Ultrasonography vs computed tomography in imaging of zygomatic complex fractures

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Abstract: The zygoma is the principal buttress between the cranium and maxilla. The zygomatic fractures can lead to significant cosmetic and functional disorders such as enophthalmos, depression of malar eminence and parathesia due to injury of infraorbital nerve. Computed tomography (CT) was the first technology capable of allowing visualization of both hard and soft tissues of the face by image processing enhancement. It was reported that CT can achieve more accurate values in diagnosis of midface fractures. Another alternative technique is ultrasonographic examination. Ultrasonography is easy and quick to be performed; it is noninvasive and free of any risks. The possibility of ultrasonographic fracture visualization in the midface has already been described by many researchers. **Objectives:** the aim of this study was to compare between the ultrasonographic and the computed tomographic findings, in the diagnosis and repair of the zygomatic complex fractures. **Patients and methods:** Between November 2008 and December 2009, 10 consecutive patients (5 males and 5 females) who were referred to Oral and Maxillofacial Department of AL-Azhar University (Girls branch), for treatment of zygomatic complex fractures, were included in this prospective study. The mean age was 34.5 (range 16-60years). The clinical criteria for patient selection included; the presence of periorbital ecchymosis, scleral hematoma, infraorbital nerve parathesia, diplopia and/or limitation of ocular movements, as well as enophthalmos and flattening of the face. Patients who had diplopia or ocular abnormalities were examined by an ophthalmologist. With each patient an axial and coronal thin-layer CT with 3D reconstruction was done (Multislice CT). Subsequently each patient was sonographically evaluated by an experienced examiner with a linear transducer. All patients were treated under general anaesthesia via closed or open reduction according to the planned surgery. Immediately after patients' recovery, CT and ultrasound images were taken for all patients to evaluate accuracy of the reduction. **Results:** The ultrasonographic findings showed clear differences in the ability to obtain a correct estimation of the selected anatomic landmarks. The zygomatic arch, the lateral wall of the orbit and the infraorbital margin can be visualized by ultrasonography very easily. The assessment of the orbital floor and the medial wall proved to be rather difficult. The ultrasound images were always concordant with the CT findings. Open reduction through extraoral and transoral accesses, was performed in 8 patients, and 2 patients were treated conservatively. The alignment of the fractured segments could be easily identified by ultrasonography in all patients. All fractured segments were adequately reduced into their normal anatomical position. The postoperative CT confirmed these results. **Conclusion:** CT has been recommended for preoperative evaluation of zygomatic trauma as a standard diagnostic method, especially in complicated cases with intracranial injuries or when there is a need for optic nerve evaluation, because they cannot be adequately seen by ultrasonography. While ultrasonography has proved to be a valuable tool in detecting uncomplicated fractures at the zygomaticofrontal process, the zygomatic arch and the infra orbital margin but its results for orbital floor and medial wall remain unsatisfactory. Also, ultrasound is more reliable in postoperative follow up, resulting in decreased cost and radiation exposure. [Journal of American Science 2010; 6(9):524-533]. (ISSN: 1545-1003).

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1. Introduction

The zygoma is the principal buttress between the cranium and maxilla. The convex shape and protrusion of the zygoma give the contour of the cheek and make this area of the midface more vulnerable to injury or fracture. Trauma of the zygomatic complex constitutes 45% of all midface fractures [1, 2]. The zygomatic fractures can lead to significant cosmetic and functional disorders such as enophthalmos, depression of malar eminence and parathesia due to injury of infraorbital nerve [3]. In addition, zygoma comprises the anterior and lateral portion of the orbit, so any zygomatic fractures may be accompanied with orbital trauma, which results in orbital blow-in or blow-out fractures and ophthalmic injuries such as entrapment of orbital content with diplopia and decreased ocular movements as well as exophthalmos or enophthalmos [4, 5].

In midfacial fractures, the alignment of the zygomatic complex is very important for facial appearance. The assessment of the position of the zygoma at additional fracture sites (i.e. the zygomaticofrontal process, the infraorbital rim and the zygomaticomaxillary buttress) may not be sufficient in many cases where the displacement around a vertical rotation axis with posterior inward or outward rotation of the zygoma might remain unrecognized. In comminuted fractures, the assessment of repositioning is even more difficult [6]. Consolidation of the zygoma in a malposition results in facial asymmetry with reduced sagittal prominence and increased transverse width of the midface [7].

Furthermore, the persisting dislocation of the zygomatic arch may lead to a visible depression of the overlying soft tissues, and interfere with the mandibular movements resulting in limitation of mouth opening. Finally, an incomplete reposition could be unstable and increases the risk of re-displacement.

Therefore, during malar fracture reconstruction, the contour of the zygomatic complex should be assessed to avoid postoperative complications[8]. There are different options for assessment of the zygomatic reduction such as transcutaneous palpation, radiological visualization using a computed tomography (CT) scanner and endoscopic visualization [9, 10].

CT has revolutionized the assessment of complex injuries[11, 12]. With the new technology of high speed scanners, CT of the face is now possible at the same time as other body regions[13] that avoiding additional transfers and delays in management. Surgeons can now co-ordinate treatments enabling craniofacial fractures to be treated comprehensively. CT is particularly useful in assessment of fracture of the skull base, orbits, zygoma, sinuses and condyles [14, 15].

Another alternative technique is ultrasonographic examination which is firstly introduced by Akizuki[16] et al., in 1990. Many studies[17-20] reported the role of ultrasonography in diagnosis of fractures in maxillofacial region. Ultrasonography has proved to be a valuable tool in detecting fractures at the zygomatico-frontal process, the lateral wall of the maxillary sinus, the zygomatic arch and the orbital walls[7, 21, 22]. So, the aim of this study was to compare between ultrasonographic and CT findings in the diagnosis and repair of the zygomatic complex fractures.

2. Patients and Methods

Between November 2008 and December 2009, 10 consecutive patients (5 males and 5 females) who were referred to Oral and Maxillofacial Department of AL-Azhar University (Girls branch) for treatment of zygomatic complex fractures, were included in this prospective study. The mean age was 34.5 (range 16-60years).

Clinical examination:

The clinical criteria for patient selection included presence of periorbital ecchymosis, scleral hematoma, infraorbital nerve parathesia, diplopia and/or limitation of ocular movement, as well as enophthalmos and flattening of the face. Patients who had diplopia or ocular abnormalities were examined by an ophthalmologist. Neurosensory deficits were quantified using conventional examination methods[23] (cold, cotton roll and two-point discrimination). The clinical data of patients were summarized in table (1). After case history and clinical examination, the patients underwent CT and ultrasonographic examinations.

Radiographic examination:

With each patient an axial and coronal thin-layer CT with 3D reconstruction was done (Multislice CT). The radiologist used the following parameters for CT images; Helical CT with 1.25mm slices, reconstruction slice thickness 1.2mm and pitch: 3.75 high qualities. The findings were evaluated by radiologist to detect the fracture of zygomatic complex and/or zygomatic arch. The CT findings were accepted as reference.

Subsequently each patient was sonographically evaluated by an experienced examiner with a linear transducer. In order to conduct homogeneous investigations, four anatomic landmarks accessible to sonography were selected which are typically affected by fractures of the zygomatic complex. They were zygomatic arch, infraorbital rim, lateral orbital wall and orbital floor. These landmarks were evaluated also in CT images. For the ultrasonographic examinations, a Siemens SONOLINE Elegra, Germany, Ultrasound System with a linear transducer was employed. The frequency was set between 7.5 and 10 MHz, depending on the image quality to be achieved. The patient was placed in a supine position; an adequate amount of gel was applied on the skin over the fractured areas. The transducer was applied longitudinally to the zygomatic fracture, parallel to its long axis. In this way, the ultrasound beam was oriented perpendicular to the bone surface producing sagittal views.

Surgical approach:

All patients were treated under general anaesthesia. Closed reduction with a zygomatic hook was first attempted. If adequate reduction and stability of the zygomatic complex was not achieved, open reduction and fixation of the zygoma was performed. Generally, this would begin with stabilization of the zygomatico-maxillary process via an intraoral maxillary vestibular incision. The fronto-zygomatic suture and infraorbital rim as well as the orbital floor were approached through extraoral local incisions. Zygomatic arch fractures were also reduced by hook except in one case in which the coronal approach was performed. The reduction of fractures was checked intra operatively by digital palpation at the infraorbital margin, the fronto zygomatic suture and the zygomatic arch. Any gap or step in these locations was considered as incorrect bony alignment. The rigid internal fixations at the corresponding sites were used to fix the fractures.

Postoperative follow-up:

Immediately after patients' recovery, CT and ultrasound images were taken for all patients to evaluate accuracy of reduction. During the first postoperative week, all patients were referred to the department of ophthalmology for re-evaluation of vision, fundus, globe position and eyeball mobility.

3. Results

The cause of injury was assault, fall and road traffic accidents. The interval between injury and treatment ranged from 2 to 14 days (average 6 days) (Table 1). Physical examination revealed neurosensory disturbance of the ipsilateral infraorbital nerve and periorbital ecchymosis, with scleral hematoma. Diplopia was present in seven patients; these were the patients with comminuted zygomatic complex fractures. Depression of the zygomatic bone was clearly visible at the site of trauma (Fig 1). Trismus was present in different degrees; this symptom, however, did not correlate with an additional zygomatic arch fracture. Three cases had limitation of extraocular movement and only one case had enophthalmos.

The type and extent of the zygomatic bone fractures were diagnosed preoperatively by CT scans of the axial and coronal planes with 3 D reconstruction. CT revealed an involvement of the orbital floor and a haematosinus in seven cases. Three fractures of the orbital floor showed an entrapment of the inferior rectus muscle.

Ultrasonographic examination was carried out on all patients. The examiner remained blinded for the CT images until the ultrasonographic examination was terminated. The findings showed clear differences in the ability to obtain a correct estimation of the selected anatomic landmarks by means of ultrasonography. The zygomatic arch can be visualized by ultrasonography very easily (Fig. 2). The assessment of the orbital floor (Fig. 3) and the medial wall was proved to be rather difficult. The lateral wall of the orbit (Fig. 4), and the infraorbital margin (Fig. 5) were proved to be quite accessible by ultrasonography. In case of a dislocation of the fracture segments, the identification of a fracture of the respective bone by ultrasonography was easily performed. It became evident that the clinical application of the ultrasography in this study proved to be practical and possible in all patients, as it could diagnose easily the site of the zygomatic fractures. The ultrasound images were always concordant with the CT findings.

Open reduction through extraoral and transoral accesses, was performed in 8 patients, and 2 patients were treated conservatively. The fracture sites over the zygomaticofrontal suture and infraorbital rim were stabilized with miniplates, while zygomatic arches were reduced by hook without any fixation except one case. The comminuted fractures of the maxillary buttress were also reduced and fixed with miniplates through the buccal incision. Orbital floor exploration was necessary in three cases, because of muscle entrapment.

Immediately after open or closed reduction of zygomatic fractures, the alignment of the fractured segments could be easily identified by ultrasonography in all patients. All fractured segments were adequately reduced into their normal anatomical position. The postoperative CT confirmed these results, CT showed symmetry of the zygomatic complex in all patients.

Clinical evaluation revealed symmetrical appearance of the zygomatic bone in all patients. None of the patients showed ocular problems such as secondary diplopia or enophthalmos. No postoperative infection or trismus occurred in any of the patients. All the patients were satisfied with the restoration of the facial contour (Fig 6), and the invisible incisional scars.

Table 1. Clinical analysis of the ten patients

Patient	Age (yr)	sex	Injury mechanism	Fracture type (site)	Interval between injury and treatment (days)
1	16	F	Assault	Zygomatic arch (RT)	3
2	60	M	Motorcycle	Zygomatic complex (RT)	7
3	19	M	Assault	Zygomatic complex (LT)	14
4	36	M	Assault	Zygomatic complex (LT)	5
5	48	F	Motorcycle	Zygomatic complex (RT)	2
6	33	M	Assault	Zygomatic complex (LT)	6
7	28	F	Fall	Zygomatic complex (LT)	7
8	26	F	Motorcycle	Zygomatic complex (LT)	2
9	37	M	Assault	Zygomatic arch (RT)	10
10	42	F	Assault	Zygomatic complex (LT)	4

M, male; F, female; LT, left; RT, right

Fig. 1: Preoperative appearance showing right periorbital ecchymosis and cheek swelling.

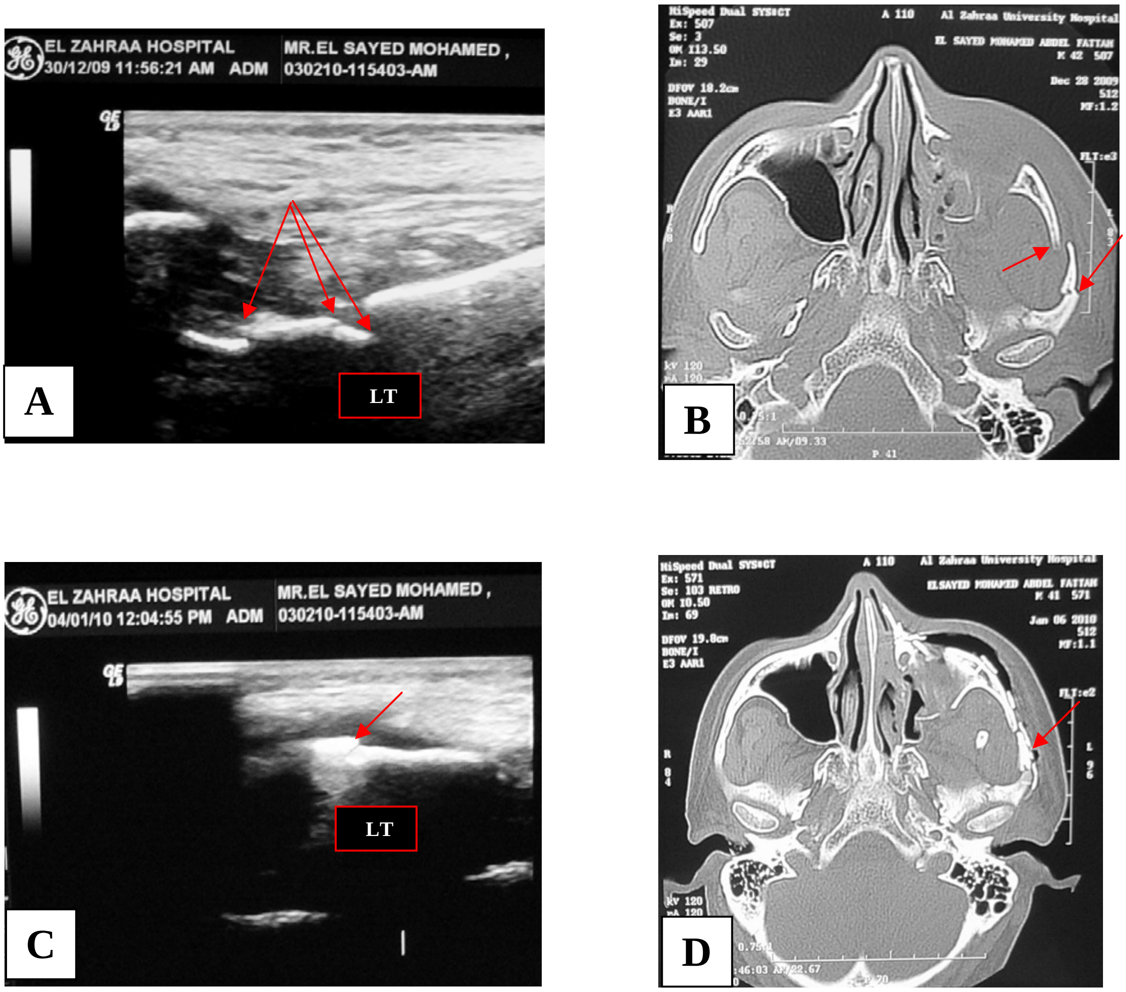


Fig. 2: (A and B) Preoperative ultrasound image and axial view CT of left zygomatic arch fracture. The dislocated segments are indicated by red arrows. (C and D) Postoperative ultrasound image and axial view CT showing the fracture segments aligned to restore the preinjury form of the zygomatic arch (arrow).

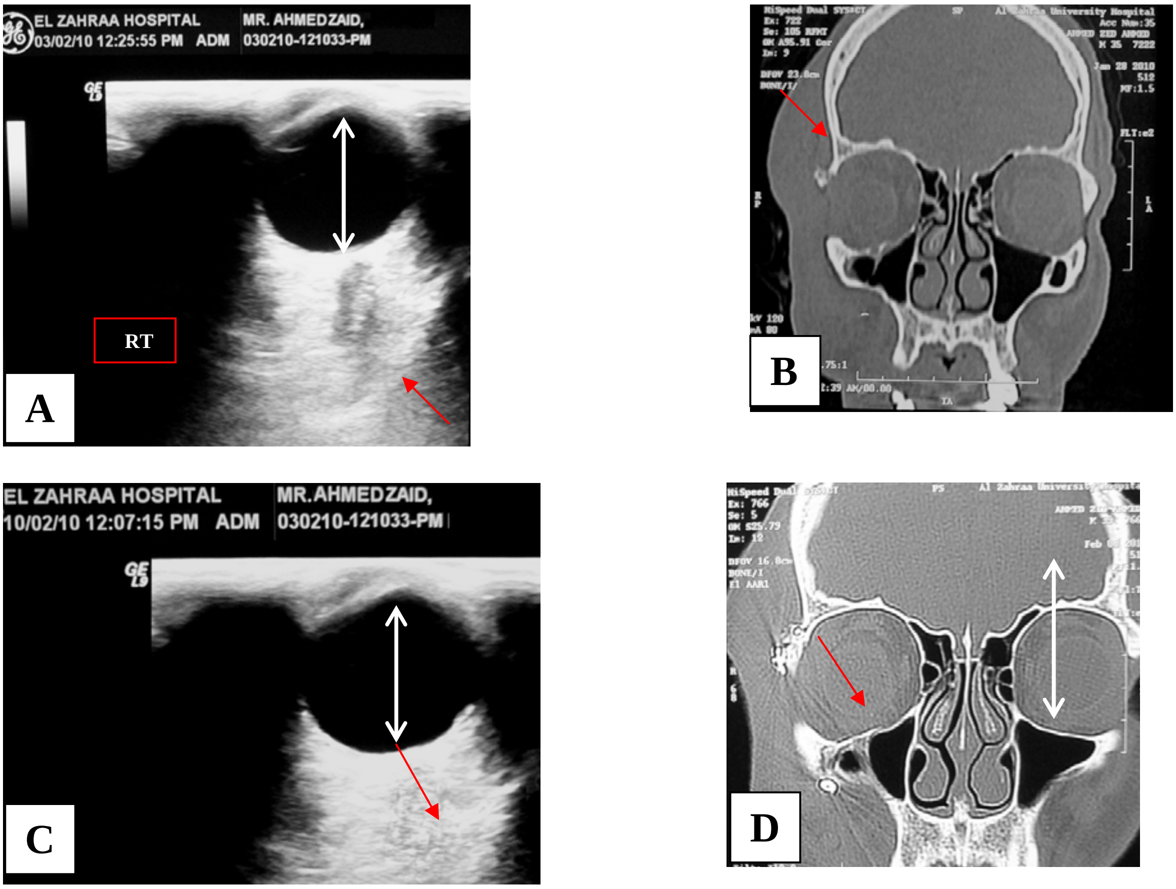
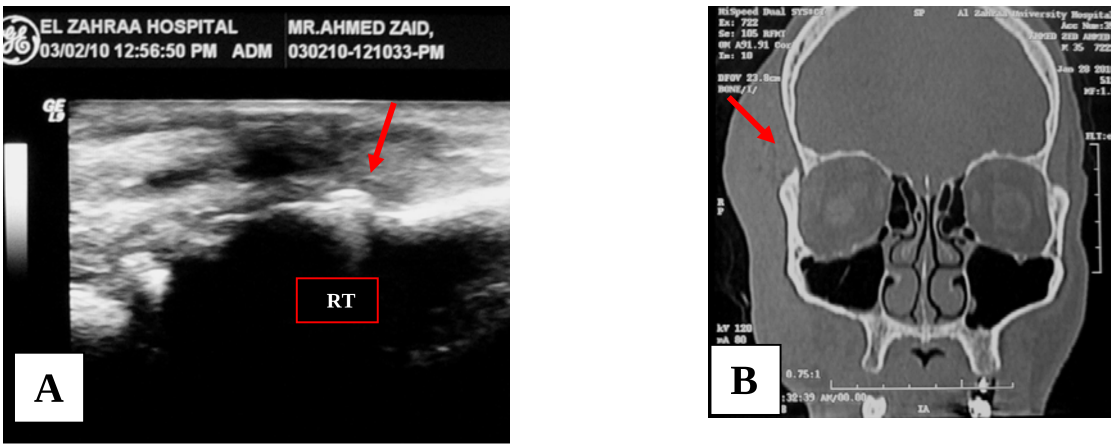


Fig. 3: (A and B) Preoperative ultrasound image and coronal view CT of right orbital floor fracture. The double arrow shows the eye ball. The red arrows show the fractured area. (C and D) Postoperative ultrasound image and coronal view CT showing the fracture segments aligned to restore the preinjury form of the orbital floor (arrow).



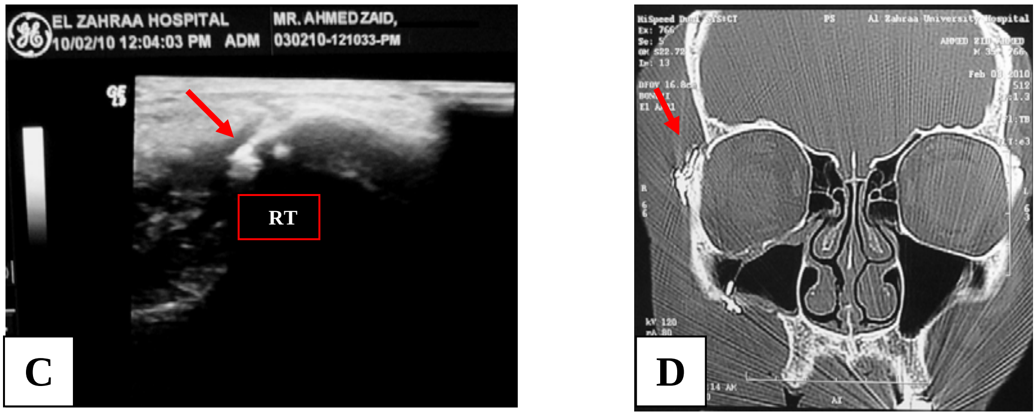


Fig. 4: (A and B) Preoperative ultrasound image and coronal view CT of right lateral orbital wall fracture at the zygomaticofrontal suture. The red arrows show the site of fracture. (C and D) Postoperative ultrasound image and coronal view CT showing the fracture segments aligned to restore the pre-injury form of the lateral orbital wall (arrow).

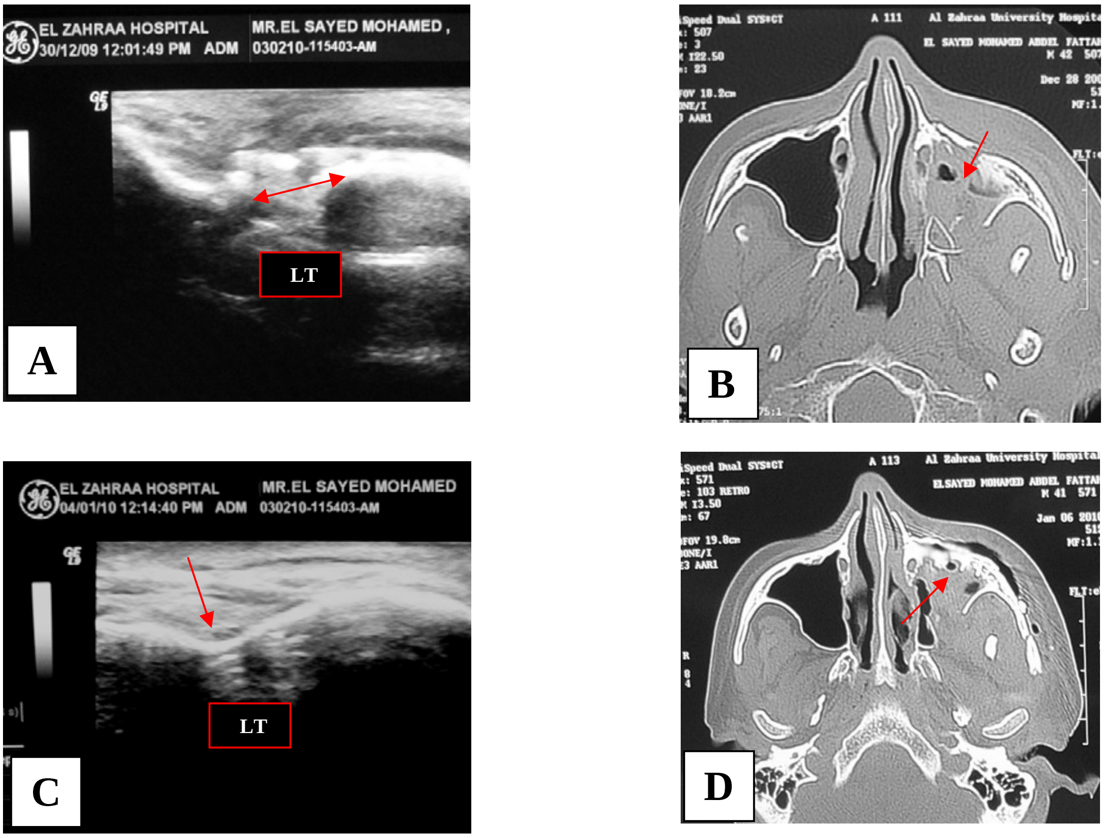


Fig. 5: (A and B) Preoperative ultrasound image and axial view CT of left infraorbital rim fracture. The red arrows show the site of fracture. (C and D) Postoperative ultrasound image and axial view CT showing the fracture segments aligned to restore the pre-injury form of the infraorbital rim (arrow).

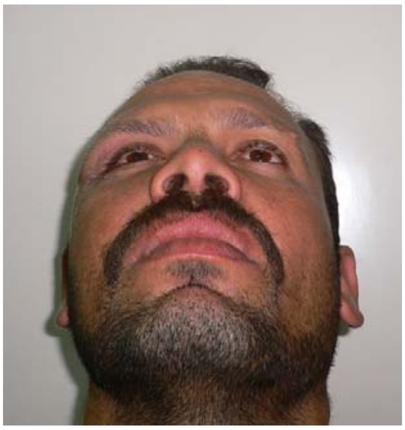


Fig. 6: Postoperative appearance. Malar symmetry was restored.

4. Discussion.

Craniofacial trauma still remains a common health problem and significant work load in many maxillofacial units [24, 25]. Fractures of the facial bones account for fewer than 15% of all maxillofacial injuries with a ratio of mandibular to zygomatic to maxillary fractures of 6:2:1[10]. Although the management has evolved considerably from wiring the fractured segments together to plate osteosynthesis, complex midface fractures can still result in cosmetic and functional deformity [26]. So the surgeon must be assured of sufficient repositioning of zygomatic complex fractures. In such patients, especially those have zygomatic arch fractures; the correct alignment of the arch ensures sufficient sagittal projection of the zygomatic complex and prevents broadening of the facial width. Also, a compressed zygomatic arch denotes that the lateral part of the zygomatic body is displaced posteriorly [6]. For these reasons, many authors[6, 7]considered the zygomatic arch the key in complex midfacial fracture repair.

Despite that the lateral and inferior orbital rim could be exposed during surgery as fractured sites; they do not reflect the position of the zygomatic bone adequately, as correct alignment in these regions may be accompanied by an unrecognized distinct impression of the lateral part of the zygoma. Furthermore, the use of zygomatico-maxillary buttress, as an assessment tool, is often uncertain because the fracture is usually comminuted at this site and it requires an additional surgical approach, which would be considered nonessential [6]. So it was suggested that the assessment of zygomatic complex fractures' reduction via palpation only is not enough especially in cases of zygomatic arch fractures with a different kind of displacement and with only impressed fragment or with a missing interfragmentary contact. This is because the repositioning movement is not so clearly detectable.

Also, in patients with combined fractures, there are several fragments being in a false position and the soft-tissue swelling persistence will complicate the clinical evaluation [26]. That is why postoperative imaging, after treatment of zygomatic complex fractures is of prime importance.

The aim of any imaging examination for maxillofacial injuries is to evaluate the positions of the anatomic elements, both hard and soft tissues, in three spatial planes. Many modalities and techniques are available to facilitate this aim since the use of conventional X rays for diagnosis of trauma. In the first part of the 20th century, the plain film radiographs were the basis for diagnosing fractures of the maxillofacial skeleton[7, 10]. The application of computer processing to the principles of tomography by Godfrey Hounsfield and Allan M. McCormack resulted in the introduction of CT in the late 1970s and 1980s. CT was the first technology capable of allowing visualization of both hard and soft tissues of the facial bones by image processing enhancement. It was reported that CT can achieve more accurate values in diagnosis of midface fractures and its reconstructed 3D images, which are introduced to medical sciences, have high accurate results[27].

The results of this study revealed that, the assessment of the zygomatic complex fractures by CT with 3D reconstruction is an accepted tool for primary diagnosis of such trauma. This agrees with the results of Nkenke [5] et al., and Dolynchuk [28] et al., who reported that CT has been recommended for preoperative evaluation of midface fracture as a standard diagnostic technique. The present study also proved that orbital floor and its lateral and medial walls are better seen in CT images. Also, as severity of injury increased, the need for CT is increased. In addition, the position of globe is better evaluated by CT images because of their two-dimensional nature where in the axial CT slices; the optical contours can be easily estimated in comparison with the data of the healthy orbit. This is proved also by the study of Kim and Choi [29]. They concluded that CT images can provide a good visualization of the changes of the globe position before and after surgery.

The major drawback of CT is the exposure of the patient to ionizing radiation as well as its higher cost. So the use of CT for postoperative follow-up examinations has to be confined to certain cases, where information about fine structures such as optic nerve is needed. That is why many authors [5, 17] suggested application of CT in diagnosis of trauma and preferred the use of non-ionizing tools during the follow-up examinations to avoid harmful effect of radiation on patients and to decrease treatment cost.

Ultrasonography is easy and quick to be performed; it is noninvasive and free of any risks. The possibility of ultrasonographic fracture visualization in the midface has already been described by many researches [6, 7,30]. In the present study, the results showed that the sonography is a reliable method as an imaging modality in cases of suspected midfacial fractures. Also, the displaced fracture of orbit, zygomatic arch and malar bone were better seen in sonography than undisplaced fractures. The same result was stated by Friedrich [7] et al. They found that the major difficulty in the use of sonography in the diagnosis of midfacial fractures; was the verification of nondisplaced fractures without the presence of a step-like structure or dislocation, there is always the danger that the fracture may remain unnoticed.

In addition, this study revealed that the clinical value of sonography mainly depends on the examiner's experience. Moreover, there was another problem with the use of ultrasound in diagnosis of zygomatic complex fractures which is that a gross swelling and emphysema make the ultrasonographic visualization of bony surfaces difficult or even impossible. This was also reported by McCann [30] et al. The problem of this extensive swelling was overcome in the present study by choosing an ultrasound frequency of 7.5 MHz or less. This is in agreement with Gulicher [6] et al., study.

During follow up period, the benefit of ultrasound images in evaluation of fracture reduction of the zygomatic complex was evident especially in the combined fractures of zygomatic bone and arch. Ultrasonography seems to be the best visualizing tool for evaluation of fracture reduction, that enabling the surgeon to assess both the alignment of the zygomatic arch and the zygomatic body. The main advantages of ultrasound are that the examination requires only about 10 minutes and it is not expensive as CT as well as it is considered non invasive method.

The comparison of the results gained by CT and sonographic examination of these 10 patients showed that no fracture had been missed by sonography. Only in the cases of non-displaced zygomatic bone fractures, the examiner was unable to identify with great certainty if a fracture was present or not and it could be superior on CT for postoperative evaluation. This is in agreement with the results of Jank [18] et al. On the other hand, if the clinical picture does not allow a reliable diagnosis, sonography is the suitable tool in case of emergency. In patients with the suspicion of a midfacial fracture, sonography offers an alternative to conventional radiographs as first line imaging. In this way it is possible to make a reliable statement while at the same time avoiding X-ray exposure. This agrees with the results of Blessmann[31] et al.

5. Conclusion

CT has been recommended for preoperative evaluation of zygomatic trauma as a standard diagnostic technique, especially in complicated cases with intracranial injuries or when there is need for optic nerve evaluation because they cannot be adequately seen in sonography. While ultrasonography has proved to be a valuable tool in detecting uncomplicated fractures at the zygomaticofrontal process, the zygomatic arch and the infra orbital margin its results for orbital floor and medial wall remain unsatisfactory. Also, ultrasound is more reliable in postoperative follow up, resulting in decreased cost and radiation exposure.

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