be particularly effective to locate an exact defect with good measurement accuracy and without any risk to the patients' health. These models could provide surgeons a realistic impression of complex structures before surgical intervention, allowing a define diagnosis and a precise preoperative simulation of skeleton modifying interventions.

This work reports on the application of innovative 3-D biomodelling technology in the maxillofacial reconstruction. This technology allows for the calculation of the exact contours, angulations, length and general morphology of iliac crest and fibula flaps for maxillofacial reconstruction in a total of 28 clinical cases. Clinical results have shown that by using this technique, much better facial symmetry and improved functionality were achieved after surgery, which resulted in enormous benefits for treated patients.

Keywords: 3D Biomodelling; Maxillofacial reconstruction; Free flap designing

1. Introduction

Biomodelling is a technology that allows three-dimensional (3D) computed tomography (CT) and other image technology data to be used to manufacture solid plastic replicas of anatomical biomodels. Mathematical techniques for describing the 3-dimensional (3D) morphology of the facial skeleton are becoming increasingly sophisticated [1–3]. Biomodelling is a generic term describing the ability to replicate the morphology of a biological structure in a solid substance. Specifically, biomodelling uses radiant energy to capture morphological data on a biological structure and processes such data by a computer to generate the code required to manufacture the structure by rapid prototyping (RP) [4–6].

Stereolithography (SL) is a rapid prototyping (RP) process. Employing these technologies, it is possible to build 3D models, with all their complexity in a very short time, under computer control and without significant human intervention [7,8]. Almost all rapid prototyping processes, either currently available commercially or under development are based on layered manufacturing methodology in which objects are built as a series of horizontal cross sections, each one being formed individually from the relevant raw materials and bonded to preceding layers until it is completed. The main process stage involved in fabricating the parts are common to most systems but the mechanisms by which the individual layers are formed may differ [9].

The accuracy of SL has been shown in the range of ±1 mm, which offers clinicians the ability to perform retrospective and prospective studies of facial aging, for example [1,10].

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In literature, D' Urso et al have studied on forty-five patients with craniofacial, maxillofacial and skull base cervical spinal pathology [5]. The conclusion was that biomodels have significantly improved the operative planning and diagnoses to 82.2% and 95.2% respectively [5].

Peckitt [11] has reported on the current and future developments in stereoscopic lithography customized titanium implants in orofacial reconstruction. All patients were reported to have an acceptable quality of life and in another report, benefits of stereolithography in orbital reconstruction in two patients were studied [12]. In these cases, SL offered highly accurate models of the bony orbit for preoperative evaluation, surgical planning and increased the orbital surgeon's options in managing complex orbital pathology. SL is an accurate technology that may find a significant application in the study of facial aging since differential growth of the facial skeleton may occur throughout life, specifically in the maxillary regions [13].

Very recently, the authors studied the application of this technology in a case report of opening wedge high tibial osteotomy [14]. Results have shown that these 3D Bonelike® macroporous scaffolds was an excellent option in the treatment of medial compartment osteoarthritis varus knee, as they offer a framework for new bone tissue formation and anchorage by providing surface and volume that will allow for cell ingrowth and an accurate cell distribution throughout the porous structure [14–18].

This paper reports the application of an innovative 3-D Biomodelling approach for the calculation of the exact

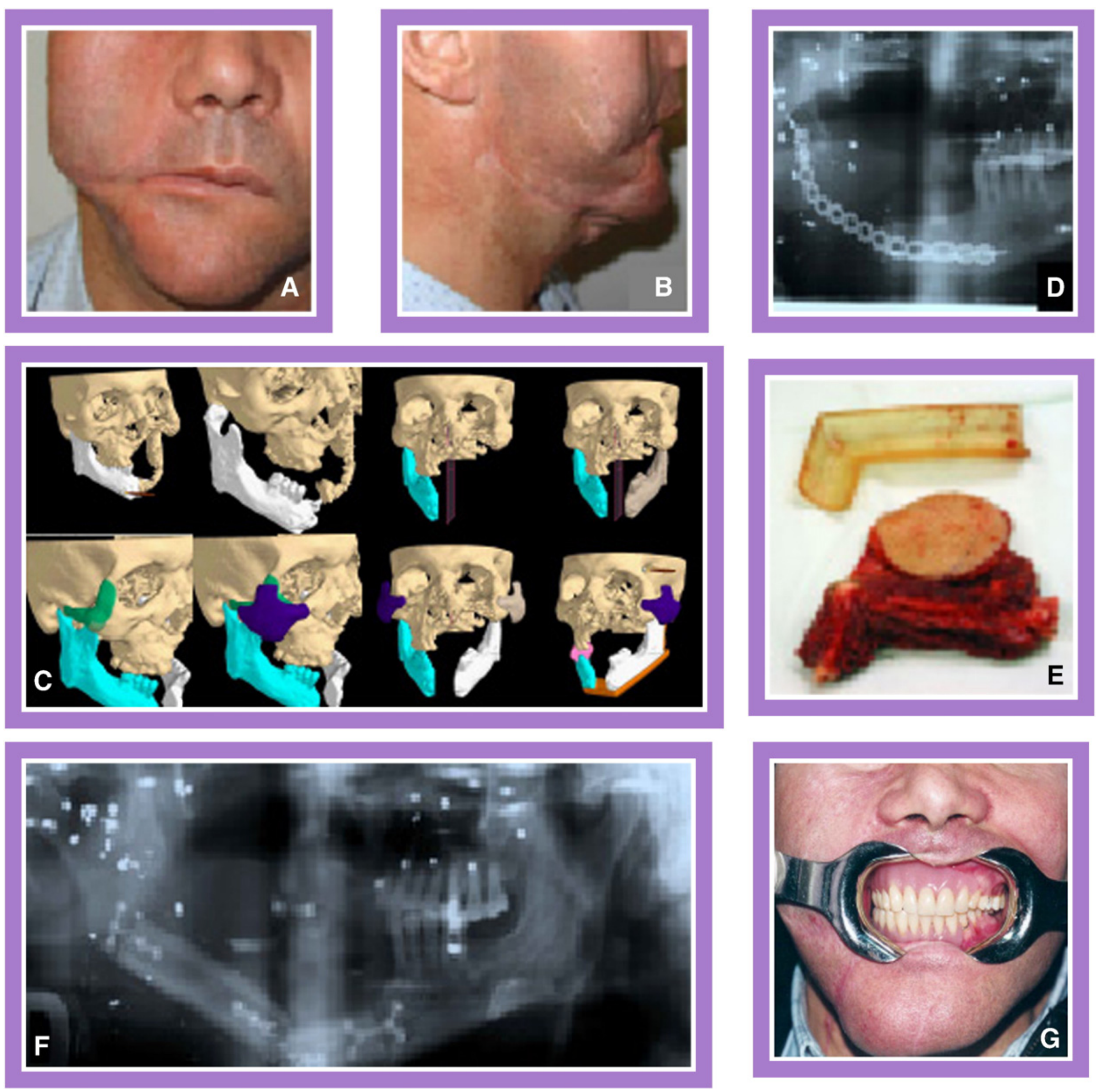

Fig. 1. Image sequence starting from (A) a pre-operative frontal view, lateral view (B) of the patient, an extensive virtual manipulation had to be performed with the aim of restoring the facial symmetry of the patient using RP surgical guides (C), radiological image showing the Ti plate that had been implanted (D), the free flap harvested from the peroneal bone was designed according to the surgical guide (E), the radiological examination showing the implanted free flap and restored symmetry after surgery (F) and complete restoration of the defect and biofunctionality was observed after 6 months of the surgery in the post operative image (G).