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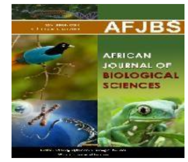

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Three-Dimensional Evaluation of Malar Eminence Position After Management of Zygomaticomaxillary Complex Fractures Using 2-Point Fixation

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Abstract: Aim: The objectives of this study were to evaluate malar eminence three-dimensional position after managing unilateral zygomaticomaxillary complex fracture using the two-point fixation technique. **Methods and Material:** This study was conducted on 20 patients with unilateral Zygomaticomaxillary complex (ZMC) fractures managed by a two-point fixation technique. The zygomaticomaxillary (ZM) buttress was used as a key point of fixation through an intra-oral approach for all patients and either the infraorbital rim (IOR) or the frontozygomatic (FZ) suture area was used as a second point of fixation. The three-dimensional malar eminence position was evaluated by preoperative and postoperative radiographic assessment of malar height, width, and projection in the fracture and the normal sides. **Results:** The difference between preoperative and 1-week, 1-month postoperative malar width and malar projection was highly significant, while the malar height difference wasn't significant. **Conclusions:** Proper malar position and adequate aesthetic outcomes can be obtained using the 2-point fixation technique to manage ZMC fractures..

Keywords: *zygomaticomaxillary complex fracture, zygomatic buttress, two-point fixation, maxillofacial trauma, facial asymmetry, malar projection, malar width, malar height*

Introduction

Zygomaticomaxillary complex (ZMC) fractures are the second most common facial fractures after nasal fractures.[1] The ZMC is an important structure, serving as a major buttress of the middle third of the face. The ZMC also projects anterolaterally to form the malar eminence and establishes the midfacial width and contour of the orbital rim; thus, it plays an important role in aesthetic appearance.[2,3]

Contrary to the previously believed idea of the zygomaticomaxillary complex fracture as a tripod fracture, the currently perceived notion is that it is a tetrapod fracture.[4] The zygoma can fracture at one, two, three, or all four articulations namely, the zygomaticofrontal suture, the zygomaticomaxillary buttress, the zygomaticotemporal suture, and the zygomatico-sphenoid suture depending upon the velocity and direction of the force inducing trauma.[5]

Treating zygomaticomaxillary complex fractures aims to achieve stability and restore aesthetic appearance through three-dimensional reduction and rigid fixation. After adequate reduction of the fracture has been achieved, it is important to maintain stability and rigid fixation to prevent functional impairment and aesthetic sequelae.[6]

Displacement of the reduced ZMC after surgery can result in facial asymmetry, primarily due to masticatory force. The optimal number of fixation sites needed to stabilize the zygoma adequately during the bone-healing period is controversial in the surgical management of zygomatic fractures. Different surgical techniques, such as one, two, three, and four-point fixation, have been proposed based on the severity and extent of the fracture. [7]

For accurate postoperative assessment, the three-dimensional position of the reduced zygoma should be recorded by measuring the malar width, malar projection, and malar height of both fracture and normal sides preoperatively and postoperatively from CT scans.

Patients and methods

Preoperative radiographic measurements:

Reference Lines, landmarks, and Measurements:

Axial midline: Axial measurements were made from a line perpendicular to an imaginary sagittal line drawn from the vertical plate of the ethmoid anteriorly to the midline of the clivus on the skull base or the midline of the foramen magnum.

Measurement of Malar width and Malar projection in axial cut:

Define the malar eminence: The grid was aligned to the axial midline and a point was marked on the most anterolateral aspect of the zygomatic complex. This point was established by the intersection of a line perpendicular to the axial midline extending laterally and through the depth of the concavity of the frontal process of the maxilla and a line parallel to the axial midline extending anterior from the most lateral aspect of the zygomatic arch. A bisecting line from the intersection of these 2 lines was drawn to the outer surface of the zygoma (white arrow)

Malar width (Horizontal length): The bilateral distances of the malar eminence to the midsagittal plane were measured to assess its position in the mediolateral dimension (red line).

Malar projection (Vertical length): The bilateral distances of the malar eminence to a coronal plane passing through the anterior border of the foramen magnum were measured to assess its position in the anteroposterior dimension (yellow line).

The axial image slice where the zygomatic arches appeared to be thickest was selected for axial measurements. When 1 axial image failed to show ideal views of both zygomatic arches, 2 axial images were used, 1 for the right and 1 for the left. [8,9]

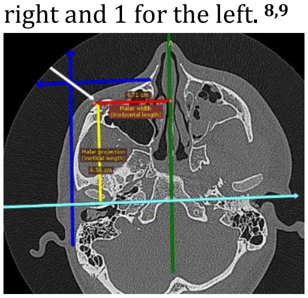

Fig (1) Showing malar width and malar projection measurements in the normal side

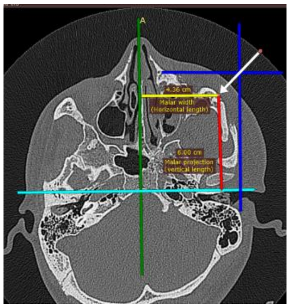

Fig (2) Showing malar width and malar projection measurements in the fracture side.

Measurement of Malar height in coronal cut: the malar eminence is defined as the most lateral aspect of the curved surface of the zygoma.

Malar height: Bilateral distances of the malar eminence to a transverse plane passing through the superior orbital rims were measured to assess its position in the supero inferior dimension. The coronal image slice selected contained the lateral orbital rims in their entirety as well as the arches. When 1 coronal image was not ideal, 2 coronal images were used, 1 for each of the right and left sides. [8,9]

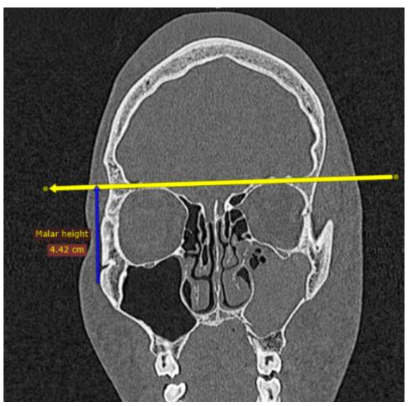

Fig (3) shows malar height measurement on the normal side.

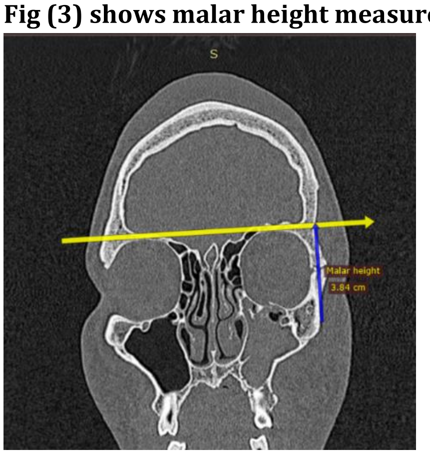

Fig (4) shows malar height measurement on the fracture side.

Surgical Procedure

Admission: All patients were admitted at the acute phase and were administered analgesics and corticosteroids. For infectious risk, our patients were administered prophylactic antibiotics. The surgical operations were performed with the patient under general anesthesia

Patient positioning, prepping, and draping:

− Supine position

−Neutral head positioning

− Sterile drapes were placed in a way that exposes the face

Reduction: Reduction of ZMC was done by one of the following methods:

(1) Gillies Temporal approach uses a 2.5 cm incision, inclined at an angle of 45° to the zygomatic arch, in the temporal region in the bearing area of the scalp. The Rowe zygoma elevator is inserted between the fascia and Temporalis muscle and fracture is reduced. (2) Keen's approach uses a small incision in the mucobuccal fold just beneath the zygomatic buttress of the maxilla. The elevator is passed upwards behind the fractured bone maintaining close contact with the bone to avoid entering the fat pad in the temporal area. Reduction is achieved by elevating the bone upward and outward: a snapping sound may be heard when the bone is replaced. (3) By manipulating a screw inserted in the body of the zygoma.

Surgical exposure of fixation points:

1- (ZM) buttress was exposed through an intraoral maxillary vestibular approach and was fixed by a 1.5 mm L-shaped miniplate.
2- (FZ) suture was exposed through lateral eyebrow approach and was fixed by a 1.5 mm mini plate.
3- (IOM) was exposed through sub ciliary or sub tarsal incisions and was fixed.

by 0.9 mm microplates.

After adequate anatomical reduction of the ZMC, the zygomaticomaxillary buttress (ZM) was used as a key point of fixation in all cases and either the frontozygomatic suture area (FZ) or the infraorbital margin (IOM) was used as the second point of fixation using mini plates.

Orbital floor exploration:

Orbital floor exploration was done when the IOM was used as a second point of fixation, Orbital floor reconstruction was achieved when reduction of the thin bone fragments was not possible or insufficient to avoid a soft tissue displacement by using soft titanium mesh.

After adequate reduction and fixation closure of the surgical wound was done.

Postoperative radiographic measurements:

Malar height, malar width, and malar projection were measured from a CT scan after one week for assessment of proper reduction and alignment of the ZMC and then after one month for assessment of proper healing.

Malar width and malar projection were measured from the axial cut as shown in (fig.5) and malar height was measured from the coronal cut as shown in (fig 6)

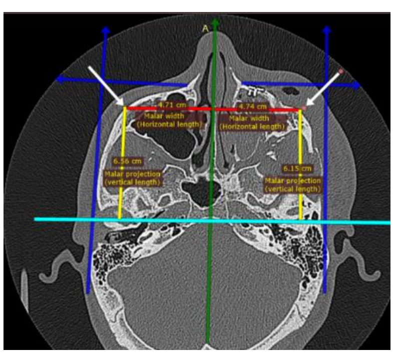

Fig (5) Showing malar width and malar projection in both sides postoperative.

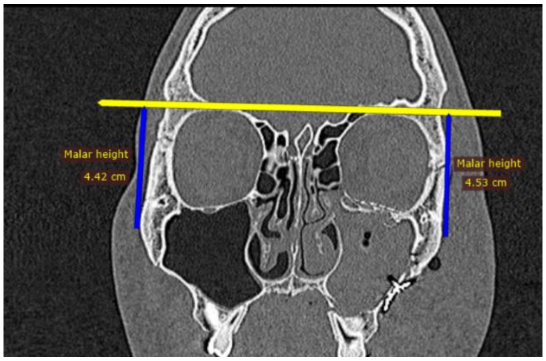

Fig (6) Showing malar height in both sides postoperative.

Postoperative clinical follow-up

. Immediate post-operative assessment:

Evaluation of the patient's vision was performed as soon as they were awakened from anesthesia and then at regular intervals until they were discharged from the hospital.

. Postoperative positioning:

Keeping the patient's head in an upright position both preoperatively and postoperatively significantly improves periorbital edema and pain.

. Nose-blowing:

To prevent orbital emphysema, patients were told to avoid nose blowing for at least 10 days following orbital fracture repair.

. Medication:

The following medications were prescribed to our patients: analgesia, antibiotics, nasal decongestant may be helpful for symptomatic improvement in some patients, regular perioral and oral wound care including disinfectant mouth rinse. The maintenance of a soft diet, and good oral hygiene was recommended for 2 weeks after surgery.

. Ophthalmological examination:

The following signs and symptoms were evaluated by ophthalmologists: vision acuity, vertical dystopia, extraocular motion, diplopia, globe position, and lid position.

Result:

Preoperative Radiographic Measurements:

Malar Width, projection, and height were measured from axial and coronal CT scans on both the fracture and normal sides.

preoperative radiographic Malar width

Malar Width was measured from axial CT scan in both fracture and normal sides and presented in Table (1)

Table 1. Malar width of the normal side and the fracture side preoperatively.

	Width	
	Normal side (mm)	Fracture side (mm)
Mean	**45.6**	**42.9**
SD	4.4	5.6
SE	1.0	1.2
Min	36.5	31.2
Max	51.7	55.1
Paired t-test		
t	3.37	
p-value	0.003**	
Pearson's correlation		
r	0.77	
p-value	<0.001***	

*, **, ***, significant at p<0.05, <0.01, <0.001, NS non-significant at p>0.05

The Malar width on the normal side (mm) ranged between 36.5 to 51.7 mm with an average (SD) of 45.6±4.4, however, the width on the fracture side ranged between 31.2 to 55.1 with an average of 42.9±5.6 mm. The difference between normal and fracture sides was highly significant as revealed by paired samples t-test (t=3.37; p=0.003). The correlation between normal and fracture side was positive strong and highly significant correlation presented in table 1.

preoperative radiographic Malar projection

Malar projections were measured from axial CT scan in both fracture and normal sides and presented in Table (2)

Table 2. Malar projection of the normal side and the fracture side preoperatively.

	Preoperative radiographic projection	
	Normal side (mm)	**Fracture side (mm)**
Mean	**61.1**	**58.4**
SD	**3.9**	**3.2**
SE	**0.9**	**0.7**
Min	**53.9**	**50.8**
Max	**66.8**	**63.5**
Paired t-test		
t	2.91	
p-value	0.009**	
Pearson's correlation		
r	0.357	
p-value	0.061 ns	

*, **, ***, significant at p<0.05, <0.01, <0.001, NS non-significant at p>0.05

the Malar projection on the normal side (mm) ranged between 53.9 mm to 66.8 mm with an average (SD) of 61.1±3.9, however, the projection on the fracture side ranged between 50.8 to 63.5 with an average of 58.4±3.2 mm. The difference between normal and fracture sides was highly significant as revealed by paired samples t-test (t=2.91; *p*=0.009**). The correlation between normal and fracture side was positive moderate and non-significant correlation presented in Table 2.

preoperative radiographic Malar height

Malar height was measured from coronal CT scans in both fracture and normal sides and presented in Table (3)

Table 3. Malar height of the normal side and the fracture side preoperatively.

	Preoperative radiographic height	
	Normal side (mm)	**Fracture side (mm)**
Mean	**44.7**	**46.8**
SD	**4.6**	**6.2**
SE	**1.0**	**1.4**
Min	**33.7**	**36.8**
Max	**55.2**	**59.0**
Paired t-test		
t	-1.592	
p-value	0.128ns	
Pearson's correlation		
r	0.464	
p-value	0.039*	

The Malar height on the normal side (mm) ranged between 33.7 mm to 55.2 mm with an average (SD) of 44.7±4.6, however, the height on the fracture side ranged between 36.8 to 59.0 with an average of 46.8±6.2 mm. The difference between normal and fracture sides was non-significant as revealed by paired samples t-test (t=-1.59; *p*=0.128). The correlation between the normal and fracture sides was positive moderate and significant correlation presented in Table 3.

Treatment:

The time between injury and admission:

The time between injury and admission ranged from 7 to 20 days with an average (±SD) of 14.15±4.04 days.

Table 4. The time between injury and admission

Descriptive measure	Time between injury and admission
Min	7.0
Max	20.0
Mean	14.2
SD	4.04
SE	0.90

Time of intervention:

It was mainly 2h.

The course of surgical intervention:

1. Admission of patients:

All patients were admitted at the acute phase and were administered analgesics and corticosteroids. For infectious risk, our patients were administered prophylactic antibiotics.

2. Patient positioning, prepping, and draping:

− Supine position

−Neutral head positioning

− Sterile drapes were placed in a way that exposes the face

3. Surgical approach:

a. Exposure:

Exposure was achieved through:

-Intraoral buccal approach to access the zygomatic buttress for all cases.

-Sub ciliary incision in 9 cases (45%) and sub tarsal incision in 6 cases (30%) giving access to areas along the orbital floor, the medial and lateral rim. Used when Orbital floor revision was considered (15 cases: 75%).

-Lateral eyebrow incision to access the frontozygomatic suture in 5 cases (25%).

b. Reduction:

Repositioning was achieved through Gillie's approach in 4 cases, keen's approach in 13 cases, and by manipulating mini screws in 3 cases.

Table 5. main approaches used for ZMC reduction

Approach	Frequency	
	n	%
Gillie's approach	4	20
keen's approach	13	65
Mini screw	3	15
Chi-square		
Chi	9.1	
p-value	0.011*	

*, **, ***, significant at p<0.05, <0.01, <0.001, NS non-significant at p>0.05

c. Orbital floor exploration:

The orbital floor was explored in 15 patients (75% of cases); the inferior rectus muscle was freed when entrapped and the fat hernia was reduced. The infraorbital nerve was gently released when compressed.

d. Orbital reconstruction (If necessary):

Orbital floor reconstruction was achieved when reduction of the thin bone fragments was not possible or insufficient to avoid a soft tissue displacement. Soft titanium mesh was used for 10 patients (50% of cases).

e. Fixation:

The reduced ZMC was fixated with mini plates and screws using 2-point fixation in the previously exposed areas:

-Zygomatic buttress as the main key point for all cases.

-Infraorbital rim as the second point in 15 cases.

-Frontozygomatic suture area as the second point in 5 cases.

Postoperative radiological assessment:

Malar Width

Malar Width was measured from axial CT scans in both fracture and normal sides preoperative and postoperative and presented in Table (6)

The Malar width in the normal side and fractured side showed an average (±SD) 45.6±4.4 and 42.9±5.9 with a highly significant difference between them as revealed by paired t-test (p=0.003). However, postoperative with recorded an average (±SD) of 45.1±4.4 and 45.1±4.5 after 1 week and 1 month; respectively.

The difference between 1 week postoperative and preoperative fracture was highly significant as revealed by paired t-test (p=0.007), furthermore, the difference between 1 month postoperative and preoperative fracture with highly significant as revealed by paired t-test and LSD (Table 6).

Table 6. Preoperative and postoperative radiological assessment of width.

Time of examination		Radiographic Width				
		Mean		SD	SE	Paired t-test
Pre-operative	**Normal**	45.6	a	4.4	0.98	0.003**
	Fractured	42.9	b	5.6	1.24	--
postoperative	**1 week**	45.1	a	4.4	0.99	0.007**
	1 month	45.1	a	4.5	1.00	0.010**
Repeated measure ANOVA						
F (Greenhouse-Geisser)		8.92				
p-value		0.004**				

[a,b] means followed by different letters are significantly different according to DMRTs
*, **, ***, significant at p<0.05, <0.01, <0.001, NS non-significant at p>0.05

Malar projection

Radiographic Malar projection was measured from axial CT scan in both fracture and normal sides preoperative and postoperative and presented in Table (7)

Table 7. Pre- and post-operative radiographic projection

Time of examination		Radiographic Projection				
		Mean		SD	SE	Paired t-test
Pre-operative	**Normal**	61.1	a	3.9	0.87	0.009**
	Fractured	58.4	b	3.2	0.70	
postoperative	**1 week**	60.7	a	3.3	0.74	0.002**
	1 month	60.7	a	3.3	0.74	0.003**
Repeated measure ANOVA						
F (Greenhouse-Geisser)		8.97				
p-value		0.004**				

*, **, ***, significant at p<0.05, <0.01, <0.001, NS non-significant at p>0.05

The radiographic Malar projection in the normal side and fractured side showed an average (±SD) 61.1±3.9 and 58.4±3.2 mm with a highly significant difference between them as revealed by paired t-test (p=0.009). However, postoperative with recorded an average (±SD) of 60.7±3.3 and 60.7±3.3 after 1 week and 1 month; respectively. The difference between 1 week postoperative and preoperative fracture was highly significant as revealed by paired t-test (p=0.002), furthermore, the difference between 1 month postoperative and preoperative fracture with highly significant as revealed by paired t-test (*p*=0.003) and LSD**.** The difference between preoperative normal, fracture, and postoperative 1 week and 1 month was significant as evaluated by repeated measure ANOVA (*p*=0.004).

Malar height

Radiographic Malar height was measured from coronal CT scan in both fracture and normal sides preoperative and postoperative and presented in table (8)

Table 8. Pre- and post-operative radiographic height

Time of examination		Radiographic Height				
		Mean		SD	SE	Paired t-test
Pre-operative	Normal	44.7	a	4.6	1.04	0.128 ns
	Fractured	46.8	a	6.2	1.40	--
postoperative	1 week	44.9	a	4.1	0.92	0.117ns
	1 month	44.9	a	4.1	0.92	0.111ns
Repeated measure ANOVA						
F (Greenhouse-Geisser)		2.48				
p-value		0.125 ns				

*, **, ***, significant at p<0.05, <0.01, <0.001, NS non-significant at p>0.05

The radiographic Malar height in normal side and fractured side showed an average (±SD) 44.7±4.6 and 46.8±6.2 mm with a non-significant difference between them as revealed by paired t-test (p=0.128). However, postoperative with recorded an average (±SD) of 44.9±4.1 and 44.9±4.1 after 1 week and 1 month; respectively. The difference between 1 week postoperative and preoperative fracture was non-significant as revealed by paired t-test (p=0.117), furthermore, the difference between 1 month postoperative and preoperative fracture was non-significant as revealed by paired t-test (*p*=0.111) and LSD. The overall difference between preoperative normal, fracture, and postoperative 1 week and 1 month was non-significant as evaluated by repeated measure ANOVA (*p*=0.125).

Discussion:

The zygomaticomaxillary complex is a frequently injured facial bone structure, especially in cases of interpersonal aggression and transportation accidents, due to its lateral prominence.

The optimal number of fixation sites to secure the zygoma in its proper position while the bone heals is a hotly debated subject in the field of zygomatic fracture treatment.10 For the best possible stability of ZMC fractures, surgeons have traditionally concentrated on the quantity and placement of buttresses that need repair. Determining the appropriate fixing method—one-point, two-point, three-point, or four-point—depends on the stability of the fracture and the amount of hardware needed to keep the fracture reduced as the patient heals.[11]

After surgery, the diminished ZMC was mostly displaced by the masticatory force, with the masseter muscle playing the most significant role among these forces. For the most part, the displacement was going inside. The displaced fracture is caused by the continued downward stress on the shattered parts. The masseter muscle, which originates at the zygoma and touches the mandibular angle, moves slightly inward and diagonally when seen from the front. The affected ZMC segment will be primarily pulled inward by the masseter muscle.[12] As a result, intraoral fixation at the zygomatic buttress is crucial for relapse prevention and to counterbalance the effect of the masseter muscle.

Many authors advocate for intraoral fixation at the zygomatic buttress for several reasons: (1) no external scarring; (2) easy surgical access; (3) sufficient soft tissue cover; (4) plate palpability is not an issue; (5) the wider area of articulation makes the ZM buttress a better indicator of zygoma alignment than the FZ region; (6) plating the ZM buttress will counteract the masseter muscle action and prove better stability; and (7) removal of the plate is easier than in other locations.[11] Results from clinical and radiological assessments showed a marked improvement after one week and one month, suggesting that the zygomatic buttress had stabilized as the fixing point in all instances in this investigation.

Successful one-point fixation in the maxillary buttress was used by Kühnel and Reichert (2015) to treat uncomplicated displaced, non-comminuted ZMC fractures.[13] The frontozygomatic and infraorbital regions were not addressed in the study by Kim et al. (2011), which utilized a single-point fixation at the zygomatic buttress. They noted that the approach is visually pleasing.[14] A single vestibular approach with a 1-point fixation at the zygomatic buttress can achieve good surgical stability, according to Chen et al., 2015.[15] Although previous research has shown that fixing the zygomatic buttress at a single point is crucial for stabilizing a reduced ZMC, this approach has not been successful in addressing the three-dimensional stability of the ZMC, which can result in facial asymmetry and long-term deformities. In their study on cadaveric subjects, Rinehart et al. found that while 2-point or 3-point mini-plate fixation can withstand static and oscillating loading, which mimics the forces experienced during chewing, neither single-miniplate fixation nor triple-wire fixation could stabilize the zygoma.[16]

Using miniplates, Gandi et al. (2012) demonstrated that two-point fixation provides stability equivalent to three-point fixation.[17] In a study conducted by Na et al., 2019, 22 patients suffering from unilateral ZMC fractures were divided into two equal groups: one group received two-point fixation, and the other group received three-point fixation. They found no difference in stability between two-point and three-point fixation when they measured the zygoma's lateral projection and height at two landmark positions on preoperative and postoperative frontal 3D CT images: the zygomaticofacial foramen and the frontozygomatic suture.[18] Mittal et al., 2019 measured the preoperative and postoperative values of malar height and vertical dystopia disparity in water's view radiographs for 20 patients as part of their investigation on the stability of two-point fixation. The study demonstrated that two-point fixation successfully stabilizes broken fragments by showing a statistically significant improvement in radiographic and clinical measures postoperatively.[19] The current study's findings corroborate those of the aforementioned research, showing that the 2-point procedure is a reliable method for fixing ZMC fractures, and producing satisfactory cosmetic and therapeutic outcomes.

Using computed tomography (CT) scans, Nasr et al. (2018) compared two-point fixation with three-point fixation in two groups and assessed surgical results. Based on their findings, two-point fixation is just as effective as three-point fixation in terms of fracture stability.[20] Also, forty patients with ZMC fractures were split into two groups in the retrospective analysis by Kim et al., 2020: group 1 received two-point fixation, and group 2 received three-point fixation. The study compared patient demographics and follow-up data with pre- and post-operative CT scans to measure malar differences, protruding zygoma differences, and asymmetry index. They came to the conclusion that two-point fixation in ZMC fractures, excluding incisions approaching the ZF, is just as effective as three-point fixation, but it takes less time to operate and has fewer complications, and there was no statistically significant difference in the protruding difference of the zygoma or facial asymmetry index between the groups.[21] Consistent with the findings of Nasr et al. (2018) and Kim et al. (2020), our investigation confirms.

There were two equal groups of 100 patients in the 2012 study by Rana et al., who had unilateral ZMC fractures. One group received two-point fixation, and the other group received three-point fixation. Vertical orbital dystopia and malar height disparity were assessed. From the patient's vertex view, we used a vernier calliper to measure the malar height and a scale on Water's view to measure the vertical dystopia, which is the difference in the level of the bony orbits as indicated by palpation and compared to the normal side. We also used tracing paper to outline the infraorbital margin. Researchers concluded that three-point fixation using miniplates is the gold standard for treating zygomatic bone fractures, since it improved malar height and vertical dystopia to a little greater extent than two-point fixation.[22] Accurate postoperative evaluation of the sufficiency of ZMC fracture reduction requires recording the three-dimensional position of the reduced zygoma by measuring the malar width, malar projection, and malar height from computed tomographic (CT) scans taken before and after surgery. Malar height alone does not address this position.

To determine the reduced zygomaticomaxillary complex's three-dimensional location, this study employed radiographic measurements of malar height, malar width, and malar projection. In cases of non-comminute ZMC fractures, the results show that the 2-point fixing technique is reliable.

List of Abbreviations:
ZMC zygomaticomaxillary complex.
ZM Zygomaticomaxillary
IOR Infraorbital rim.
ZF Zygomaticofrontal
Source(s) of support: No funding was received.
Ethical policy and Institutional Review Board statement: The study was authorized by the Research Ethics Committee, Faculty of Dentistry Suez Canal University. Established,
according to WHO-2011 Standards, Approved in 3\5\2020 with (serial no. 277\2020).
Patient declaration of consent statement: an informed consent was signed by each participant.
Declaration of competing interest: The authors declare that they have no conflict of interest.

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