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Reliability of Ultrasound-Guided One-Point Fixation for Zygomaticomaxillary Complex Fractures

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Abstract: This study aimed to analyze the precision and postoperative stability of ultrasound guided 1-point fixation on the zygomaticomaxillary buttress for the treatment of zygomaticomaxillary complex (ZMC) fractures. The authors analyzed 24 consecutive patients who underwent ultrasound-guided 1-point fixation for ZMC fractures without separation of the fracture at the frontal process of the zygomatic bone. The authors used titanium plates in the first 6 cases, and biodegradable plates in the remaining 18 cases. The authors obtained computed tomography images preoperatively, and again the first day after surgery (T1) and 6 months after the surgery (T2). The authors calculated vertical change (VC) and horizontal change (HC) of the zygoma on computed tomography. Precision was evaluated with T1 images. Stability was evaluated from T1 to T2, and titanium and biodegradable plates were compared. From T1 images, the mean VC and HC was 0.22° (range, 1.60°–1.08°) and 0.33° (range, 1.86°–1.03°), respectively. From T1 to T2, the mean VC and HC was 0.08° and 0.28°, respectively. Comparing the types of plates, the mean HC in the biodegradable plate group was 0.39°, which was significantly greater than that in the titanium plate group (mean −0.10°). However, as the degree of change was relatively small, this did not pose any clinical problems. Our findings suggest that ultrasound-guided 1-point fixation on the zygomaticomaxillary buttress provides accurate reduction on ZMC fractures without the separation of the frontal process of the zygomatic bone fracture. Sufficient stability was obtained, even with the use of biodegradable plates.

Key Words: Biodegradable plate, malar fracture, 1-point fixation, ultrasound, zygomaticomaxillary complex fractures

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Former treatments for zygomaticomaxillary complex (ZMC) fractures included Kirschner wire fixation and osseointegration wiring.[1] However, the stability of these treatments was insufficient. In recent times, open reduction and multiple-plate fixation techniques are recommended to avoid facial deformity caused by delayed bone displacement.[2] However, multiple-plate fixation requires a longer incision and larger periosteum stripping area. Such procedures may contribute to associated morbidities, such as prolonged postoperative swelling, induration, unfavorable scarring, and deformities of the lower eyelid.[3] Therefore, the use of a minimum number of plates to achieve zygomatic stability is preferred to reduce incisions and to avoid postoperative deformities. In addition, the use of a biodegradable plate eliminates the need for plate removal, making therapy less invasive.

Recently, several studies have reported less-invasive treatments for simple ZMC fractures.[4–9] Soejima et al[6] described a semiclosed reduction and 1-plate fixation with a transmalar Kirschner wire to treat simple tripod fractures. Hwang[7] performed 1-point fixation of ZMC fractures through a lateral brow incision. Uda et al[9] reported a closed reduction and internal fixation method that used a cannulated cortical screw system. Despite these reports, there has been little mention of the biomechanical basis for applying less-invasive treatments and the time-dependent postoperative dislocation of the zygoma to assess the stability of fixation.

We have developed a minimally invasive surgical protocol based on anatomical and biomechanical considerations. We perform ultrasound-guided zygoma reduction only with the maxillary vestibular approach and fix the plate on the zygomaticomaxillary buttress (ZMB) for selected patients. In this study, we evaluated ultrasound-guided reduction accuracy and the stability of 1-point biodegradable plate fixation on the ZMB as a treatment for ZMC fractures.

METHODS

Of 135 ZMC fracture patients who visited the plastic surgery clinic at Tohoku University Hospital between 2008 and 2015, we applied ultrasound-guided 1-point fixation to 24 patients in accordance with our ZMC fracture treatment protocol. Our protocol is shown in Figure 1. In the protocol, we check whether the fracture at the frontal process of the zygomatic bone (FZ) is separated or not using preoperative computed tomography images (CT). When the FZ fracture is separated longitudinally by less than 2 mm or not dislocated at all, we check for ocular problems related to the orbital fracture. When we do not detect any ocular problems, we apply the 1-point fixation procedure to the patient. We obtained CT images after surgery and evaluated ultrasound-guided reduction accuracy and the stability of this treatment.

Patient profiles are shown in Table 1. The mean age of the 24 patients (11 men; 13 women) was 38.3 years (range, 13–89 years). The right side was affected in 6 patients and the left in 18. Among them, 15 cases (62.5%) were type III, 4 cases (16.7%) were type IV, and 5 cases (20.8%) were type V according to Knight and North classification.[10]

This study complied with all provisions of the Declaration of Helsinki and its current amendments and was approved by The Institutional Human Research Ethics Board of Tohoku University Hospital (permission number: 2015-1-801). Written informed consent was obtained from all patients for their participation in this study.

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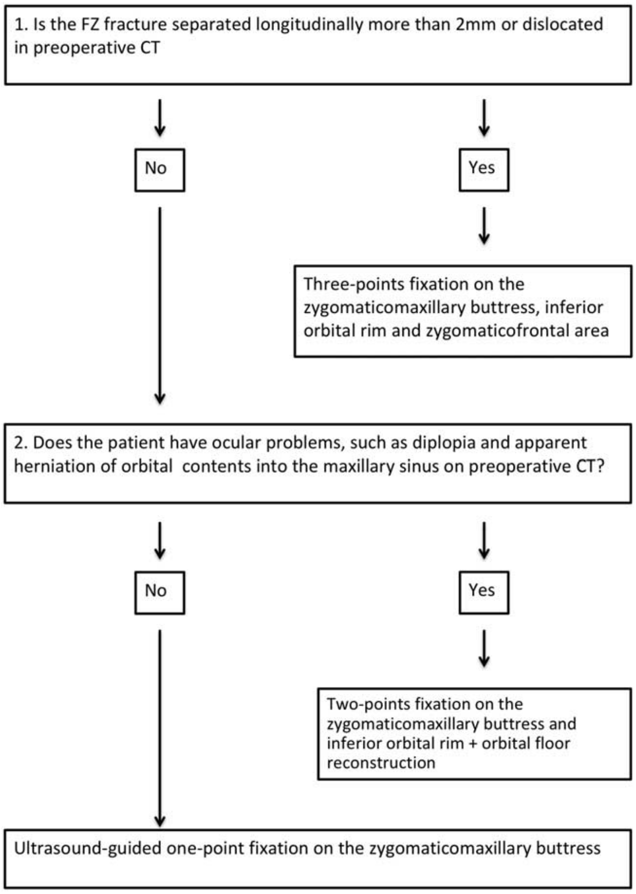

FIGURE 1. Our treatment protocol for zygomaticomaxillary complex fractures. CT, computed tomography; FZ, frontal process of the zygomatic bone.

SURGICAL PROCEDURE

With the patient under general anesthesia, the ZMB was exposed using a maxillary vestibular approach (Fig. 2A). An elevator was inserted in the temporal fossa. Traction was applied until the ZMB was aligned under direct visualization. At the same time, we confirmed the inferior orbital rim and zygomatic arch alignment using ultrasound (Fig. 3). After adequate reduction, osteosynthesis was performed. We used a 2.0-mm titanium plate (Mini-Plate, Leibinger, Stryker, Japan) until 2012, and a 1.4-mm biodegradable plate (Super FIXSORB-MX, TAKIRON, Japan) was used thereafter (Fig. 2B).

TABLE 1. Characteristics of Patients Who Underwent 1-Point Fixation on the Zygomaticomaxillary Buttress

	Values
Age, (yr)	13–89 (average, 38.3)
Sex (male: female)	11:13
Knight and North classification	
Type III	15
Type IV	4
Type V	5
Type of plate	
Titanium plate	6
Biodegradable plate	18
Period from injury to operation (d)	0–21 (average, 8.08)

ZMB, zygomaticomaxillary buttress.

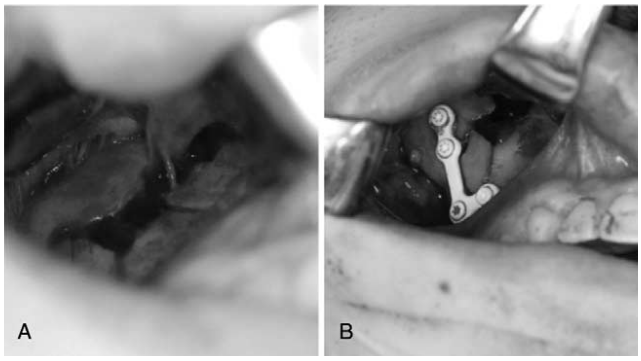

FIGURE 2. Operative technique using a maxillary vestibular approach and 1-point fixation. The elevator is placed under the zygomatic body to reduce it (A). After reduction, the zygomaticomaxillary buttress is stabilized using plate fixation (B).

POSTOPERATIVE ASSESSMENT

Three-dimensional CT (3D CT) images were obtained for all patients the first day after surgery (T1) for the assessment of the accuracy of zygomare positioning under ultrasound guidance. In 12 cases (titanium plate: 5 cases, biodegradable plate: 7 cases), CT images were obtained 6 months after surgery (T2) to assess the stability of 1-point fixation of the zygoma and reliability of the biodegradable plate. Postoperative relapse was calculated as changes from T1 to T2.

Considering the effect of the masseter muscle, measurements of 2 orthogonal aspects, vertical change (VC), and horizontal change (HC) of the zygoma were obtained to evaluate postoperative

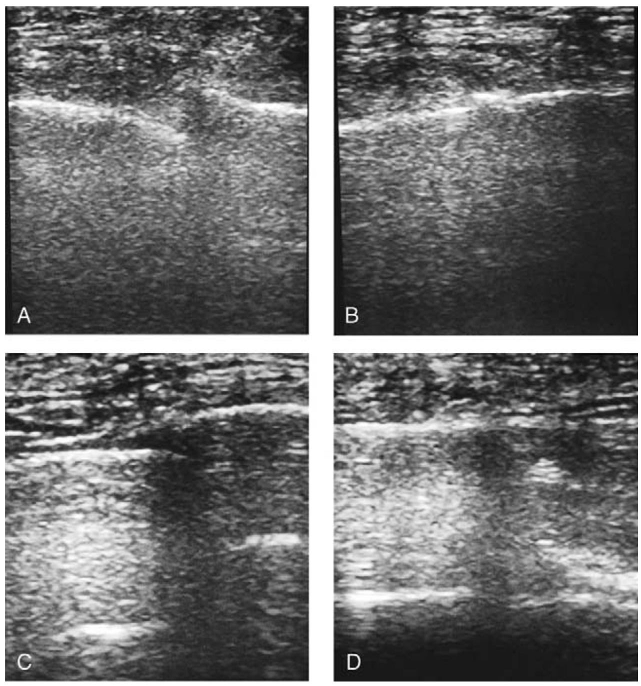

FIGURE 3. Ultrasound images before and after reduction. Ultrasound images of the inferior orbital rim before reduction (A) and after reduction (B), and the zygomatic arch before reduction (C) and after reduction (D).

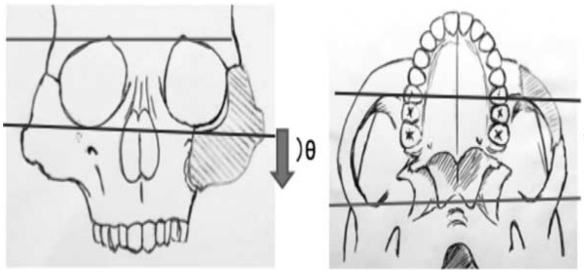

FIGURE 4. Orthogonal measurements in postoperative 3-dimensional computed tomography. Left: the movement of the bilateral infraorbital rim line represents the vertical change. Right: the movement of the bilateral anterior margin of the fossa temporalis line represents the horizontal change.

zygomatic movement (Fig. 4). Vertical change is the movement of the bilateral infraorbital rim line. Horizontal change is the movement of the bilateral anterior margin of the fossa temporalis line. These measurements were obtained from the image using the public domain software ImageJ.[11–13] A Wilcoxon signed rank of 0.05 was considered statistically significant. Postoperative complications were also recorded in each case.

RESULTS

Of 24 patients, the first 6 patients (25%) were treated with a titanium plate for ZMB fracture fixation. A biodegradable plate was used in the remaining 18 patients (75%). Surgery was performed within 0 to 21 days (mean, 8.08 days) after trauma (Table 1). On postoperative reduction assessment, all fractures were reduced within 2°. The mean VC and HC was −0.22° (range, −1.60° to 1.08°) and −0.33° (range, −1.86° to 1.03°), respectively (Table 2).

Regarding relapse, displacement of the zygoma was within 1° in both groups. The mean VC and HC was −0.08° (range, 0° to −0.23°) and −0.28° (range, 0 to −0.58°), respectively. In comparison, displacement of HC in the biodegradable plate group was significantly greater than that in the titanium plate group ($P > 0.05$) (Table 3).

Postoperative radiographic findings did not reveal any newly developed defects of the orbital floor or herniation of ocular contents into the maxillary sinus in any patient. The orbital floor was restored, as the zygoma was repositioned at the anatomical position and was properly remodeled. No ocular problems occurred, and there were no cases of enophthalmos greater than 2 mm. Major complications such as plate infection, trigeminal nerve injury, scleral show, sinusitis, diplopia, and distinct enophthalmos did not occur.

TABLE 2. Analysis of Postoperative Changes in Zygoma Movement According to Three-Dimensional Computed Tomographic Findings*

Measurements	Mean	SD	95% CI	P
Vertical change				
T1	−0.22	0.59	−0.44 to 0.00	0.58
T2	−0.13	0.41	−0.65 to 0.02	
Horizontal change				
T1	−0.33	0.57	−0.57 to −0.10	0.16
T2	−0.65	0.63	−1.01 to −0.29	

CI, confidence interval; SD, standard deviation; T1, a few days after surgery; T2, half a year after surgery.

*All values other than *P* values are presented as mean (SD) and are reported in degrees.

TABLE 3. Comparison Between the Titanium Plate Group and the Biodegradable Plate Group

Measurements	Mean	SD	95% CI	P
Vertical change (T2–T1)				
Titanium plate group	−0.03	0.05	−0.10 to 0.05	0.20
Biodegradable plate group	−0.11	0.10	−0.20 to −0.02	
Horizontal change (T2–T1)				
Titanium plate group	−0.10	0.20	−0.41 to 0.21	0.045*
Biodegradable plate group	−0.39	0.18	−0.55 to −0.22	

All values other than P values are presented as mean (SD) and are reported in degrees.

CI, confidence interval; SD, standard deviation; T1, a few days after surgery; T2, half a year after surgery.

*Statistically significant difference.

REPRESENTATIVE PATIENT

A 40-year-old man sustained a left ZMC fracture in a traffic accident (Fig. 5). He presented with left cheek depression and infraorbital hypoesthesia without ocular problems. Preoperative CT showed inward and backward displacement of the left zygoma without separation of the FZ suture. We performed ultrasound-guided zygoma reduction using the maxillary vestibular approach and fixed the biodegradable plate on the ZMB. Six months after surgery, the postoperative photograph and three-dimensional CT show good contour and favorable malar alignment.

DISCUSSION

Recently, several studies have reported minimally invasive treatment for ZMC fractures. However, the criteria for these procedures are inconsistent and controversial.[14] It is widely accepted that

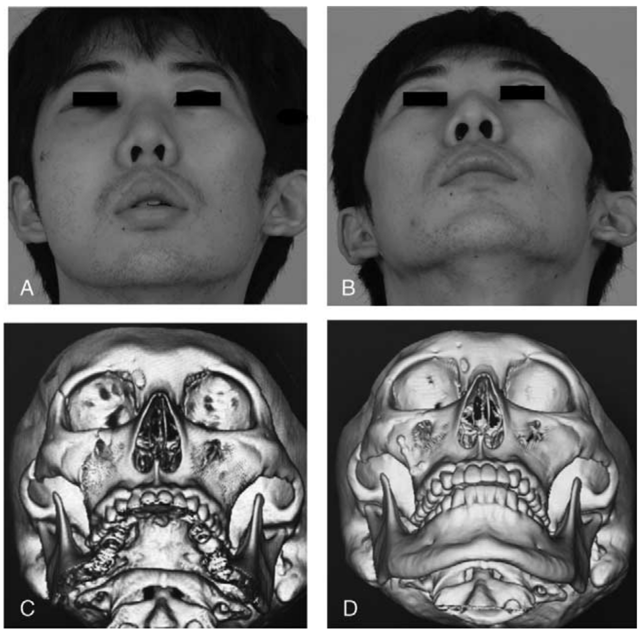

FIGURE 5. Representative case. The preoperative photograph shows a depressed right malar deformity (A) and the preoperative 3-dimensional computed tomogram (3D CT) reveals a comminuted fracture of the zygomaticomaxillary buttress and inferior orbital rim without the zygomatic frontal suture shearing (C). The postoperative photograph (B) and the postoperative 3D CT (D) show good contour and favorable malar alignment after 1-point fixation at the zygomaticomaxillary buttress.

stability of the FZ suture is very important for zygomatic segment stability,[15–19] as it can longitudinally resist the traction of the masseter muscle. In addition, the temporal fascia must be attached securely to the side of the FZ area to resist the traction from the masseter muscle.[20] Considering these findings, the FZ fracture should be stable if the attached temporal fascia is not torn at the fracture site. In these cases, we presume that we do not need to fix the FZ fracture. In our protocol, we check whether the FZ fracture is separated or notusing preoperative CT. When the FZ fracture is separated longitudinally by more than 2 mm or dislocated, we presume that the temporal fascia is torn. However, when the FZ fracture is separated by less than 2 mm, the temporal fascia should be intact. We consider that we can apply a 1-point fixation safely to these patients. In this study, we have proven that our protocol is feasible.

Davidson et al[16] and Reinhart et al[17] reported that in their in vitro studies, 1-point fixations of the ZMB resulted in an unstable fixation. However, these findings were based on cadaveric studies in which very heavy loading on the fragments was selected. In contrast, the mastication force should be decreased for several weeks after injury because of the direct muscle damage. Tarabichi[4] reported successful results with 1-point fixation and indicated that in vitro studies are misleading as the effects of the periosteum and superficial musculoaponeurotic system are not considered. Fujioka et al[5] reported that there were no significant differences in the postsurgical movement of zygoma between the 1-plate fixation group and multiple-plate fixation group, when the fracture was not comminuted and 3-point alignment (Orbital rim, FZ, ZMB) was achieved. From our result, the change in zygomatic location 6 months postoperatively was within 1°. These findings suggest that 1-plate fixation at the ZMB was sufficient to resist the traction of the masseter muscle when the FZ was not separated on the preoperative CT. If stability of the zygoma after reduction can be obtained using 1-plate fixation with a biodegradable plate, this treatment method could be the least invasive treatment for ZMC fractures.

Former biomechanical studies have shown less strength with the biodegradable plate system.[21] However, in some cases, the biodegradable plate system appears to provide adequate strength to resist the deforming forces of the masticatory muscles.[22–24] Kim et al[8] reported that 1-point fixation at the ZMB using a biodegradable plate provided sufficient stability in ZMC fractures without comminuted fractures of the lateral orbital rim. However, the postoperative stability of the zygoma has not been studied. We compared findings of postoperative CT the first day after surgery with 6 months after surgery, which enabled more precise assessment of the stability of 1-point fixation with a biodegradable plate. Our study revealed that postoperative relapse was found only in the posterior direction in the biodegradable group compared with that in the titanium plate group, and that it was negligible and did not pose any clinical problem. The advantage of this method is that soft-tissue damage is avoided, such as postoperative lower eyelid ectropion, and it maintains the bone-healing potential by preserving the periosteum of the fractured site.[25,26] While the Hwang method leaves scars on the face, our method is cosmetically superior because it only cuts the oral mucosa.

Cutaneous ultrasonography is very useful for the accurate assessment of reduction.[6] We used ultrasonography to evaluate the alignment of the inferior orbital rim, FZ suture, and zygomatic arch. When the remaining displacement is identified by ultrasonography, a repositioning instrument can be accurately positioned beneath the bone fragments and applied to restore the correct anatomical position using ultrasonographic guidance. In our study, we could reduce the zygoma within 2°, so we suggest that accurate reduction was obtained using ultrasonographic guidance. Major complications such as ocular problems, delayed postoperative foreign-body reactions, and broken plates did not occur in any case.

Ellis and Reddy[27] reported minimal (or no) soft-tissue herniation and minimal disruption of the internal orbit on preoperative CT, suggesting zygoma reduction alone without orbit intervention is an adequate treatment. Uda et al[9] reported that if the periosteum of the orbital floor is not removed from the bone segments, these fragments can be well repositioned by retracting the continuous periosteum by reduction of the zygoma. In addition, the "eggshell membrane phenomenon" could also be seen in other regions, such as at the inferior orbital rim fragment. In our study, fracture of the orbital floor was well repositioned in postoperative CT in all cases.

At present, various biodegradable plates made of various materials have been developed and clinically applied. It is not clear in this study whether the same results are obtained even when using other plates, because the strength varies according to the material of the plate.

In conclusion, our findings suggest that ultrasound-guided 1-point fixation using a biodegradable plate on the ZMB provides accurate reduction and sufficient stability of ZMC fractures without separation of the FZ suture in preoperative CT. This treatment method could be the least invasive treatment for ZMC fractures.

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