Journal of Cranio-Maxillo-Facial Surgery 42 (2014) 397–402

Contents lists available at SciVerse ScienceDirect

Journal of Cranio-Maxillo-Facial Surgery

journal homepage: www.jcmfs.com

3-D analysis of dislocation in zygoma fractures

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ARTICLE INFO

Article history:
Paper received 18 May 2012
Accepted 3 June 2013

Keywords:
Zygoma
Fracture
Analysis
Evaluation
Reposition
Diagnosis

ABSTRACT

Objective: When fractured, zygomas rotate and dislocate. The present study quantitatively elucidates the pattern of the rotation.
Methods: 50 patients with tri-pod-type zygoma fractures were involved in this study. After defining a 3-dimensional coordinate system – consisting of the M–L axis (the axis directed from the medial to lateral side of the skull), I–S axis (directed from the inferior to superior side), and P–A axis (directed from the posterior to anterior side), the degree with which the fractured zygomas rotated around each of these axes was measured using 3-dimensional graphic software. Thereafter, the tendency of the rotation was compared between the three rotational axes.
Results: Rotation around the I–S axis was the most frequent with a 96% incidence, followed by a substantial margin by rotation around the M–L axis with a 26% incidence; rotation around the P–A axis was rare, with an incidence of 10%. Furthermore, the degree of P–A axis rotation was minor compared to I–S and M–L axis rotations.
Conclusion: The main factor of zygoma dislocation in zygoma fracture is rotation around the I–S axis. This finding is helpful for effective performance to reposition fractured zygomas.

1. Introduction

Zygoma fractures – one of the most common facial fractures – can result from situations such as traffic accidents, interpersonal violence, and athletic activities (Antoun and Lee, 2008; Bogusiak and Arkuszewski, 2010; Chrcanovic et al., 2010; Calderoni et al., 2011; Yamamoto et al., 2011; Naveen Shankar et al., 2012; Karabekir et al., 2012). Asymmetry of the malar region, limitation of mouth opening and closure, double vision, and numbness of the upper lip are common complaints following zygoma fracture (Feng et al., 2011; Hwang and Kim, 2011; Singh et al., 2011). For cases that present with these complaints, surgical intervention is performed.

The basic principle of surgical treatment for zygoma fracture is to return the fractured bone to its initial position and fix the returned bone at the correct position. In order to achieve optimal outcomes through this treatment, the direction and degree of dislocation of the zygoma should be evaluated prior to operation.

Although numerous studies (Nagasao et al., 2007, 2009; Hwang, 2010; Kurita et al., 2010; Olate et al., 2010) regarding surgical approaches and fixation methods for zygoma fracture have been published, few studies have been conducted that quantitatively analyse the degree of displacement the zygoma presents due to fracture. This study performs three-dimensional analyses of the parallel and rotational displacements fractured zygomas present. Evaluation of the results clarifies the patterns by which fractured zygomas tend to dislocate.

2. Materials and methods

2.1. Examinees

Among patients who received treatment for zygoma fractures at Keio University Hospital from 2004 to 2009, those for whom tri-pod type fractures had occurred, for whom preoperative computer-tomography data were available, and for whom consent to participate in this study was obtained were included. 50 patients (36 males and 14 females) met all three conditions. All of these patients were included in this study.

The ages for males and females were 38.2 ± 8.4 SD y/o and 43.9 ± 7.5 SD y/o, respectively. The causes of the fractures were

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http://dx.doi.org/10.1016/j.jcms.2013.06.003

accidental fall (18 cases), traffic accident (16 cases), athletic activities (10 cases), interpersonal violence (5 cases), and suicide attempt (1 case). The morphological data of these patients' facial bones were obtained by performing computer-tomography in 0.5 mm slices. The data obtained were transformed into Digital Imaging and Communication Medicine (DICOM) format to be used in the following processes.

2.2. Measurement

Each patient's DICOM data were transferred to a workstation (FMV Deskpower, Fujitsu Co., Tokyo), whereby the data were visualized and operated on using three-dimensional computer-aided simulation software (Mimics13, produced by Materialise Co., Leuven, Belgium). First, each patient's skull image was placed so that the medial–lateral (**M**–**L**), posterior–anterior (**P**–**A**), and inferior–superior (**I**–**S**) axes of the skull matched the x-, y-, and z-axes of the three-dimensional coordinate system of the software (Fig. 1). The planes formed by (M–L)–(P–A) axes, (M–L)–(I–S) axes, and (P–A)–(I–S) axes, respectively, correspond to the axial, coronal, and saggital planes of the CT data.

Thereafter, the degree of parallel and rotational displacement of the fractured zygomas was quantitatively evaluated through the following two steps.

First, parallel displacement was evaluated. Fractured zygomas were virtually repositioned by being shifted parallel in the virtual space of the software, so that fractured edges of the frontal process reached their original positions (meaning the counterpart edge of the frontal process of the frontal bone) (Fig. 2 **Left Above** to **Right Above**). With each zygoma, distances by which the displaced zygoma were shifted to reach the frontal process were measured along the M–L, I–S, and P–A axes. Referring to the measured values, the degree of the initial parallel displacement was evaluated. Positive values were given for displacements in medial, inferior, and posterior directions. For instance, when a fractured zygoma was shifted in the medial direction by 2 mm to reach the fractured edge of the frontal process, the initial coordinate value of the zygoma along the M–L axis was evaluated to be zero minus two mm. Hence, the degree of the initial displacement for along the M–L axis is evaluated as −2 mm. In this manner, the degree of parallel displacement was evaluated along the M–L, I–S, and P–A axes for each fractured zygoma.

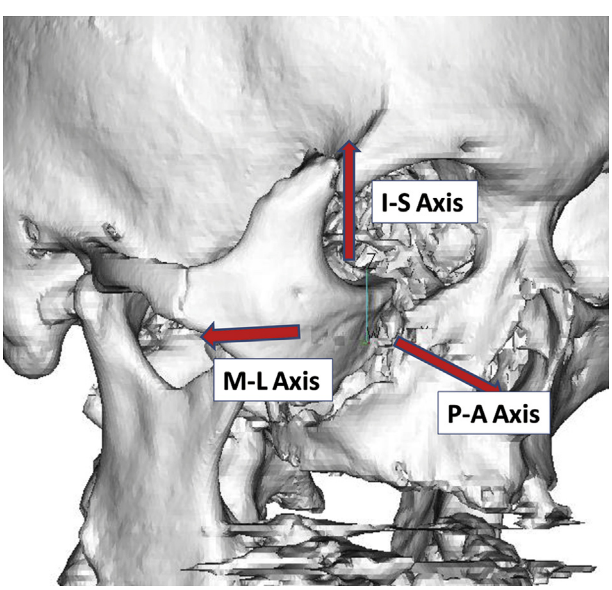

Fig. 1. Each patient's skull was fixed in the 3-D coordinate system so that the M–L (Medial–Lateral), I–S (Inferior–Superior), and P–A (Posterior–Anterior) axes matched the x-, y-, and z-axes, respectively.

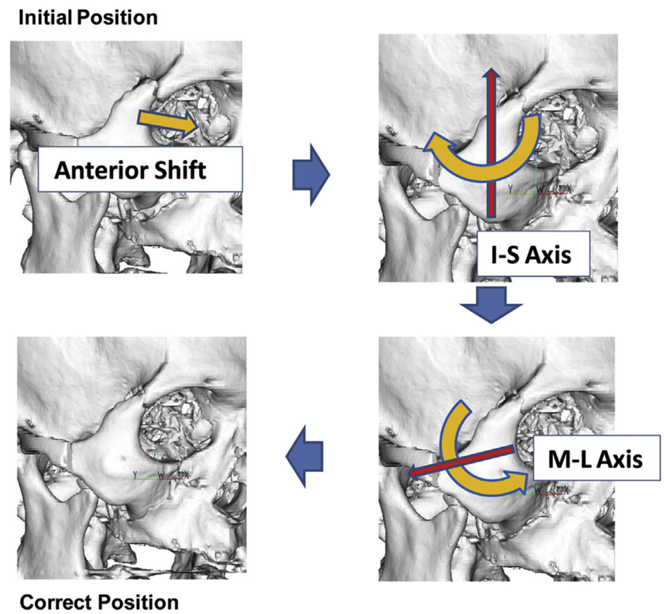

Fig. 2. An example of virtual repositioning. This displaced zygoma was repositioned to its correct position by first being shifted parallel in the anterior direction (from **Left Above** to **Right Above**), then by being rotated anticlockwise around the I–S axis (from **Right Above** to **Right Below**) and clockwise around the M–L axis (from **Right Below** to **Left Below**).

After shifting the zygomas parallel to these axes to match the frontal process, fractured zygomas were rotated around the three axes to return them to their correct positions. For each patient, respective angles required to rotate the zygoma to its correct position were measured around the M–L, I–S, and P–A axes (Fig. 2 **Right Above**, **Right Below** and **Left Below**).

In measuring the rotation angles, attention was paid to the direction of the rotation. With the M–L axis, each zygoma's rotation was classified as clockwise or anticlockwise viewing from the medial to the lateral sides of the skull (Fig. 3. To clarify from what viewpoint the rotation is evaluated, the direction of the view is indicated by an "eye" in the figures. The same is true for Figs. 4 and 5); with the P–A axis, the clockwise/anticlockwise classification was made viewing from the posterior to anterior sides (Fig. 4); with the I–S axis, the classification was made viewing from the inferior to superior sides (Fig. 5).

A zygoma rotates from its correct position due to fracture by distances and angles of the same sizes and opposite directions as it will move when returned to its correct position. For instance, assume a situation in which a fractured zygoma is rotated by 10 degrees clockwise around the M–L axis, 5 degrees anticlockwise around the P–A axis, and 8 degrees clockwise around the I–S axis. In this situation, the rotation pattern of the zygoma is evaluated as "10 degrees *anticlockwise* around the M–L axis, 5 degrees *clockwise* around the P–A axis, and 8 degrees *anticlockwise* around the I–S axis."

By means of the above-stated methods, the directions and angles of rotation due to dislocation by fracture were measured for each fractured zygoma.

2.3. Evaluation

The degree of parallel and rotational displacement was evaluated in the following fashion.