ORIGINAL RESEARCH

A Study to Evaluate the Efficacy of Ultrasonography as a Diagnostic Screening Tool in Maxillofacial Fractures: A Prospective Study

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Abstract

Aim: The aim of the study was to estimate the diagnostic efficacy of high-resolution ultrasonography (USG) in the diagnosis of maxillofacial fractures.

Materials and Methods: A descriptive diagnostic evaluation study was carried out on 30 patients with suspected maxillofacial fractures, out of which 26 were male (86.7%) and 4 were female (13.3%). After initial management, detailed clinical examinations were carried out and significant findings were noted. Computed tomography (CT) scans were performed in fracture-suspecting patients followed by USG examination which was done in a standardized pattern on both sides of the face. The result of USG was compared with the CT scan report.

Result: Based on CT findings, 65 sites were found to be fractured, and this was considered the gold standard. Ultrasonography detected 58 fractures at these 780 sites, of which 54 were true fractures, while 4 were false-positive results. However, USG was not able to detect eleven fractures. The overall sensitivity and specificity of USG were 83.1% and 99%, respectively. The positive and negative predictive values were 93% and 98%, respectively.

Conclusion: According to our study, it may be concluded that USG may be recommended as a diagnostic screening tool to detect superficial maxillofacial fractures.

Clinical significance: Ultrasonography provides a safe, cost-effective, reliable, non-invasive, easily available, and portable imaging modality to screen for maxillofacial fractures.

Keywords: Computed tomography, Maxillofacial, Sensitivity, Specificity, Ultrasonography.

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Introduction

Maxillofacial injuries are one of the most common injuries associated with other injuries and adult males are the most common victims. The prevalence of maxillofacial injuries ranges 17–69%, and this significant variation may be attributed to a number of environmental factors, socioeconomic circumstances, cultural reasons, and traffic rules. Road traffic accidents, assaults, falls from height, sports, and work-related injuries are the most common causes of facial fractures.[1]

In oral and maxillofacial surgery, the first step toward treating any patient is making a correct diagnosis. Missed and maltreated fractures might result in functional and aesthetic problems, thus making an accurate diagnosis of the fracture is essential. An accurate diagnosis is required to execute a proper treatment and to avoid long-term complications. History taking, clinical examination, and radiographic imaging form the diagnostic sequence for any maxillofacial injury.

Computed tomography (CT) scans are considered the gold standard for the detection of maxillofacial fractures.[2,3] Although CT is the gold standard, it has several drawbacks. Its use is restricted in pregnant women and children due to high radiation exposure.[4,5] Expensive and advanced equipment is needed which makes it inaccessible to all treatment centers.[6,7] With a CT scan it is not possible to create a real-time image. Patients with metallic implants and restorations may cause blurring of the image due to artifacts.[6,7] In addition, it requires patient positioning, which is not possible in some cases such as spinal cord injuries and patient's non-cooperation.[8]

Ultrasonography (USG) has been used in the head and neck region and maxillofacial surgery for the identification of pathological alterations related to soft tissue. Sound waves used in Ultrasonographs are not electromagnetic like X-rays.[8,9] Therefore, there is no risk of ionizing radiations and it can be used safely in pregnant women and also multiple fracture sites can be evaluated without any risk of radiation exposure.[10]

Unlike CT scans, USG images are not influenced by metal artifacts. So, it will be helpful for screening maxillofacial fractures

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in patients with multiple dental restorations, fixed partial dentures, and metallic implants.[10,11]

Ultrasonography provides a safe, cost-effective, reliable, non-invasive, easily available, and portable imaging modality to screen, diagnose, follow, and treat diseases.[11,12]

Considering various studies in the literature about USG as a diagnostic tool in maxillofacial fractures, this present study is being conducted in the Department of Oral and Maxillofacial Surgery and in the Emergency Department of MES Medical College and Hospital, Perinthalmanna, Kerala, India to evaluate the efficacy of USG as a diagnostic screening tool in maxillofacial fractures and its usefulness in the management of maxillofacial injuries.

Materials and Methods

This was a descriptive diagnostic evaluation study conducted in the Department of Oral and Maxillofacial Surgery, MES Dental College and Hospital, Perinthalmanna, Kerala, India in collaboration with the Department of Radiology and Emergency Department of MES Medical College and Hospital, Perinthalmanna, Kerala, India during the period from 1 January 2021 to 31 August 2022 (19 months).

We calculated the sample size and found that it should be a minimum of 13, with an expected sensitivity of 83%, a prevalence of 18, and an absolute error of 5. However, to obtain a wide range of fractures we recruited a total of 30 individuals. Each patient was screened for 13 sites bilaterally (26 sites per patient) which accounted for a total of 780 sites. The study protocol was approved by the institutional ethical committee, MES Medical College (IEC/MES/62/2020).

Patients reported to our institution with maxillofacial trauma and suspected fracture of the facial skeleton, and those who were conscious and cooperative were included in the study. Because of the ethical reasons patients with severe soft tissue lacerations, edema, and dressings over the site of the expected fracture were excluded. Transducer manipulation might cause discomfort and agony due to which they were not enrolled in this study. Patients with absolute contraindications for CT scans were also excluded from the study since CT evaluation was a mandate for the current study.

After initial management, the patient was provided with the informed consent form which was filled and signed by the patient or by the parent if the patient is a minor. Detailed clinical examinations were carried out and significant findings were noted.

Computed tomography scans were performed using multi-detector brilliance 16-slice CT scanner (Philips). Along with coronal axial and sagittal sections, three-dimensional reconstruction of facial bone was done. A single experienced radiologist interpreted the scans. The CT scan results were considered as the gold standard against which comparisons were made.

The same patients were subjected to an USG examination which was carried out using a Logiq Pro 100 USG machine. A jelly/coupling agent was applied to the probe which is the transmitting medium. The transducer used was a linear transducer, using frequencies of the range 7–15 MHz. Ultrasonography was done in a standardized pattern on both sides of the face, beginning from the frontal region, nasal bone, orbit, zygoma, maxilla, and mandible (condyle, ramus, angle, body, parasymphysis, and symphysis) in that order. Any interruption in the continuity of the radiopaque line of the bony contour, including displacement or depression, was considered a fracture.[13] The procedure was completed without exerting pressure. The examiner who was unaware of the result of CT scans performed USG examinations.

The sensitivity, specificity, positive predictive values, and negative predictive values were calculated for USG using a CT scan as a gold standard.

Statistical Analysis

Data were analyzed using the statistical package statistical package for the social sciences (SPSS), version 26.0 (SPSS, Inc., Chicago, Illinois, USA), and the level of significance was set at $p < 0.05$. Sensitivity analysis was performed to find out the diagnostic accuracy. Sensitivity, specificity, positive predictive value (PPV), and negative predictive value (NPV) were calculated.

Results

A total of 30 patients were evaluated in this study out of which 26 were males (86.7%) and 4 were females (13.3%). Patient age ranged from 6 to 57 years with a mean age of 28.53 years. The study period was from 1 January 2021 to 31 August 2022.

In each patient, 13 sites of the face were examined bilaterally, that is, a total of 780 sites. Frontal bone, nasal bone, inferior orbital rim, orbital floor, frontozygomatic process, superior orbital rim, zygomatic arch, zygomatic body, anterior/posterolateral wall of the maxillary sinus, mandibular condyle, mandibular angle, mandibular body, mandibular parasymphysis and symphysis.

A total of 65 sites were found to be fractured based on CT findings, and this was considered as the gold standard. Ultrasonography detected 58 fractures in these 780 sites, of which 54 were true fractures, while 4 were false-positive results. However, USG was not able to detect 11 fractures.

In this study, an ultrasound scan was able to identify fractures in 9 out of 13 anatomical sites taken up for the examination with 100% accuracy (Table 1). The fracture sites which showed 100% accuracy in ultrasound scans were the zygomatic arch, zygomatic body, frontal bone, infraorbital rim, supraorbital rim, nasal bone, mandibular symphysis/parasymphysis, mandibular angle, and mandibular body.

Fractures in the case of mandibular condyle identified were 6 out of 11 cases with sensitivity and specificity of 54.5% and 100%, respectively. Undisplaced high condylar fractures and diacapitular fractures were not able to detect using ultrasonogrphy. Any of the fractures on the orbital floor was not able to identify using USG.

The overall sensitivity and specificity of USG were 83.1% and 99% respectively. The positive and negative predictive values were 93% and 98%, respectively (Fig. 1).

Discussion

Facial injuries, especially bone fractures, are clinically very significant due to their functional and cosmetic significance. Missed and maltreated fractures might result in functional and aesthetic problems, thus making an accurate diagnosis of the fracture very essential. History taking, clinical examination, and radiographic imaging plays a key role in deriving an accurate diagnosis.

Based on the clinical evaluation, an oral and maxillofacial surgeon can opt for conventional radiographic imaging or more advanced imaging modalities such as CT, cone–beam computed tomography (CBCT), magnetic resonance imaging, and USG.

Computed tomography scan is considered as the gold standard for the detection of fractures. It was the first technology to allow visualization of both hard and soft tissues of the facial bones by image processing enhancement and the ability to acquire

Table 1: Distribution of fractures detected by USG

	TP	*FP*	*FN*	*TN*	*SEN*	*SPEC*	*PPV*	*NPV*
Zygomatic arch	8	1	0	51	1	0.98	0.889	1
Zygomatic body	2	0	0	58	1	1	1	1
Frontal bone	3	0	0	57	1	1	1	1
Symphysis/parasymphysis	8	0	0	52	1	1	1	1
Mandibular angle	4	0	0	56	1	1	1	1
Mandibular body	6	0	0	54	1	1	1	1
Mandibular condyle	6	0	5	49	0.545	1	1	0.91
Frontozygomatic process of orbit	6	0	1	53	0.857	1	1	0.98
Inferior orbital rim	2	2	0	56	1	0.97	0.5	1
Superior orbital rim	1	0	0	59	1	1	1	1
Orbital floor	0	0	2	58	0	1	–	0.97
Anterior/posterolateral wall of maxillary sinus	6	0	3	51	0.667	1	1	0.94
Nasal bone	2	1	0	57	1	0.98	0.667	1
Total	54	4	11	711	0.831	0.99	0.931	0.98

FN, false negative; FP, false positive; NPV, negative predictive value; TN, true negative; TP, true positive; SEN, sensitivity; SPEC, specificity; PPV, positive predictive value, Site-wise analysis

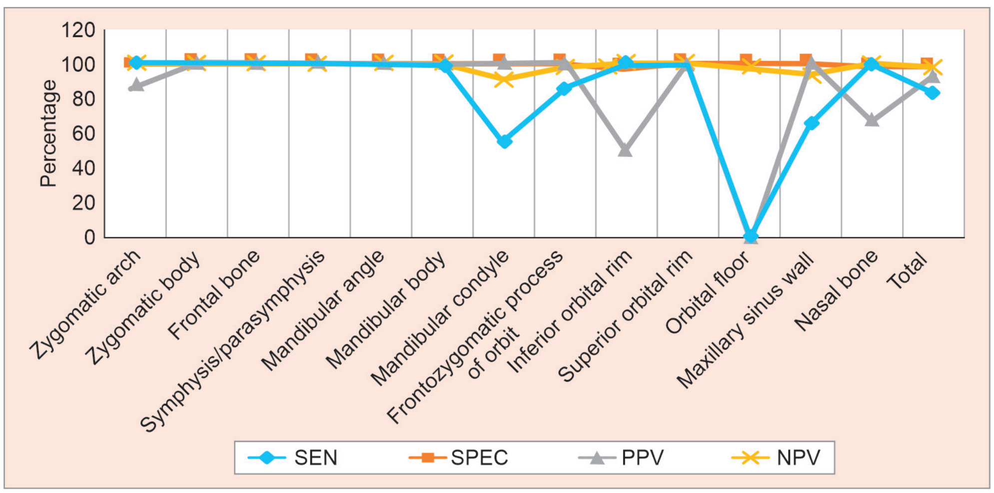


Fig. 1: Graphical representation of sensitivity specificity positive predictive value and negative predictive value of USG in fracture sites
NPV, negative predictive value; PPV, positive predictive value; SEN, sensitivity; SPEC, specificity

multiple, non-superimposed cross-sectional images.[14] Computed tomography provides high contrast resolution and the images obtained are less grainy. Three-dimensional reconstruction of the maxillofacial skeleton is also possible with CT.

However, it has certain limitations such as failure to create a real-time image, high cost, need for advanced equipment, inaccessibility to all treatment centers, and high exposure to radiation. It is contraindicated in patients with claustrophobia. Computed tomography scan requires a patient's positioning, which is not possible in some cases, such as spinal cord injuries and a patient's non-cooperation. In patients with metal implants and multiple restorations CT may cause blurring of the image due to artifacts.[14]

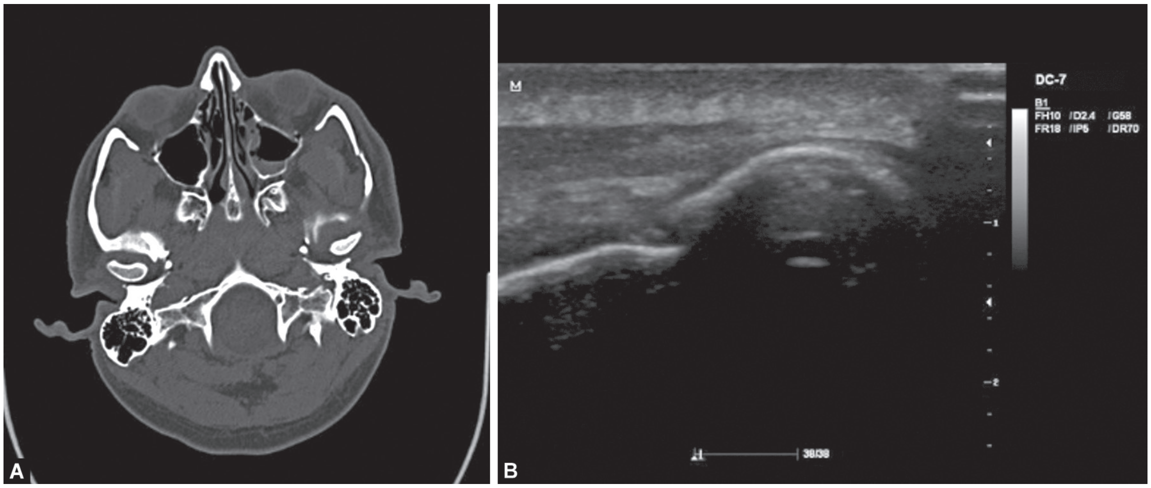
Diagnostic imaging in the field of maxillofacial surgery advanced significantly with the introduction of recent technologies in radiographic imaging such as CBCT.[14] However, considering the demerits of these imaging techniques, there is a need for a simple, cost-effective, and low-radiation exposure diagnostic screening tool.

Ultrasonography is one of the most commonly used imaging modalities worldwide. It is primarily recommended in the head and neck region for detecting pathological changes in soft tissue.[15] However, the effectiveness of USG as a diagnostic screening tool for maxillofacial fracture is less recognized.

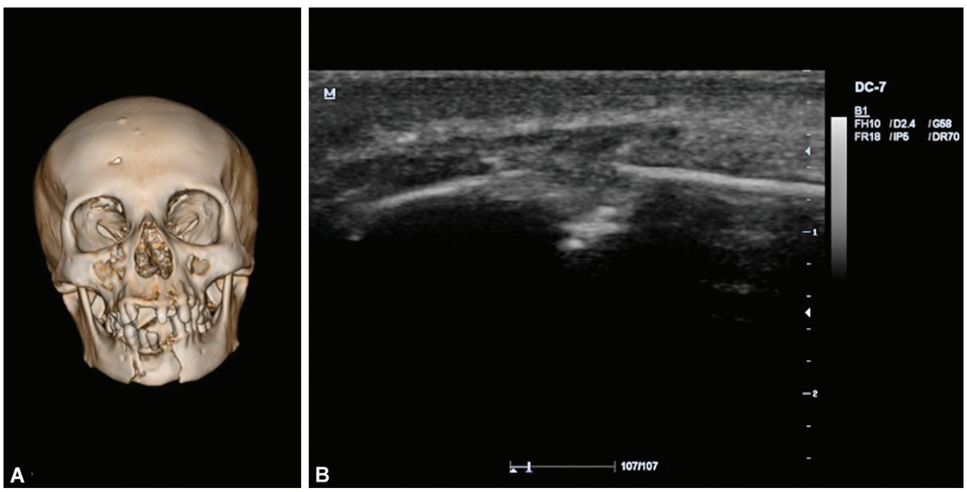
When compared with CT scan USG has its own set of advantages such as no exposure to radiation, less expense, easy availability, patient cooperation required is less and there is no requirement of patient positioning. Because of no radiation exposure, it can be used in pregnant women safely. There is no contraindication for patients with claustrophobia.[15]

With recent technological advancements, now we can transmit ultrasound waves to bony lesions and fractures of the maxillofacial region. However, ultrasound has poorer deeper bony penetration, which limits its use to the evaluation of superficial facial structures.[15]

Our study was intended to detect the diagnostic accuracy of USG as a diagnostic screening tool in the detection of maxillofacial fractures. The study was conducted in the Department of Oral



Figs 2A and B: Zygomatic arch fracture. (A) CT axial view; (B) USG



Figs 3A and B: Mandibular symphysis fracture. (A) CT 3D reconstruction; (B) USG

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In this study, only patients with fractures confirmed by CT scan were examined. A total of 30 patients with maxillofacial fractures in different anatomical sites were included in this study.

In the present study, it was found that the incidence is significantly higher in males (86.7%) as compared to females (13.3%). Shah AS et al.[16] conducted a study where the incidence of facial bone fractures in males was 84.4% and in females 15.6% which shows that males outnumber females in road traffic accidents and various forms of assaults.

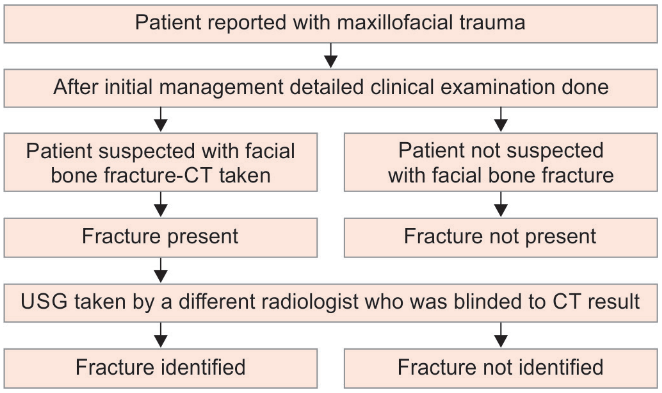
When each site was considered separately, we found that the sensitivity and specificity of USG, when compared to CT scan, were 100% for the zygomatic body, frontal bone, mandibular symphysis/parasymphysis, mandibular angle, mandibular body and superior orbital rim in the present study. This shows that there were no false-positive or false-negative values at these sites. The sensitivity of the zygomatic arch fracture (Fig. 2) was 100% but the specificity was 98% because of the one false-positive report obtained in our study. In most of the studies, the specificity and sensitivity of USG in zygomatic arch fractures were 100%. In 2014, Singh KS and Jayachandran S assessed the diagnostic accuracy of USG in zygomatic arch fractures and they also got a result of 100% sensitivity and specificity for USG in zygomatic arch fractures.[17]

Fractures over other anatomical sites over the mandible [mandibular angle, body, parasymphysis, and symphysis (Fig. 3)] were accurately detected with USG in our study with a sensitivity of 100%. Other works of literature also shows the higher accuracy of USG in the detection of mandibular fracture. In 2014, Singh KS and Jayachandran S evaluated the diagnostic accuracy of USG in the detection of mandibular fractures and the result shows an overall sensitivity of 94.7% for USG.[17]

Considering the mandibular condylar fracture, we were only able to detect 6 out of 11 fracture which accounts for a sensitivity of 54.5% and no false-positive results was present which gives a specificity of 100%. In our study USG fails to detect intracapsular fractures and simple non-displaced fractures of condyle. A study was conducted by Nezafati S et al.[18] in 2020 about the accuracy of USG in the diagnosis of mandibular fractures. In their study, the sensitivity of USG in the condyle and condylar neck was 91.6% and 85.7%, respectively (Flowchart 1).

As USG cannot penetrate deeper bony structures, detection of orbital floor fractures is difficult. In our study, we were not able to

Flowchart 1: Methodology



detect both the 2 orbital floor fractures which were identified by CT. Especially in cases where the infraorbital rim is intact, it is difficult to visualize orbital floor fracture. In a similar study conducted by Rajeev A et al.[19] in 2019, they were also not able to identify any of the three orbital floor fractures that were present in their study population.

A total of 780 sites were examined in our study, and according to CT scan 65 sites were found to be fractured. In our study, USG evaluation of all fracture sites together showed a sensitivity of 83% and a specificity of 99.4%. The positive and negative predictive values were 93.1% and 98.5% respectively (Table 1).

Rajeev A et al.[19] in 2019 conducted a study on diagnostic accuracy of USG for the assessment of facial fractures. They observed in their study that the sensitivity and specificity of USG in all fracture sites were 83.33 and 98.88% and the positive and negative predictive values were 94.59 and 96.17%.

Experience and knowledge of the examiner are very important in the case of USG examination. A thorough knowledge of the anatomy of maxillofacial bone is necessary or else it may lead to false-positive results.[20] All the Ultrasonographic examinations in our study were performed by a single experienced radiologist which helped us to reduce false results.

Results of our study suggest that the diagnostic accuracy of USG in the detection of maxillofacial fracture is satisfactory especially in case of displaced fractures except for orbital floor fracture. The zygomatic body, zygomatic arch, frontal bone, infraorbital rim, supraorbital rim, nasal bone, mandibular symphysis/parasymphysis, mandibular body, and mandibular angle were some of the sites where it was particularly helpful because all the fractures at these sites were accurately detected. As none of the orbital floor fractures was detected by USG, suggesting that a CT scan may be required to confirm the presence of a fracture at this specific location.

Computed tomography scans were more accurate in detecting maxillofacial bone fractures compared to USG, especially in deeper bone and undisplaced fractures. The major advantages of USG compared to CT were relatively less expense, absence of blurring of the image due to artifacts in patients with metallic implants, and radiation-free imaging.

Conclusion

It can be inferred from the results that the diagnostic accuracy of USG in the detection of maxillofacial fractures is satisfactory except for the orbital floor fractures. Ultrasonography was beneficial at certain sites such as the zygomatic body, zygomatic arch, frontal bone, infraorbital rim, supraorbital rim, nasal bone, mandibular symphysis/parasymphysis, mandibular body, and mandibular angle where all the fractures were accurately detected.

It may be concluded that USG may be recommended as a diagnostic screening tool to detect superficial maxillofacial fractures, as per our study.

However, further studies with larger sample sizes in multiple fracture sites should be done to draw definitive conclusions and to use USG as a diagnostic screening tool in the management of maxillofacial trauma.

Clinical Significance

Ultrasonography provides a safe, cost-effective, reliable, non-invasive, easily available, and portable imaging modality to screen maxillofacial fractures. There is no risk of ionizing radiation and it can be used safely in pregnant women and children. Ultrasonographic images are not influenced by metal artifacts, so they will be helpful for screening maxillofacial fractures in patients with multiple dental restorations, fixed partial dentures, and metallic implants.

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