Content available at: https://www.ipinnovative.com/open-access-journals

IP International Journal of Maxillofacial Imaging

Journal homepage: https://www.ijmi.in/

Original Research Article

Ultrasonography as an alternative to radiographs in assessing fracture healing

Dimple Sethia[1,*], Amith Hadhimane[1], Kirthi Kumar Rai[1], Shiva Kumar HR[1], Shiva Kumar Patil[2]

[1]*Dept. of Oral and Maxillofacial Surgery, Bapuji Dental College and Hospital, Davangere, Karnataka, India*
[2]*Dept. of Radiology, J.J.M Medical College, Davanagere, Karnataka, India*

ARTICLE INFO

Article history:
Received 22-02-2023
Accepted 14-03-2023
Available online 18-04-2023

Keywords:
Fracture healing
Ultrasound
OPG
Mandible fractures

ABSTRACT

Purpose: To determine whether ultrasound can assess healing of bone and check the development of callus prior to conventional radiograph thereby enabling early diagnosis of delayed union or confirmation of union.

Materials and Methods: Fracture healing was evaluated with ultrasonography and radiography on specific intervals until healing was complete; in 20 fracture sites. Based on the findings of ultrasonographic and radiographic scores were assigned to classify healing.

Result: 18 out of 20 fracture sites had completely healed with mature callus formation at the end of 3 months while only 2 fracture sites showed delayed healing. In patients with normal healing, colour doppler ultrasound showed neovascularisation in the 1^{st} month of healing. With time, it was noticed that the depth and width of the fractured site was reducing and becoming more isoechoic with the adjacent normal bone sites. Assessment of these parameters being more evident on the USG were statistically significant when compared with OPG.

Conclusion: Ultrasound can be considered as a useful guide in assessing fracture healing as a replacement to conventional imaging modalities such as the OPG, particularly in the early prediction of impaired fracture healing.

1. Introduction

High mortality and morbidity have been attributed to fractures of the human body. The incidence of fractures is on rise due to changes in socio-economic behaviours. The medical, economic and social effects of fractures are manifold.[1] In all facial injuries, a mandibular fracture must be excluded within the viscero-cranium. A mandibular fracture is suspected if a patient presents with malocclusion, trismus, broken teeth or obvious step deformity. Diagnostic imaging allows the severity of the fracture to be classified, which therefore decides treatment options.[2] Hence, the aim of the treatment is to help the patient to return to the routine activities of living independently as soon as possible. But if the process of fracture healing is not appropriate it may lead to complications like delayed healing, non-healing, or even fibrous union. Therefore, to correctly detect whether the process of healing is taking at par or not is the main requirement. Non-invasive diagnosis is possible with the help of plain radiography, CT scan, MRI scan as well as ultrasound scan.[1] Ultrasonographs have provided with valuable information about the bony union and has predicted the delayed and non-unions earlier than standard plain radiographs.[3] Additionally, it is cheaper and does not cause any radiation exposure. Hence, the aim of this study was to evaluate ultrasonography as a sound alternative for

* *Corresponding author*.
E-mail address: dimple.sethia@gmail.com (D. Sethia).

https://doi.org/10.18231/j.ijmi.2023.004

diagnosing, instead of plain radiographs and other expensive modalities.

2. Materials and Methods

All the patients were informed about the procedures involved, and those willing to be part of the study were enrolled and were provided with printed informed consent forms. After getting their consent, Case pro forma was made to record the history and the associated signs and symptoms in detail.

Clinical examination of the patient was done intraorally and extra-orally, preceded by detailed recording of history of the patient. After determining the proper diagnosis, radiological confirmation was obtained using Orthopantomogram and other necessary radiographs, Ultrasonography was also carried out using GE machines (Logiq S7 & Logiq P9) and with a linear high frequency probe 7-12MHz.

Routine preoperative biochemical investigations were carried out.

The surgery was carried out under general anaesthesia with nasal intubation. Appropriate incision was made to approach the region of mandibular fracture. After the location and reduction of fractured fragments, a stable osteosynthesis of the fracture was performed. Post-op radiograph and ultrasonography was taken periodically, i.e., immediate post-op, 1month post-op and at 3 months post-op.

This project has been reviewed and approved by ethical committee of Bapuji Dental College and Hospital, RGUHS (2018).

3. Results

The study consisted of 20 fracture sites in the mandibular region. The patients were operated for the fracture through open reduction and internal fixation.

3.1. The following parameters were assessed

Discontinuity of bone, Presence of fractured fragment, Vascularity, Approximation of fractured fragments, Alignment of fractured fragments, Hematoma, Displacement of the fracture.

A fracture is described as discontinuity in the bone. Hence, this is a parameter of choice. In all pre-op cases except 1, discontinuity was observed in USG. The 1 case that was not evident on USG was a non-displaced condylar fracture, which however was evident on the OPG. A significant difference between OPG and USG was noted, in the presence of discontinuity at 1-month post-operative period. The OPG showed absence of discontinuity in 4 fracture sites whereas USG showed discontinuity only in 1 site instead, showing the presence of soft callus which was not picked by the OPG. However, there was no statistical difference in the visualization of discontinuity in the 3^{rd} month, suggesting healing of the fracture site. Clinically at end of 3 months there were was no step deformity or mobility of the segments.

A fracture is classified into simple and comminuted fracture based on the number of fracture lines or fracture fragments. The fractured Fractured that were observed in OPG and USG were found to be similar across the views.

The alignment of the fractured fragments showed no significant difference between OPG and USG. But, the quality of being ‘well aligned’ rather than just ‘Aligned’ was more evident and better visualized using USG throughout the study period.

In the immediate post-op USG, hematoma was noted in all the fracture sites. As the time period of healing increased, the hematoma in the fracture site was replaced by homogenous tissue and later with mature callus and it was significantly viewed in USG but OPG doesn’t show this progress (Table 1).

Also, the absence of vascularity in fracture site was gradually replaced by development of normal vasculature and it was significantly viewed in the USG (Table 2). A well vascularised callus indicates a healthy callus.

Approximation of the fracture fragments is an indication of replacement of hyaline cartilage with bone thereby predicting endochondral ossification and bony substitution of woven bone. Through the healing period, USG shows significantly more substantial information about the approximation of fracture fragments as compared to OPG (Table 3).

The depth of fracture Site was not amenable to be studied in OPG, which was clearly seen in USG and it showed a significant reduction in the depth of fracture dimensions over the healing period (Table 4).

The 2 fracture sites that showed delayed Union had no significant clinical signs and symptoms, but on USG it was observed that the bridging of the fracture gap with inhomogeneous tissue (mix of hypoechoic and hyperechoic) was persistent till 3.5 months and the gradually became homogenous and progressed to complete healing by 4 months. The changes during the 3^{rd} month were however not significantly observed in OPG.

4. Discussion

Diagnosis of maxillofacial fractures are based on clinical and radiographic findings. The plane radiographs obtained in emergency settings are often of minimal diagnostic value. Fractures of the mandibular symphysis, body and angles are identified clinically, subcondylar fractures however are not accessible for clinical evaluation. The aid of ultrasonography is reliable, highly sensitive and specific and cost-effective.[4] The creation of an image from sound is done in 3 steps- producing a sound wave, receiving echoes and interpreting the echoes.[4] Bone has some intrinsic features that make ultrasound examination attractive. The interface between the skin, the soft-tissue envelope, and the bone structure has distinctive planes. The dense nature of bone causes reflection of the ultrasound waves, allowing a clear distinction from the soft-tissue envelope and creating a hyperechoic (bright) reflection from the cortical surface. Fractures can be visualized as a break in the smooth cortical contour and the developing haematoma, and subsequent callus formation can be visualized from an early stage starting as an anechoic (dark) shadow, with a similar appearance to articular cartilage, becoming increasingly hyperechoic with calcification such that the normal appearance of cortical bone is restored. Ultrasound has several appealing features for evaluating fracture healing. It is noninvasive, does not use ionizing radiation, and is delivered in real time. Healing of fracture occurs in phases following the order sequentially – Inflammation (1-7 days post fracture), Soft callus formation (2-3weeks post fracture), Hard callus formation (3-12 weeks post fracture) and Remodelling (months to years) (AO-trauma). Conventional radiographs are slow to detect callus formation, which limits their accuracy for the early diagnosis of a delayed union. It is reported to take six to eight weeks for callus to be present and often beyond ten weeks for bridging callus to be evident on plain radiographs.[5,6] Furthermore, given the 2D Projection nature of radiographs, the sensitivity of detecting a bridging callus can be challenging.[7] However, it can reliably be detected in ultrasonography. While reading a USG scan, a predictable pattern of anechoic signal was present before the site evolved into hyperechoic cortical bone, which did not allow transmission of the ultrasound beam. Hyperechoic signal indicated conversion of soft callus to calcification of it. This was consistently detected prior to the appearance of callus on plain radiographs, which was not apparent before eight weeks.[6] Sensitivity of USG in detecting a fracture is 92% slightly higher than an OPG which is 66%.[8] In a larger study by Ricciardi et al, 239 diaphyseal fractures treated with external fixators were monitored for fracture healing at regular intervals. The authors found that seven days after surgery, a haematoma could be seen in the fracture gap as a hypoechogenic area with an irregular perimeter.[9] Beyond 10 to 16 days, a dense, dark anechoic material was visible in keeping with soft callus formation. This became increasingly hyperechogenic, in keeping with calcification of the fracture site seen between days 20 and 35, but with some penetration, which allowed it to be distinguished from the intact cortical bone. Beyond 35 days, the callus was no longer penetrated by the ultrasound and a uniform acoustic shadow was observed. At this point, the early callus could be visualized on conventional radiographs. In our study, stages of fracture healing were compared to the characteristics of ultrasonography and radiography as described in the tables 5 and 6[10,11 12] The staging gives a clearer distinction of healing and a better insight to understanding the comparison of radiographs and US.[13]

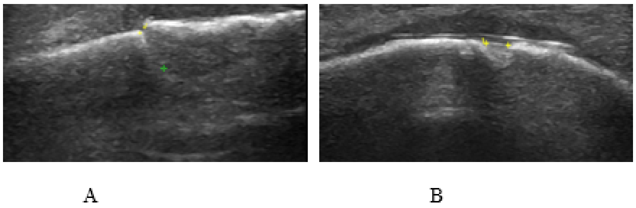

Fig. 1: USG at fresh right body fracture, **A:** Depth of the fracture marked with yellow and green +, **B:** Approximation of fragmanets marked with yellow ++

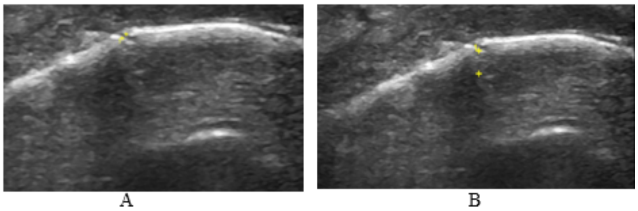

Fig. 2: **A:** USG at right body showing immediate approximation after open reduction and internal fixation marked by yellow++, **B:** USG at right body showing immediate depth after open reduction and internal fixation marked by yellow++

4.1. Right body 1 month: Approximation

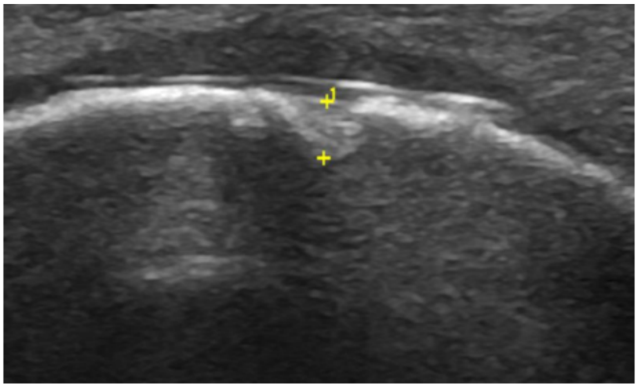

Fig. 3: USG at right body at 1 month post-operative period showing depth of the fracture healing marked by yellow++. Approximation, alignment of the fracture can be visualised.

Our results suggest that US can be used to assess primary fracture healing. It appeared to allow earlier assessment of fracture healing than radiography. All our cases except 2 fracture sites showed healing without any delayed union or non-union. The limitation of USG is that it has a learning curve, continuous moving of the probe over the fracture site can induce painful experience in the patient, measurements

Table 1: Presence of hematoma in USG group

Timeline	Hematoma					P value
	Absent	Present	In-homogenous tissue	Increasingly homogenous	Replaced by mature callus	
Pre-op	18	2	0	0	0	0.001
Immediate post-op	0	20	0	0	0	
1^{st} month PO	0	0	17	3	0	
3^{rd} month PO	0	0	0	2	18	

Pre-op=Pre operative, Post-op=Post operative, PO= Post operative, OPG=Orthopantamograph, USG=Ultrasound

Table 2: Presence of vascularity in USG Group

Timeline	Vascularity		P value
	Absent	Present	
Pre-op	20	0	0.009
Immediate post-op	20	0	
1^{st} month PO	2	18	
3^{rd} month PO	18	2	

Pre-op=Pre operative, Post-op=Post operative, PO= Post operative, OPG=Orthopantamograph USG=Ultrasound

Table 3: Approximation of fracture fragments over time in the groups

Timeline	Group	Mean	SD	P value
Pre-op	OPG	1.8350	.70050	0.18
	USG	2.2550	1.2028	
Immediate post-op	OPG	.5510	.29813	0.008
	USG	1.1190	.85901	
1^{st} month PO	OPG	.4190	.24931	0.001
	USG	.6810	.21220	
3^{rd} month PO	OPG	.2203	.01890	0.007
	USG	.1080	.16926	

Pre-op=Pre operative, Post-op=Post operative, PO= Post operative, OPG=Orthopantamograph, USG=Ultrasound

Table 4: Change in depth of fracture site in USG view

Timeline	Mean (mm)	SD	P value
Pre-op	5.0190	1.88891	0.001
Immediate post-op	3.6445	1.41015	
1^{st} month	2.4910	1.71522	
3^{rd} month	.4270	.87871	

Pre-op=Pre operative, Post-op=Post operative, PO= Post operative, OPG=Orthopantamograph, USG=Ultrasound

Table 5: Ultrasonographicscoring system

Stage of fracture healing	Charactersitics
1	Tissue within the fracture gap appears anechoic to hypoechoic, with possible hematomas and fragments; no vascularization is visible by use of power Doppler ultrasonography
2	Tissue appears hypoechoic (soft tissue callus) but is now heterogeneous; vascularization (determined by use of power Doppler ultrasonography) is clearly present in the soft tissue
3	Evidence of bridging of the fracture gap with inhomogeneous tissue (mix of hypoechoic and hyperechoic areas); vascularization (determined by use of colour Doppler ultrasonography) is present but less abundant than in stage 2
4	Increasingly homogeneous, hyperechoic image of the tissue at the fracture site (acoustic shadow returns); vascularization is still present and appears to be located on the bone surface rather than in the soft tissue
5	Mature callus is present; homogeneous, hyperechoic tissue bridging the facture gap; the surface of this bridge will progressively appear smoother, compared with previous interrogations; vascularization is not detectable by use of power Doppler ultrasonography

Table 6: Radiographic scoring system

Grade of fracture healing					
Variable	1	2	3	4	5
Callus Formation	Homogeneous bone structure	Massive bone trabeculae crossing fracture line	Apparent bridging of fracture line	Trace or no bridging of fracture line	No callus formation
Fracture Line	Obliterated	Barely discernible	Discernible	Distinct	Distinct
Stage of Union	Achieved	Achieved	Uncertain	Not Achieved	Not Achieved

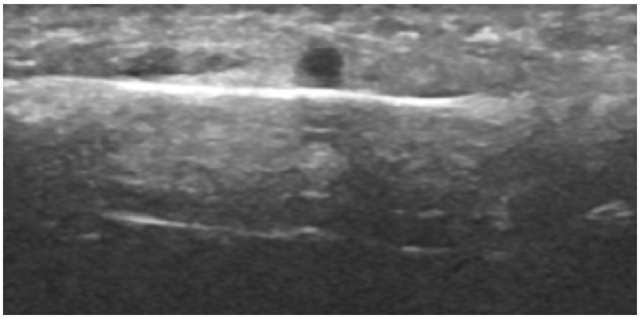

Fig. 4: USG at right body at 3 month post operative period showing healed fracture.

should be made in real time only. But it can be safely said that ultrasonography is a very good assessment tool in assessing instant fracture healing.

5. Conclusion

Ultrasound can be considered as a useful guide in assessing fracture healing as a replacement to conventional imaging modalities such as the OPG, particularly in the early prediction of impaired fracture healing.

6. Source of Funding

None.

7. Conflict of Interest

None.

References

1. Kachewar SG, Kulkarni DS. Utility of Diagnostic Ultrasound in Evaluating Fracture Healing. *J Clin Diagnostic Res*. 2014;8(3):179.
2. Naeem A, Gemal H, Reed D. Imaging in traumatic mandibular fractures. *Quant Imaging Med Surg*. 2017;7(4):469–79.
3. Chachan S, Tudu B, Sahu B. Ultrasound Monitoring of Fracture Healing: Is This the End of Radiography in Fracture Follow-ups? *J Orthop Trauma*. 2015;29(3):133–8.
4. Thiyagarajan V, John R, Narendran. Efficacy of USG in detection of fractures in maxillofacial trauma. *Papirex Indian J of Res*. 2018;7(5).
5. Leow JM, Clement ND, Tawonsawatruk T, Simpson CJ, Simpson A. The radiographic union scale in tibial (RUST) fractures: reliability of the outcome measure at an independent centre. *Bone Joint Res*. 2016;5(4):116–21.
6. Young JW, Kostrubiak IS, Resnik CS, Paley D. Sonographic evaluation of bone production at the distraction site in Ilizarov limb-lengthening procedures. *AJR Am J Roentgenol*. 1990;154(1):125–8.
7. Perks F, Simpson AH. What is the role of ultrasound in fracture management? *Bone Joint Res*. 2019;8(7):304–12.
8. Chayra GA, Meador LR, Laskin DM. Comparison of panoramic and standard radiographs for the diagnosis of mandibular fractures. *J Oral Maxillofac Surg*. 1986;44(9):677–9.
9. Ricciardi L, Perissinotto A, Dabala M. Mechanical monitoring of fracture healing using ultrasound imaging. *Clin Orthop Relat Res*. 1993;293:71–6.
10. Risselada M, Kramer M, Bree HV. Ultrasonographic and radiographic assessment of uncomplicated secondary fracture healing of long bones in dogs and cats. *Vet Surg*. 2005;34(2):99–107.
11. Risselada M, Bree HV, Kramer M. Ultrasonographic assessment of fracture healing after plate osteosynthesis. *Vet Radiol Ultrasound*. 2007;48(4):368–72.
12. Whelan DB, Bhandari M, Mckee MD. Interobserver and intraobserver variation in the assessment of the healing of tibial fractures after intramedullary fixation. *J Bone Joint Surg Br*. 2002;84(1):15–8.
13. Pozzi A, Risselada M, Winter MD. Assessment of fracture healing after minimally invasive plate osteosynthesis or open reduction and internal fixation of coexisting radius and ulna fractures in dogs via ultrasonography and radiography. *J Am Vet Med Assoc*. 2012;241(6):744–53.

Author biography

Dimple Sethia, Consultant

Amith Hadhimane, Reader

Kirthi Kumar Rai, Professor and HOD

Shiva Kumar HR, Professor

Shiva Kumar Patil, Consultant

Cite this article: Sethia D, Hadhimane A, Rai KK, Shiva Kumar HR, Patil SK. Ultrasonography as an alternative to radiographs in assessing fracture healing. *IP Int J Maxillofac Imaging* 2023;9(1):25-29.