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Original Research

Clinical evaluation of computer-assisted surgical technique in the treatment of comminuted mandibular fractures

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ABSTRACT

Objective: The aim of this study is to establish the advantages and efficiency of computer-assisted surgical (CAS) technique in the treatment of comminuted mandibular fractures compared with conventional technique.
Methods: In the CAS group, 12 patients with comminuted mandibular fractures were treated with computer-assisted technique. Before surgery, a virtual reduction surgery was carried out in the software program MIMICS10.01. Then a reconstructed physical mandible was manufactured for preforming the titanium reconstruction plates. Based on the preoperative planning, the real surgery was carried out. Twelve cases with the same type of fracture treated with conventional technique were reviewed as the part of the control group. The clinical outcome of the surgery was evaluated in the two groups.
Results: Compared with the patients in the control group, in the case of 12 patients in the CAS group a decrease in the operation time and the amount of intraoperative bleeding as well as a superior outcome with respect to satisfaction, mandibular symmetry and postoperative level of opening the mouth were achieved.
Conclusion: The CAS of preoperative 3-D planning and preformed plates is a clinically feasible tool for surgeons to improve the treatment of comminuted mandibular fractures.

1. Introduction

Comminuted mandibular fractures are serious injuries in the maxillofacial area. These fractures would affect the occlusion of the mandible and the appearance of lower regions of the face, which challenge the maxillofacial surgeons. The treatment of these fractures necessitates accurate anatomical reduction and stable fixation of the bony fragments, decreasing the chances of infection, and finally re-establishing the proper occlusion and the appearance of mandible [1–3].

A successful surgery depends on both surgical techniques and accurate plans. With the development of imaging and computer technology in recent years, computer-assisted surgical (CAS) technique became an advanced tool that is being continually developed for different maxillofacial surgeries, especially in orbital reconstruction [4–7]. Many research papers have demonstrated the accuracy of CAS technique, including the three-dimensional (3-D) virtual planning and rapid prototyping. But few of them have performed clinical comparison between the conventional technique and CAS technique for evaluating the cost-effectiveness of the latter. They also had not addressed the question of whether the use of CAS results in better treatment outcomes. The main reason is the complexity of the fracture types; therefore, it is hard to establish two comparable groups with one certain fracture.

So in this article, a comparative study was conducted to establish the clinical advantages and the efficiency of CAS technique

☆ Asian AOMS: Asian Association of Oral and Maxillofacial Surgeons; ASOMP: Asian Society of Oral and Maxillofacial Pathology; JSOP: Japanese Society of Oral Pathology; JSOMS: Japanese Society of Oral and Maxillofacial Surgeons; JSOM: Japanese Society of Oral Medicine; JAMI: Japanese Academy of Maxillofacial Implants.

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compared with conventional techniques for the treatment of comminuted mandibular fractures.

2. Patients and methods

2.1. Patients and data acquisition

Between October 2010 and January 2013, 24 consecutive adult patients with a single comminuted mandibular fracture presenting to the Department of Trauma and Reconstruction Surgery at the West China Stomatology Hospital were included in this study. The single comminuted mandibular fracture was defined as multiple lines of fracture in one region of the mandible; however, there had to be at least one free bony fragment of 1 cm or more in diameter, but without other associated facial bones fractures. The diagnosis was made clinically and radiographically. Due to the extraordinary change of mandibular symmetry, those patients with condylar fractures and other craniofacial anomalies or asymmetries were excluded. In this study, all patients needed the inevitable mandibular reconstruction with titanium reconstruction plates, and were randomly divided into two groups: 12 in the control group who was treated without the CAS technique and 12 in the CAS group.

For preventing operational bias, all these surgeries were performed by the same surgeon (Wei Tang); however, the person responsible for the postoperative measurements was blindfolded regarding the type of the patient. This study was approved by our institutional ethics committee and an informed consent was obtained from each patient.

2.2. Computer-assisted technique in CAS group

All patients in the CAS group had undergone the surgeries with the preoperative 3-D virtual planning and preformed reconstruction plates. The details of the process are described in the sections that follow.

2.2.1. Virtual surgical procedure

The computed tomography (CT) data (slice thickness of 0.5 mm) of the craniofacial area in DICOM (Digital Imaging and Communications in Medicine) format were imported into software MIMICS 10.01 (Materialise, Leuven, Belgium) in a personal computer workstation. The appropriate threshold (in Hounsfield units) that specifies the desired craniofacial skeleton was determined for reconstructing the 3-D model [8]. The next step is the segmentation which needs to be performed manually. It involved outlining the shapes of every fractured bony fragment in all slices and assigning different colors. Then, each fractured fragment became a separate object and can be moved or rotated in all directions for the virtual operation. After achieving normal occlusion and anatomical continuity of the mandible, the 3-D model was exported and saved in STL (Standard Triangle Language) format.

2.2.2. Preforming of the titanium reconstruction plates

A physical model of the reconstructed mandible was manufactured using PLA (polylactice acid) material in our rapid prototyping (RP) machine, with a precision of 0.8 mm. Then according to the fracture characteristics of each patient, one reconstruction titanium plate together with some fixing plates (Synthes, Bettlach, Switzerland) were chosen and bent along the outer surface of the model precisely, bridging the fractured fragments. All these preformed plates were sterilized preoperatively.

2.2.3. Surgical techniques

Under general anesthesia, the fractured areas were fully exposed through an interoral or submetal approach, according to the usual procedure. After fibrous tissues and contaminated hematoma between bony edges were removed, intimate bony contact of all the fragments was obtained as preoperatively simulated planning. As the preformed reconstruction plates were implanted and gradually tightened, the displaced bony segments automatically moved to the planned position. For achieving much more precise reduction, those small fragments were fixed with some small plates or screws after the reconstruction plate was applied.

After surgery, all patients were kept in intermaxillary fixation (IMF) for 1 week and the antibiotics (750 mg of cefuroxime sodium every day, intramuscularly) and analgesics (75 mg of diclofenac sodium every day, intramuscularly) were prescribed for 3–5 days.

2.3. Postoperative evaluation

At 3–6 months after the surgery, another cone beam computed tomography (CBCT) scanning was performed for postoperative evaluation. All these postoperative CBCT data were imported into the MIMICS 10.01 to measure the level of mandibular symmetry (LMS) according to the following formula:

$$\mathrm{LMS} = \frac{\mathrm{VIP}}{\mathrm{VTM}} \times 200\%$$

where VIP is the volume of the intersecting part. Based on the midsagittal plane, the total mandible is divided into two parts. One part is mirrored and superimposed onto the contralateral side for getting the volume of intersecting part. VTM is the volume of the total mandible.

A questionnaire was given to all the patients to know how they felt about the outcome of the surgery. The level of satisfaction with the outcome was acquired from each patient and graded as satisfied, either satisfied or dissatisfied, and dissatisfied. Furthermore, the operation time, amount of intraoperative bleeding and postoperative level of opening the mouth (measured by maximum interincisal opening, MIO) were reviewed and compared between the two groups.

2.4. Statistical analysis

We used the Student *t*-test to check for statistical significance of the quantitative parameters. A *p*-value less than 0.05 was considered to be statistically significant. The statistical analysis was conducted using SPSS11.5 software (SPSS Inc., Chicago, IL, USA).

2.5. Case report

A 44-year-old man who suffered blunt trauma to the mandible in a traffic accident was referred to our department. Radiographical examination revealed the comminuted fracture in the mental region of the mandible (Figs. 1 and 2). Based on the approach of CAS technique, a virtual surgical procedure of mandibular reconstruction was performed in MIMICS 10.01. Before operation, a physical model of the reconstructed mandible was manufactured. Then, one reconstruction titanium plate together with a fixing plate (Synthes, Switzerland) was bent along the outer surface of the model precisely (Fig. 3). During operation, these preformed plates were used according to the preoperative planning (Fig. 4).

3. Results

For 12 patients in the CAS group, all steps of the surgery were identical to the virtual planning procedure, and the preformed reconstruction plates matched the surface of mandible precisely. At 3–6 months after the surgery, the functional and facial reconstructions were successfully achieved. All 12 patients showed complete bone healing without any major complications or requiring further treatment.