Objective: To evaluate the pooled sensitivity and specificity of ultrasonography (USG) in maxillofacial fractures. Materials and Methods: A systematic search was performed in five databases (PubMed, Scopus, CINAHL, Web of Science, Dentistry and Oral Sciences Source) from inception to September 12, 2020. Studies that reported or from which sensitivity and specificity can be calculated and studies published in the English language were included. Conference proceedings, letter to editors, and case reports were excluded. Screening of studies, data extraction, and risk of bias assessment (QUADAS -2) were done separately by two review authors. A bivariate random-effects model was used to calculate the pooled estimates. Results: After the removal of duplicates, 1852 studies were included for screening of title and abstracts. Only 22 studies were included in the quantitative synthesis. The sample size ranged from 6 to 87. The majority of the studies assessed orbit and nasal bones fractures. Only two studies included a comprehensive assessment of facial fractures. The overall sensitivity and specificity values were 0.94 and 0.96, respectively. Conclusion: USG has good diagnostic accuracy for the assessment of fractures of orbit and nasal bones. Clinicians need to consider the advantages and limitations of USG before recommending advanced imaging modalities.

Keywords: Computed tomography, diagnostic accuracy, fractures, maxillofacial, ultrasonography

INTRODUCTION

Maxillofacial fractures are due to direct trauma to the face resulting in mandibular fracture, zygomaticomaxillary complex fracture, orbital floor fracture, nasal bone fracture, or a combination of any of these patterns. They are of great concern for the healthcare provider and the individual due to the complex care involved in the management. The most common causes of these fractures are road traffic accidents. The etiology and incidence of these fractures vary in different countries. The nasal bone being the most prominent bone is often prone to fracture (39% of maxillofacial fractures). The mandible and zygomaticomaxillary complex play an essential role in facial contour and mastication. A fracture in this area can affect facial appearance, function, and quality of life.[1] To restore aesthetics, function, and quality of life, it is essential to completely diagnose these fractures for effective management.

Various imaging modalities are available, ranging from simple “plain film radiography,” “ultrasonography” (USG), and “computed tomography” (CT). In the past, plain film radiography was the norm for diagnosing facial fractures. It has many disadvantages like lack of details in imaging complex facial bones, superimposition of overlying structures, image distortion, and unavailability...
of real-time imaging. These disadvantages can be readily alleviated by the use of CT, which is considered as a gold standard in imaging for maxillofacial fractures due to its enhanced clarity and details. CT is an essential tool for clinicians in diagnosing and visualizing maxillofacial fractures. It enables the diagnosis of undisplaced fractures, which are overlooked in plain film radiography. However, CT is known to have few disadvantages such as high radiation exposure, routine unavailability, high cost, distortion due to artifacts, and inability to provide real-time imaging.\(^2\)

USG is a safe, easy, and readily available imaging modality for soft tissues. The use of USG for fractures of skull, clavicle, foot and ankle, ribs, facial bones like zygomatic arch, orbit, nasal bone, mandible has been reported previously.\(^3\)\(^-\)\(^6\) Many advantages like low cost, easy availability, lack of ionizing radiation, and real-time imaging have made it an attractive low-cost, safer, and reliable imaging modality for diagnosing fractures of the maxillofacial region. A previous systematic review had recommended USG owing to its high sensitivity and specificity.\(^5\) Since then, there has been a substantial number of published studies on the use of USG for the diagnosis of maxillofacial fractures. Hence, our review aimed to evaluate the pooled sensitivity and specificity of USG in maxillofacial fractures.

**Materials and Methods**

The protocol for this systematic review was registered with INPLASY (2020120064; doi:10.37766/inplasy2020.12.0064). A systematic search was conducted in five databases (PubMed, Scopus, CINAHL, Web of Science, Dentistry and Oral Sciences Source) from inception to September 12, 2020. The references from the selected studies were searched manually. Search terms used were “Ultrasonography,” “Ultrasonic,” “echography,” “Tomography, X-Ray Computed,” “CT Scan,” “Computed Tomography,” “CBCT,” “Cone Beam Computed Tomography,” “Mandible Fracture,” “Mandibular Fracture,” “Zygoma Fracture,” “Facial Fracture,” “Zygomatic Fracture,” “Zygomatic arch Fracture,” “Orbit Fracture,” “Orbital Fracture,” “Maxilla Fractures,” “Maxillary Fractures,” “Nasal fracture,” “Nasal Bone Injuries,” “Comparison,” “Diagnosis,” “Diagnostic,” “Sensitivity,” “Specificity,” and “Accuracy.” Appropriate filters specific for various databases were applied.

**Eligibility criteria**

Studies that reported or from which sensitivity and specificity can be calculated and studies published in the English language were included. We excluded conference proceedings, letter to editors, and case reports [Table 1].

**Screening**

Two review authors (K.-C. P. and K. S.) conducted title and abstract screening independently in web-based software (Rayyan).\(^25\) Included studies were subjected to full-text screening and data extraction by two review authors separately (S. G. and A. S.). A third review author (K.-C. P.) resolved discrepancies. The reliability between the review authors was assessed using the Kappa coefficient.

**Risk of bias (RoB) assessment**

“Quality Assessment of Diagnostic Accuracy Studies-2 (QUADAS-2)” was used for RoB assessment. It has four domains (“patient selection,” “index test,” “reference standard,” and “flow and timing”).\(^26\) The first three domains also have questions on concerns regarding the applicability (CRA). Included studies were rated as “low”/“high”/“unclear.” The RoB assessment was performed by two review authors separately (K.-C. P. and A. S.).

**Statistical analysis**

Meta-analysis was performed on the data extracted from various studies (TP, FP, TN, and FN) using MetaDTA software (https://crsu.shinyapps.io/DTA_ MA/).\(^{27,28}\) and “summary receiver operating characteristic” (SROC) curve was plotted. Sensitivity analysis was performed by excluding low-quality studies to evaluate the robustness of the model. Subgroup analysis would be performed based on the study characteristics (RoB) and patient characteristics (site, transducer, and operator).

**Results**

A search from five databases yielded 2171 studies [PubMed (1173), Scopus (688), CINAHL (90), Web of Science (49), Dentistry and Oral Sciences Source (171)]. Two additional studies were identified from reference lists. After duplicates removal, 1852 studies were screened for title and abstracts. Out of these, 28 studies were screened for full-text. Only 22 studies were eligible for qualitative and quantitative synthesis [Figure 1]. The sample size ranged from 6 to 87.

| Table 1: PICOS |
| --- |
| **PICOS** |
| **Participants** | Patients (male or female) with suspected maxillofacial fractures |
| **Intervention** | Ultrasound imaging or ultrasonography |
| **Comparison** | Computed tomography scan or cone beam computed tomography (CBCT) scan |
| **Outcome** | True positive, true negative, false positive, false negative |
| **Study design** | Diagnostic accuracy studies (which report sensitivity and specificity) |
AGE AND GENDER DISTRIBUTION
The age of the participants ranged from 10 to 85. Five studies have not specified the age range of the participants. Also, three studies did not specify the sex distribution of the patients and data from 19 studies showed 544 males and 178 females.

SITE
The majority of the included studies included patients with fractures of the orbit, ZMC, NB maxilla, mandible, and only two studies included a comprehensive assessment of facial fractures. Majority of the studies used individual patients as a unit of the study. In contrast, only eight studies have used the site as a unit to calculate sensitivity and specificity.

ULTRASOUND TRANSDUCER
The ultrasound transducer used among the included publications had a range of 3–15 MHz. Three studies used a 5 MHz transducer, and one study used an additional water bath with the 5 MHz transducers. Eight studies used a 7.5 MHz transducer and two studies used a 10 MHz transducer exclusively for all the patients.

SENSITIVITY AND SPECIFICITY
Among the included publications, the sensitivity values ranged from 83% to 100%, whereas the specificity values ranged from 0 to 100% [Table 2].

ASSESSMENT OF ROB AND CRA
The quality assessment was evaluated by the QUADAS-2 tool. The majority of the studies fall under low-risk category for the RoB assessment in various domains assessed viz., “patient selection” (n=17), “index test” (n=16), “reference standard” (n=15), and “flow and timing” (n=21). All the studies had low CRA in the domains of “patient selection,” “index test,” and “reference standard.” Overall, 11 studies were categorized as low risk and 11 as high risk [Table 2].

Figure 1: PRISMA flow chart
The threshold effect was assessed using Spearman's correlation analysis between sensitivity and false positivity rate which was below the cut-off point of 0.6 (coefficient = 0.53), suggesting a low heterogeneity. The overall pooled sensitivity and specificity were 0.94 and 0.96, respectively. Three studies showed null value for specificity. We conducted sensitivity analysis by excluding these studies, which showed minimal variation in the pooled estimates.

### Subgroup analysis
The pooled sensitivity (0.91) and specificity (0.96) showed only minimal variation in low RoB studies when compared with overall estimates. Similarly, the pooled sensitivity (0.97) and specificity (0.92) also showed only minimal variation in high RoB studies. Studies conducted on orbit showed similar values to overall estimates, whereas studies conducted on nasal bone showed higher pooled sensitivity. The majority of the studies have used high-resolution transducers. Studies that used low- and high-resolution USG transducer have reported sensitivity and specificity estimates similar to overall estimates. In most of the studies, radiologists or sonologists have performed the USG.

### Discussion
The pooled sensitivity and specificity obtained in this meta-analysis were 94% and 96%, respectively. Subgroup analysis with respect to RoB, site, transducer, and operators showed no much variations when
compared with overall estimates of sensitivity and specificity.

A previous systematic review highlighted that the factors such as the operator’s experience, resolution of the transducer, standardized technique, real-time visualization, and USG investigation from the time of injury might influence the validity of USG. The majority of the included studies have used experienced operators and a standardized technique. There were substantial variations in the transducer used in the included studies. Higher frequency transducers allow the evaluation of superficial characteristics as it has minimal depth penetration. Lower frequency transducers allow greater depth penetration with lowering image quality at more than 6 cm. However, in the maxillofacial region, deeper imaging may not be required with USG. Most of the studies used real-time visualization of the fracture. The USG investigation from the time of injury was not reported widely among the included studies.

The majority of studies have evaluated fractures in the orbital and nasal bone areas. Nasal bone fractures showed high sensitivity and specificity values followed by orbital fractures. This supports the use of USG as a diagnostic tool for orbital and nasal bone fractures. Good quality studies in other maxillofacial areas are required to endorse the diagnostic validity of USG. Future research should evaluate the influence of timing of USG from the time of injury, the time required for complete standardized USG, pain or discomfort due to the application of transducer on abrasions or wounds.

Many advantages of USG include availability even in low resource settings, portable, relatively cheap, minimal patient compliance and positioning,

Figure 2: SROC curve
real-time imaging, repeatable, and minimal radiation. However, there are certain limitations noted in earlier studies such as the inability to differentiate complex fractures, identification of intracapsular fracture of the condyle, new vs. old fractures, anatomical vs. fractures, inability in the detection of non-dislocated fractures, poor visualization of the posterior orbital floor, and limited coverage during acute situations. Clinicians need to consider the above limitations and adapt to the advanced imaging modalities as per the trauma presentations.

ACKNOWLEDGEMENTS
Nil.

FINANCIAL SUPPORT AND SPONSORSHIP
Nil.

CONFLICTS OF INTEREST
There are no conflicts of interest.

AUTHORS CONTRIBUTIONS
Not applicable.

ETHICAL POLICY AND INSTITUTIONAL REVIEW BOARD STATEMENT
Not applicable.

PATIENT DECLARATION OF CONSENT
Not applicable.

DATA AVAILABILITY STATEMENT
Not applicable.

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