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British Journal of Oral and Maxillofacial Surgery 54 (2016) 170–175

BRITISH Journal of Oral and Maxillofacial Surgery

www.bjoms.com

Potential new method of design for reconstruction of complicated mandibular defects: a virtual deformable mandibular model☆

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Accepted 28 November 2015
Available online 20 December 2015

Abstract

The treatment of complicated mandibular defects, including misshaped and missing bones, is challenging, and the success of reconstruction depends to a large extent on the formulation of a precise surgical plan. There is still no ideal preoperative method of design for reconstruction to deal with large, cross-midline, mandibular, segmental defects. We have built a virtual deformable mandibular model (VDMM) with 3-dimensional animation software. Sixteen handles were set on the model, and these could be easily controlled with a computer mouse to change the morphology of the deformable mandibular model. The computed tomographic (CT) data from 10 normal skulls was used to validate the adjustability of the VDMM. According to the positions of the mandibular fossa of the temporomandibular joint, the maxillary dental arch, and the craniomaxillofacial profile, the model could be adjusted to an ideal contour, which was coordinated with the skull. The VDMM was then adjusted further according to the morphology of the original mandible. A 3-dimensional comparison was made between the model of the deformed mandible and the original mandible. Using 16 control handles, the VDMM could be adjusted to a new outline, which was similar in shape to the original mandible. Within 3 mm deviation either way, the absolute mean distribution of deviation between the contour of the deformed model and the original mandible was 92.5%. The VDMM might be useful for preoperative design of reconstruction of complicated mandibular defects.

Keywords: Mandibular defect; Reconstruction; Computer aided design; Deformable mandible model

Introduction

The treatment of complicated mandibular deformities is challenging as,[1] with the development of microsurgical techniques, composite mandibular defects can be repaired with various forms of osteocutaneous free flaps such as fibular or iliac flaps.[2,3] Although many studies have described the authors' personal experiences, it is difficult to achieve optimal aesthetic and functional results, particularly in those cases with large segmental defects of the mandible,[1,4–10] because it is hard to replicate its complex 3-dimensional conformation.

CAD/CAM technology has been used in calvarial bone reconstruction, orbital floor reconstruction, zygomatic reconstruction, and orthognathic surgery,[1,6,11–15] and it has been used to facilitate reconstruction of mandibular segmental defects.[5,9] A standard procedure for preoperative planning uses the mirroring tool for unilateral defects, and reconstructs the defects with its normal counterpart as the reference.[5,9] Various materials and bone grafts have been used to reconstruct mandibular defects with varying degrees of suc-

☆ This study was supported by the national high technology research and development program of China (863 Grogram), (2012AA041606, 2012-2015).

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http://dx.doi.org/10.1016/j.bjoms.2015.11.029
0266-4356/

cess. However, the mirror cannot be used in those patients in whom segmental defects cross the midline.[8] On most occasions, preoperative planning has to be done by digitally manipulating bone segments using personal experience, just as in conventional methods.

In the present study, we describe a new way of replicating the complex 3-dimensional conformation of the mandible. A virtual deformable mandibular model (VDMM) was created using 3-dimensional animation software (Autodesk®, Maya® 2013, San Rafael, CA, USA), and its morphology could be easily changed by adjusting the control handles. Computed tomography (CT) data from 10 human skulls was used to validate its adjustability.

The study was approved by the Institutional Review Board of Peking University School of Stomatology.

Material and methods

Building the VDMM

A skull from the 3-dimensional craniofacial database at the Department of Oral and Maxillofacial Surgery, Peking University School of Stomatology, was selected as the prototype on which to build a standard VDMM. This reference skull was from an adult man with excellent craniofacial proportions, good mandibular bone, no loss of teeth, good dental occlusion, no absorption of alveolar bone, and no bony lesions. Spiral CT data were collected with a 0.75 mm slice thickness, a slice reconstruction interval of 0.75 mm, in a 512 × 512 image matrix. The CT data were imported into the commercial software program ProPlan CMF 1.4 (Materialise, Leuven, Belgium). A thresholding and dynamic region growing tool was used to extract the contour of the mandible without teeth from the CT data. The 3-dimensional digital data of the mandibular model were constructed and saved as an ".stl" file. The digital model file was imported into Maya® 2013 (Autodesk®) to design a VDMM.

The left side of the mandible was mirrored to the right side to build a symmetrical model. The centre plane between the two central incisors and the condyles was considered to be the mirror plane. Using the animation software package of Maya® 2013, basic polygonal primitives were used to create the general shape of the outline of the mandible. Sixteen handles were then set on the VDMM to control its deformation.

Validation of the deformability of the VDMM

CT data from a total of 10 skulls (Samples 1–10 in Table 1[16]) in the 3-dimensional craniofacial database of people with normal occlusion in north China were selected to validate the adjustment ability of the VDMM.[17] All the cases were imported into ProPlan 1.4 to be segmented and reconstructed. The lower jaw was excluded and the residual skull skeleton was imported into the VDMM scene in the Maya® 2013 platform. According to the position of the fossa in the temporomandibular joint (TMJ), the maxillary dental arch, and the craniomaxillofacial profile, the model was adjusted to an ideal outline. Then the original mandibular model was also imported into the scene, and the VDMM was adjusted further to match the original mandibular morphology. The outline of the original mandible was set as the reference object. A 3-dimensional comparison was made between the morphology of the original mandible and the new deformed mandible model using Geomagic Qualify 12 (Geomagic, Cary, NC, USA).

The detailed control process using the VDMM is illustrated with Sample 1 (Table 1[16]).

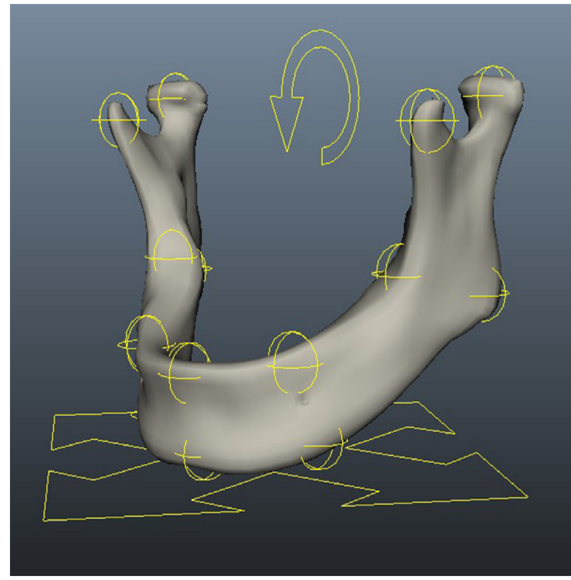

Fig. 1. Virtual deformable mandibular model (VDMM) (grey) and its 16 control handles (yellow).

Results

The VDMM had been built with 16 control handles (Fig. 1), and the contour of the model could be adjusted by moving those handles. The VDMM has the following functions: the whole mandibular model could be translated, rescaled, or rotated; its shape could be adjusted by angle, length, or volume. (Video 1, supplemental digital content 1.) The final adjusted model data could be used in conjunction with other surgical planning software.

We made a preliminary validation of the adjustability of the deformed mandibular model, followed by 3-dimensional comparisons using Geomagic Qualify 12. The contour of the original mandible was set as the reference model and the adjusted deformable mandible model was set as the test model. The mean absolute deviation, within a 3 mm deviation distribution either way, and the maximum and minimum critical values of the 10 skulls (Samples 1–10) are included in Table 1.[16]