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ScienceDirect
British Journal of Oral and Maxillofacial Surgery xxx (2017) xxx–xxx
BRITISH Journal of Oral and Maxillofacial Surgery
www.bjoms.com

Accuracy of maxillary repositioning by computer-aided orthognathic surgery in patients with normal temporomandibular joints

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Accepted 13 February 2017

Abstract

Our aim was to assess the accuracy of computer-aided orthognathic surgery for maxillary repositioning in 15 patients with mandibular hyperplasia and normal temporomandibular joints (TMJ). We aligned preoperative and postoperative virtual skulls at the cranium using surface superimposition then recorded and calibrated three 3-dimensional coordinates (maxillary dental landmarks U0, 6R, and 6L) on the skulls. Errors between these preoperative and postoperative landmarks were calculated and the largest error of every patient was chosen for assessment. Landmark errors ranged from 1.00 – 2.49 mm, and recording errors from −0.06 – 0.07 mm. The superimposition error was mean (SD) 0.036 (0.002) mm. The accuracy of the method is acceptable in patients with a normal TMJ.

Keywords: Computer-aided orthognathic surgery; Accuracy; Maxillary repositioning; Superimposition; Three-dimensional measurement; Bland-Altman method

Introduction

In orthognathic surgery, successful outcomes depend on precise repositioning of the maxilla. Assessment by traditional two-dimensional cephalometry is thought to be inadequate,[1] and reports of its accuracy are inconsistent.[2–8] Computer-aided orthognathic surgery[9–12] allows assessments to be made in three dimensions, and a few authors have reported comparable results,[13–16] but their studies may be questionable because they did not describe the condition of the temporomandibular joint (TMJ).[13–16] They also failed to report statistical data on the superimposition of reference points[14–16]; reported errors only on the three orthogonal planes, which concealed the real 3-dimensional ones,[13–16] or used the wrong statistical methods.[14,16]

We use the technique (Fig. 1) at our centre, and validated the feasibility of point-based superimposition of a digital dental model on a 3-dimensional skull in a previous study.[17] We have now designed a retrospective study to assess the accuracy of maxillary repositioning using computer-aided orthognathic surgery and 3-dimensional measurements.

Material and methods

We studied patients who were treated by one-piece Le Fort I osteotomy and bilateral sagittal split osteotomy (BSSO)

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http://dx.doi.org/10.1016/j.bjoms.2017.02.018
0266-4356/

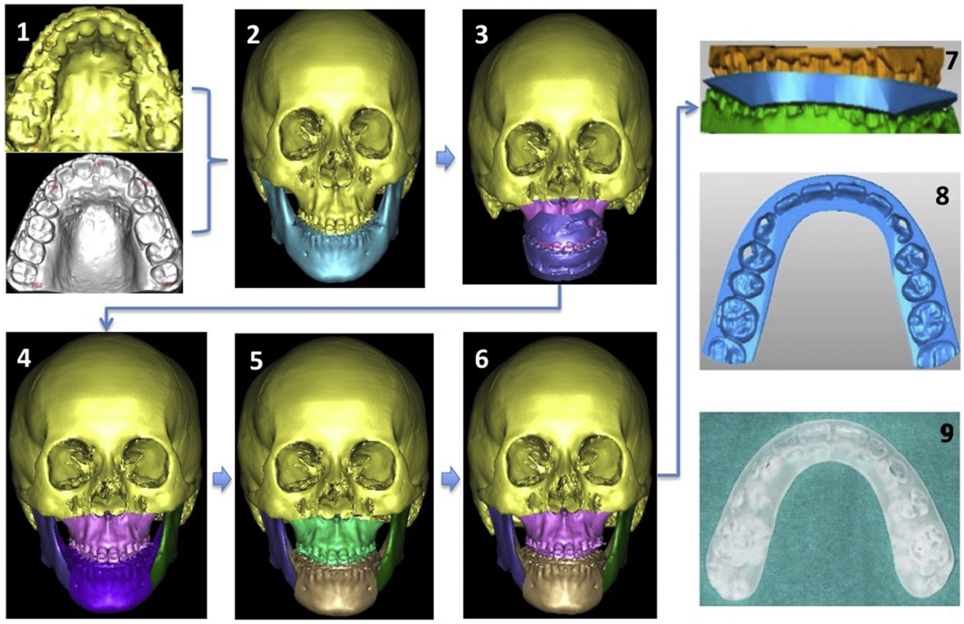

Fig. 1. Workflow of computer-aided orthognathic surgery. 1: the digital dental casts are recorded on the virtual model using point-based superimposition; 2: the compound model clearly shows the facial skeleton and dentition. The orientation of the head is calibrated using the observer's best interpretation; 3: after virtual Le Fort I osteotomy and bilateral sagittal split osteotomy, the final occlusion is shown on the maxilla in the original position; 4: the distal mandible in the final occlusion; 5: the maxillomandibular complex is manoeuvred as a whole into the final position; 6: the intermediate occlusion (based on the original mandible or maxilla) is formed with the repositioned maxilla or mandible depending on whether it is maxilla-first or mandible-first; 7-9: a virtual splint is generated and printed.

with computer-aided orthognathic surgery between January 2014 and September 2015 at the Department of Oral and Craniomaxillofacial Science at The Ninth People's Hospital affiliated to Shanghai Jiaotong University School of Medicine. All the patients had skeletal malocclusion without cleft lip and palate or any other syndrome, and no noise, pain, or limited mandibular movement in the TMJ. They had also had normal internal arrangement of the joint confirmed by magnetic resonance imaging (MRI) before operation. Preoperative stereolithographic virtual plans and data on postoperative computed tomograms (CT) before discharge were available, and patients were operated on by senior surgeons (Drs Wang and Shen) with no complications. The Institutional Review Board of the hospital approved the study.

Patients had a CT (variables: 120 kV, 30 mA, 4000 ms, slices 0.625 mm thick, pixel size 0.5469 mm, 512×512 resolution, and 28×28 cm field of vision; Philips Brilliance 64 CT scanner, Philips Healthcare, DA Best, The Netherlands) from the vault to the hyoid one month before operation. The CT datasets were then imported to SimPlant Pro 11.04 (Materialise Dental, Leuven, Belgium) to create a 3-dimensional model of the head. During the scan patients were required to occlude at their maximal intercuspation. Stone dental casts were taken routinely and scanned with a 0.01mm-resolution laser scanner (Smart optics Activity 880 3D Scanner, Smart Optics Sensortechnik Gmbh, Bochum, Germany) to generate digital casts. After virtual operations, intermediate and final splints were generated digitally (Fig. 1) and printed using a medical-grade, rapid-prototyping machine (ProJet, 3D Systems, Rock Hill, SC, USA). After down-fracture, the maxilla was fixed to the mandible with the intermediate splint. The first assistant then exerted a gentle but stable superior-posterior vector at the chin to reposition the maxilla, and the chief surgeon checked the position of the maxilla and then inserted 2.0 mm titanium mini-plates for internal fixation.

Patients had CT a few days later. On the postoperative 3-dimensional model, the area below the orbit was cut off, leaving only the cranium. On the preoperative model, the area below the orbit and above the osteotomy was cut off, leaving the cranium and the maxilla. These were then transported into 3-matic 8.0 software (Materialise, Leuven, Belgium) for superimposition. The postoperative cranium was set as "fixed", the preoperative cranium was set as "moving", and its maxilla "moving along", which allowed the maxilla to move simultaneously with the cranium if the orientation of the preoperative cranium was changed. The preoperative cranium (moving) was then superimposed on to the postoperative cranium (fixed), and the error recorded. In this way, the orientation of the preoperative maxilla was calibrated and the differences between the preoperative and postoperative maxillas compared (Fig. 2).

We used the 3-dimensional coordinates to digitise the preoperative and postoperative landmarks (Table 1). To record them, we located and checked points on all three orthogonal planes. The postoperative model carried artefacts, so the recording was further calibrated using a maxillary triangle (Fig. 3).