COMPUTER METHODS AND PROGRAMS IN BIOMEDICINE 111 (2013) 642–649

journal homepage: www.intl.elsevierhealth.com/journals/cmpb

Establishment of sequential software processing for a biomechanical model of mandibular reconstruction with custom-made plate

Peng Li[a], *Youchao Tang*[b,1], *Jia Li*[a], *Longduo Shen*[a], *Weidong Tian*[c,*], *Wei Tang*[a,*,1]

[a] *Department of Oral and Maxillofacial Surgery, West China College of Stomatology, Sichuan University, No. 14, 3rd Section, Renmin South Road, Chengdu 610041, PR China*

[b] *Institute of Biomedical Engineering, Sichuan University, No. 24, 1st Section, Yihuan South Road, Chengdu 610064, Sichuan, PR China*

[c] *State Key Laboratory of Oral Disease, Sichuan University, No. 14, 3rd Section, Renmin South Road, Chengdu 610041, Sichuan, PR China*

ARTICLE INFO

Article history:
Received 1 February 2013
Received in revised form
27 May 2013
Accepted 29 May 2013

Keywords:
Biomechanics
Mandible
Custom-made plate
Finite element analysis

ABSTRACT

The aim of this study is to describe the sequential software processing of computed tomography (CT) dataset for reconstructing the finite element analysis (FEA) mandibular model with custom-made plate, and to provide a theoretical basis for clinical usage of this reconstruction method. A CT scan was done on one patient who had mandibular continuity defects. This CT dataset in DICOM format was imported into *Mimics 10.0* software in which a three-dimensional (3-D) model of the facial skeleton was reconstructed and the mandible was segmented out. With *Geomagic Studio 11.0*, one custom-made plate and nine virtual screws were designed. All parts of the reconstructed mandible were converted into NURBS and saved as IGES format for importing into *pro/E 4.0*. After Boolean operation and assembly, the model was switched to *ANSYS Workbench 12.0*. Finally, after applying the boundary conditions and material properties, an analysis was performed. As results, a 3-D FEA model was successfully developed using the softwares above. The stress-strain distribution precisely indicated biomechanical performance of the reconstructed mandible on the normal occlusion load, without stress concentrated areas. The Von-Mises stress in all parts of the model, from the maximum value of 50.9 MPa to the minimum value of 0.1 MPa, was lower than the ultimate tensile strength. In conclusion, the described strategy could speedily and successfully produce a biomechanical model of a reconstructed mandible with custom-made plate. Using this FEA foundation, the custom-made plate may be improved for an optimal clinical outcome.

* *Corresponding authors*. Tel.: +86 028 85503456; fax: +86 028 85582167.
E-mail addresses: drtwd@sina.com (W. Tian), mydrtangwei@yahoo.com.cn (W. Tang).

[1] These authors contributed equally to this work.

0169-2607/$ – see front matter © 2013 Elsevier Ireland Ltd. All rights reserved.
http://dx.doi.org/10.1016/j.cmpb.2013.05.024

1. Introduction

With the development of imaging and computer technology in recent years, computer-assisted surgical (CAS) technique has become an advanced tool that is being continually developed in different surgical disciplines. The custom-made plate, one of the major outcomes resulting from the CAS technique, has been widely used in maxillofacial, orthopedic and cerebral surgery [1]. For some special cases with mandibular continuity defect, it has been an ideal choice, but has also presented a remarkable challenge, not only because of the special esthetic requirement in maxillofacial area, but also due to the functional restoration of occlusion. However, there are no definitive guidelines yet available regarding the design and restorative materials for the plate.

Studies based on laboratory experiments could potentially provide insight to these questions, however, it is difficult to perform validation research on live subjects. The method of finite element analysis (FEA) was introduced into dental research in 1973. The main principle of FEA is that one structure is divided into a number of shaped elements with individual stress/strain characteristics to show internal stresses. Due to the relative ease of this approach, it has become a useful tool when demonstrating the biomechanical behavior of complex structures [2–5]. Recently, some authors have investigated FEA optimization methods for the design of plate and reported different techniques to create FEA models using dataset from CT and Magnetic Resonance Imaging (MRI) scans. Many different software packages, such as *Surgicase, 3-D Slicer* and *3DMSR* have been used for the construction of 3-D models, while other computer aided design (CAD) softwares, such as *Pro/E, Solidworks, Autocad, Unigraphics NX*, have been used for the design. For the virtual simulation of FEA, software such as *ANSYS, ADINA, ABAQUS, MSC Patran* have been employed [6,7]. Due to the sophisticated techniques and confusion as to which of the above softwares to use and in what sequence, the process of FEA has become a difficult and time-consuming task.

A previous study in our lab supported the accuracy of a 3-D FEA model of mandibular reconstruction with custom-made plate [8], though there are few studies that have explored the details of data-processing in FEA models. The aim of the current study is to describe the sequential software processing of the Digital Imaging and Communications in Medicine (DICOM) dataset for establishment of the 3-D FEA model. We also investigate the feasibility of FEA as a research tool for the iterative optimization design of a custom-made plate.

2. Materials and methods

One female patient who had been diagnosed with adamantoblastoma on the left body of the mandible was studied. The patient had previously undergone surgery using a fibular graft for reconstruction of the mandible however the graft had failed. The development of FEA model was based on this actual geometry and the sequential software processing was carried out as follows.

2.1. *Acquisition of DICOM data from CT scanning*

A CT scan was performed on the head region of this patient using a spiral CT (Siemens Sensation 16, Munich, Germany). The scan was comprised of 340 cross-sectional “cuts” with the slice distance of 0.7 mm and each image resolution of 512 × 512 pixels. All data in DICOM format were imported into the software package *Mimics 10.0* (Materialize, Leuven, Belgium) for the construction of the 3-D model (Fig. 1).

2.2. *Construction of the 3-D model*

With the appropriate threshold (with the range of 250–2976 HU) and the “Region Growing” tool, the virtual

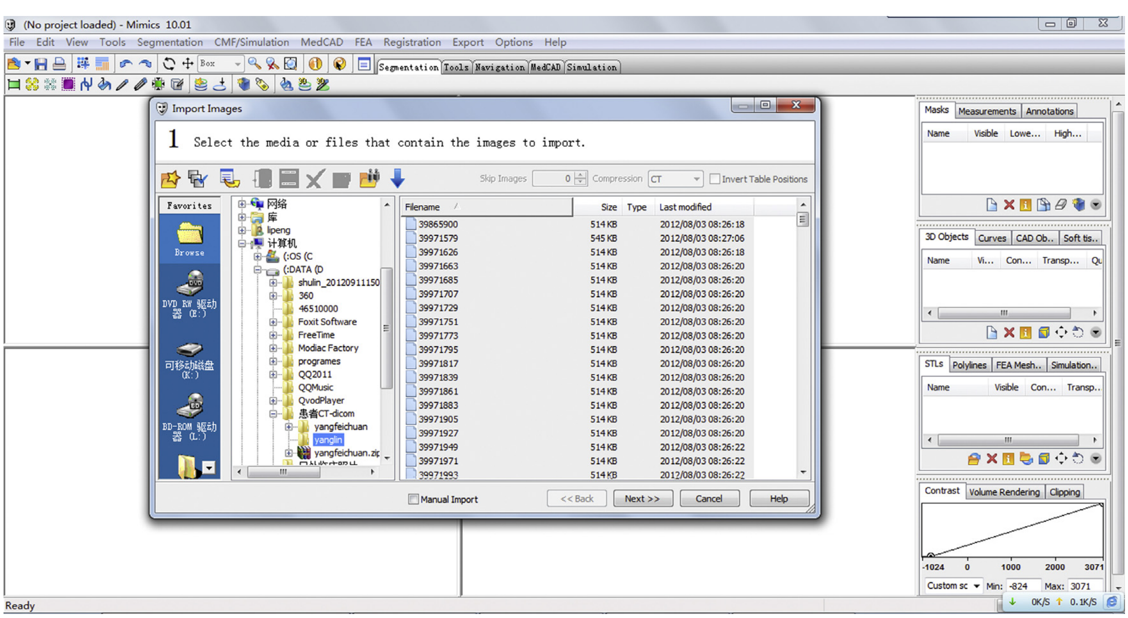

Fig. 1 – All DICOM data were imported into the software package *Mimics 10.0* (Materialize, Leuven, Belgium) in a personal computer system.