Journal of Oral and Maxillofacial Surgery, Medicine, and Pathology xxx (xxxx) xxx–xxx

Contents lists available at ScienceDirect

Journal of Oral and Maxillofacial Surgery, Medicine, and Pathology

journal homepage: www.elsevier.com/locate/jomsmp

Original research

Effect of different miniplate osteosynthesis in different mandibular angle fracture patterns on bite force: A 3D finite element analysis☆

Kazem Khiabani[a], Seied Omid Keyhan[b,c,d,e], Roohollah Razmdideh[a], Zeynab Chaleh Chaleh[f], Mohammad Hosein Amirzade-Iranaq[g,h,*]

[a] Department of Oral and Maxillofacial Surgery, Ahwaz Jundi Shapur University of Medical Sciences, Ahvaz, Iran
[b] Department of Oral & Maxillofacial Surgery, Faculty of Dentistry, Birjand University of Medical Science, Birjand, Iran
[c] Vice Presidential Organization of Technology, Tehran, Iran
[d] Stem Cell & Regenerative Medicine Network, Shahid Beheshti University of Medical Sciences, Tehran, Iran
[e] Cranio Maxillofacial Research Center, Tehran Dental Branch, Islamic Azad University, Tehran, Iran
[f] Private Practice, Tehran, Iran
[g] Universal Network of Interdisciplinary Research in Oral and Maxillofacial Surgery (UNIROMS), Universal Scientific Education and Research Network (USERN), Tehran, Iran
[h] International Otorhinolaryngology Research Association (IORA), Universal Scientific Education and Research Network (USERN), Tehran, Iran

ARTICLE INFO

Keywords:
Bite force
Finite element analysis
Mandibular angle fracture
Miniplate osteosynthesis
Maxillofacial trauma

ABSTRACT

Objective: Bite force can be used as a clinical indicator of masticatory performance. As bite force is reduced with fractures and also, miniplate fixation has become the standard treatment, the aim of this study is to determine the optimal method for mini-plating in the fracture of the mandible angle to reach the best mastication power.
Methods: A three-dimensional model generated from CBCT (Cone-beam computed tomography) of human mandible for Finite Element Analysis. Four different fracture patterns were simulated on the models. Each fracture pattern was fixed by five different methods of miniplate fixation. Each compared to others after simulation and applying the force of the masticatory muscles and result reported in Newton unit.
Results: The highest mastication force belonged to a pattern in which a miniplate was placed on an outer oblique ridge and another miniplate in the lower border of the buccal mandibular cortex. The lowest mastication force also belonged to placing a mini plate on the upper side of the cortex.
Conclusion: Finite Element Analysis is an effective method for indirect measurement of mastication power. In order to biomechanically rebuild optimal mastication force in patients with fracture of the lower angle of the jaw, it is recommended to use two miniplates in two different planes.

1. Introduction

Mandibular bone fracture is very common due to its protrusion and estimated to covering about 23–97% of the entire face fractures [1,2]. The most common causes of mandibular fractures are: motorbike accidents, fall from heights, fights and sports injuries [3,4]. A wide variety of methods are introduced for bone fragments fixation [5–7]. Among these methods the best and the most standard method is internal fixation using miniplates and screws [8–10], which is widely used nowadays [11,12]. In addition to the fact that the use of plates can reduce the mentioned complications, it can also lead to fast patient recovery, reduce hospitalization time, eliminate the need of intermandibular fixation (IMF) and it can help improve the jaw relation [8].

On the other hand the anatomical and biomechanical restrictions in mandible will complicate the use of miniplates on some areas of mandible. These complications include: loose screws [13–15], bent miniplates [16] and in some cases broken plates [17], which is seen in about 20–25% of the patients [18].

Some studies have shown that if the fixation using a miniplate is placed on the superior boarder of the angle of mandible, as suggested by Champy, it may achieve better results and fewer complications comparing to placement of 2 miniplates in the area [19].

Other studies have shown that the use of 2 miniplates in mandibular angle fractures can have better stability and less complications [20,21].

☆ AsianAOMS: 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.

* Corresponding author at: Universal Network of Interdisciplinary Research in Oral and Maxillofacial Surgery (UNIROMS), Universal Scientific Education and Research Network (USERN), Tehran, Iran.
E-mail address: h.amirzade@gmail.com (M.H. Amirzade-Iranaq).

https://doi.org/10.1016/j.ajoms.2018.02.014
Received 13 January 2018; Received in revised form 20 February 2018; Accepted 26 February 2018

On the other hand the studies have shown that the direction, length, shape, favorable or unfavorable fractures will affect the way muscles insert force into fractured area [22].

Efficiency of mastication system and the bite force is documented in different articles [23]. It is also evident that the maximum bite force is known as a parameter and an index for function and efficiency of mastication systems which is easily measurable. This force is created during the dynamic activity of mastication system during its physiological function and it is an important parameter in assessing the masticatory system's health [23].

Meanwhile the direct evaluation of bite force on the patient is not practical and/or is ethically not acceptable. As result of the mandibular fracture, trauma to muscles of mastication and neurovascular protective system, and also psychological factors during the operation, it is probable that the patient is unable to apply the maximum muscle force required for recording the bite force [24–27].

The Finite Element Analysis (FEA) method, is one of the invented methods for achieving the answers to biomechanical questions. This method was first used in Aerospace industry, but it quickly spread through all sciences including biological and health sciences [28]. This method has proved its efficiency in wide range of sciences including medicine and dentistry. Today, this method is used in all sciences and industries to solve may complex problems and provide the possibility to study the details of many issues and complications [28].

Due to this contraversy on using one or two miniplates and placing it on the fractured area [29] and also due to shortcoming of previous studies, we aim to evaluate the bite force of different mandibular angle fracture patterns with several miniplate osteosynthesis using finite element analysis method. The result of this study leads to choosing the best osteosynthesis method in different mandibular angle fractures pattern in terms of returning the bite force close to its normal state and also accelerating the healing process and reduction of the postoperative complications.

2. Materials and methods

2.1. Mandibular arch model generation

The CBCT imaging (NewTom VGi, QR S.r.I; Verona, Italy) achieved from the mandibular arch of the patients referring to Department of Oral and Maxillofacial Surgery, Ahwaz Jundi Shapur University of Medical Sciences, Ahvaz, Iran. All images had axial section with 0.3 mm thickness, 0.3% spaced and 512 × 512 pixel. One random CBCT image with the following criteria was selected: having a normal occlusion, absence of craniofacial abnormalities and pathologic lesions, absence of history of trauma, absence of wisdom tooth in the area and age between 20 and 30 years [30].

The chosen sample had 419 sections. The images were saved in 419 different files with the file format of DICOM. Then the files were transferred to Mimics Ver. 16.0 software (Materialise b.v, Leuven, Belgium). Construction of all 3 planes of axial, coronal and sagittal were manually done to increase the accuracy of the models. Images were classified and therefore the separation of the cortical bone, spongy bone and the teeth were done. The teeth were considered to be attached to the cortical bone. After placing the pieces together the model was renovated with STL file format. The completed model of the mandibular arch was given to a 3-Matic Ver 6.0 software (Materialise b.v, Leuven, Belgium) to construct the 3D geometric solid surfaces.

2.2. Screws and miniplate model generation

Modeling the screws and the miniplates, creating a bone cuts, assembling screws and miniplates on the cutted model and replacing the other parts of the model on to each others were done with SolidWorks-CAD 2012 software (Dassault Systems ©, Solid Works Crop. Canada).

In this study the screws and miniplates manufactured by SYNTHES (Synthes GmbH Eimattstrasse CH-4436, Oberdorf, Switzerland) were used as a sample. Straight 4-wholed Plates with bar, with 1.25 mm diameter and the length of 28 mm and screws with the diameter of 2 mm and the length of 8 mm were modeled (Fig. 1).

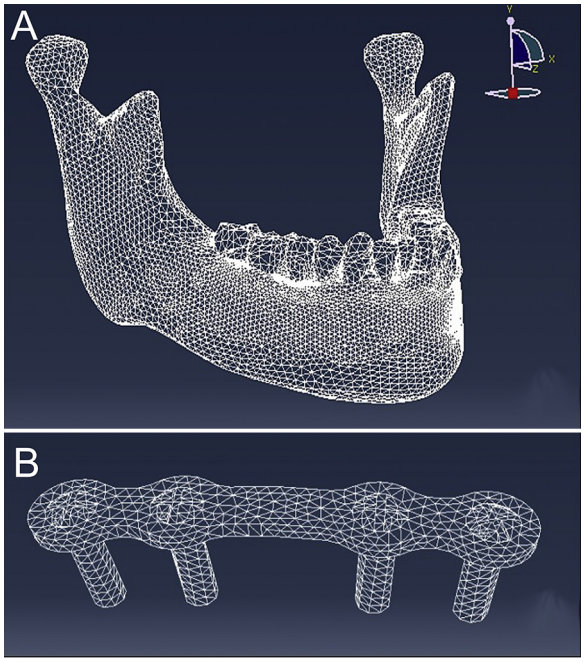

Fig. 1. Meshing of simulated model of mandible (a) and miniplate with screws (b).

2.3. Various fractures and miniplate placement simulation

Various type of bone fractures (4 types including horizontal favorable and unfavorable and vertical favorable and unfavorable) and plate placements (5 types) summing up to 20 different models, were simulated by 3-mastic Ver 6.0 modeling software (Materialise b.v, Leuven, Belgium) (Fig. 2).

To create a favorable and unfavorable horizontal fracture, the osteotomy lines were made at an angle of 20° clockwise and 20° counterclockwise in sagittal plane. Also, to create a favorable and unfavorable fracture form in vertical dimension, the fracture lines were made at an angle of 20° clockwise and 20° counterclockwise compared to a line perpendicular to buccal cortex in axial plane. The distance between the separated pieces were considered to be a tenth of a millimeter.

Then the different miniplate osteosynthesis placement patterns were applied on the 3D models (Fig. 3).

These patterns are as follow:

- **Pattern I**: One miniplate placed on external oblique ridge.
- **Pattern II**: One miniplate placed on superior border of lateral cortex [19].
- **Pattern III**: One miniplate placed on external oblique ridge and 1 miniplate on superior border of lateral cortex [31].
- **Pattern IV**: One miniplate placed on external oblique ridge and 1 miniplate on inferior border of lateral cortex.
- **Pattern V**: One miniplate placed on the superior border of lateral cortex and 1 miniplate on inferior border of lateral cortex [32].

Each miniplate was fixed mono-cortically in close contact with the bone on both sides of the fracture line using 4 screws. To rebuild the masticatory force we used Abaqus version 6.12 software (Dassault Systems ©, Solid Works Crop. Canada), in which the superior part of the condyle on both sides were kept fixed and only rotational