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FOLLOW UP OF BONE HEALING BY ULTRASONOGRAPHY IN MANDIBULAR TRAUMA PATIENTS. IS IT VALUABLE?

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ABSTRACT

OBJECTIVE: Only a few studies have described successful monitoring of the fracture healing process. The study aims to assess the efficacy of ultrasonography in monitoring mandibular fracture healing and compare it to conventional panoramic radiography.

MATERIALS AND METHODS: The study is a prospective trial conducted on 40 adult patients with a recent non-comminuted mandibular fractures requiring internal fixation with functionally-stabilized osteosynthesis. Patients were postoperatively evaluated for the clinical assessment of complication. Fracture healing analysis was assessed at regular intervals for 12 postoperative weeks using ultrasound and the conventional panoramic Xray. The Moed scoring index was utilized for quantitative representation of the data. Statistical analysis was performed along with data correlation and agreement analysis. Significance was set at the 5% level.

RESULTS: Thirty-eight of 40 fractures achieved union whereas 2 developed non-union at the 8th postoperative week. ultrasonography and radiography showed statistically significant monitoring of mandibular osseous fracture healing. Moreover, ultrasonography was significant in detecting the dynamic callous formation at the fracture site earlier than the radiography. Hyperechogenisty on USG was found to be more evident than radiography in confirming fracture healing progress.

CONCLUSION: Ultrasonography sounds to be significantly efficient and safe alternative to conventional radiography with high rates of sensitivity in the monitoring of mandibular fractures healing. Moreover, In the early phases of bone healing monitoring, USG is quite useful for identifying bone healing problems earlier than the radiography.

KEYWORDS: bone healing, ultrasonography, mandibular fractures, bone healing, fracture healing analysis.

RUNNING TITLE: Bone Healing assessment by Ultrasonography in Mandibular Trauma.

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INTRODUCTION

Mandibular fracture management is in continuous evolution in the literature, by introduction of contemporary fixation modalities and biomechanical studies, in order to achieve a prompt bone healing and rapid return of both mandibular function and bone natural remodeling course[1, 2]. Internal fixation of mandibular fractures with respect to the biomechanical principles and bone trabeculae trajectories using 2.0 miniplates is considered a functionally stabilized fixation modality for mandibular fracture management. This achieves a predictable and proven return of mandibular function and curbs the fracture immobilization period[3]. Despite that, the contemporary literature only stress on the prompt return-to-work regarding functionally-stabilized mandibular fracture fixation modality, with a long term radiographic follow-up to check the bone healing progression[1, 4].

One of the most important and fundamental clinical decisions in fractures' management is to determine bone healing, however this could be monitored radiographically or histologically[5, 6]. Fracture healing radiographic evaluation methodologies should be repeatable, which result in escalation of total patient radiation exposure over time, and generating concerns about the overall administered dosage. According to the ALARA methodology, radiographic examinations to provide necessary diagnostic information should be curbed to bare minimum[7, 8].

The most commonly utilized radiographic evaluation modality in mandibular fracture is ionizing X-ray, with either conventional projection, Ortho-pantographic panoramic (OPG) view, or three-dimensional topographic modalities[9]. Albassal et al reported that OPG is a reliable radiographic assessment modality for mandibular fractures, with 92% reported sensitivity[10].

Ultrasonography (USG), with its different modes, has a plethora of applications in the oral and maxillofacial field, ranging from soft tissue pathology detection,

vascular masses diagnosis and flow assessment, Fine-needle biopsy guidance and salivary sialolith detection[11, 12]. Utilization of USG as bone-related radiographic modality is rare. When compared to other adjunctive diagnostic modalities, USG offers a non-ionizing real-time imaging which is patient-compatible, cost-effective, and readily-available[13].
The non-ionizing nature of USG make it a preferable modality for treatment follow up in several medical fields[14]. Rathwa et al reported that USG is reliable imaging modality for monitoring bone healing progression in the orthopaedic filed, reporting temporal association of USG hyper-echogenicity and fracture healing[15].
Only a few records exist in the current literature that show the follow up of fracture healing with ultrasonography in orthopaedic trauma patients[16, 17]. Hence, this study aimed to question the efficacy and outcomes of ultrasonography in bone healing sequential monitoring of mandibular fractures management. Patient clinical assessment and occlusal analysis was set as the secondary outcome of this study. The null hypothesis was set that there is no difference in the functional outcome between the USG and conventional OPG in scrutinizing mandibular fracture bone healing.

PATIENTS AND METHODS

Study design

The study was implemented as a prospective clinical trial design where each patients received a single treatment simultaneously following the STARD guidelines (https://www.equator-network.org/reporting-guidelines/stard/)[18]. This study was conducted on forty adult patients who met the eligibility criteria based on sample size calculation with respect to procedural errors and follow up loss. Software Sample size was calculated based on the mean (SD) required duration for fracture diagnosis of 10.85 (3.40) and 14.08 (4.72) weeks for the ultrasonography and radiography respectively (12). To calculate the required sample to achieve a 80% study power and 5% alpha error, difference between dependent means using the highest SD (= 4.72) was utilized based on the Rosner's method (Gpower 3.1.9.7) [19, 20]. Local ethical committee approval was granted (Fayoum University-FU-SCSRE- EC 2310). Informed written consents agreement were obtained from all patients prior to enrolment in this study, which was conducted with respect to the Helsinki guidelines.
Patients were selected from those admitted to the emergency department of Alexandria University Teaching Hospital from February 2023 to March 2024. Enrolled patients were adults, above 18 years old, with no gender predilections, suffering from recent, uninfected, non-comminuted, unfavourable mandibular fracture, that demands open reduction and internal fixation (ORIF). patients with history of metabolic or systemic diseases affecting bone or healing process, and those with neglected, infected, comminuted, and old fractures were excluded. All the surgical procedures were performed in the Oral and Maxillofacial Surgery Department, Faculty of Dentistry, Alexandria University.
All of the selected subjects were thoroughly assessed and properly examined clinically and radiographically. A preoperative high resolution Computed Tomography (CT) scan (Philips Brilliance 64 MDCT, Philips, Eindhoven, Netherlands) was taken for all the patients to reveal the site, number, extent, and pattern of fracture lines.

Surgical Phase

ORIF for the mandibular fractures were conducted under general anesthesia with nasotracheal intubation, and single operator was used for all the enrolled patients (N.A). After scrubbing and draping of the field, the fracture/s were exposed through either extraoral or intraoral surgical approaches according to each case. Dis-impaction of the fracture segments and removal of any granulation tissues or any soft tissue entrapped within the fracture line was conducted before manual reduction of the fractured segment into proper anatomical configuration. The patient's occlusion was checked and placed into maximum intercuspation with temporary intermaxillary fixation (IMF), then fracture fixation was performed using conventional titanium miniplates and screws (JEIL Medical Corporation Company: Seoul, Korea). Chosen fixation protocol was selected according to the fracture configuration, location, and based on Champy's recommendations. IMF was released, occlusion was verified, and closure of the surgical wound was conducted according to the selected approach.
Patients were prescribed antibiotics for 5 days (Amoxicillin 875 mg + Clavulanate 125 mg: Augmentin ,GlaxoSmithKline, UK) (Metronidazole: Flagyl,GlaxoSmithKline UK), along with anti-oedematous (α-chemo-trypsin) and analgesic anti-inflammatory (Ibuprofen: Brufen, Abbott) drugs. All patients were given instructions of soft, fully liquid, high protein, high calorie diet, maintenance of good oral hygiene, avoid clenching, and any other traumatic overload to the mandible for a period of up to 4 weeks postoperatively.

Clinical assessment parameters

All patients were evaluated clinically at the following intervals, immediate postoperative, every week for one month, 2, and 3 months postoperatively for the assessment of postoperative complications, and for occlusal assessment.

Radiographic Vs Ultrasonographic Fracture Healing Assessment (FHA)

For comparison of the fracture healing, radiographic and ultrasonographic methods were utilized for all of the enrolled patients. FHA was conducted at 24-hours session, followed by 2^{nd}, 4^{th} , 8^{th} and 12^{th} postoperative weeks periods. All patient's personal information was recorded, and direct contact with the patient's was established using the telephone numbers in order to ensure ease of recall and to provide keen and up to date follow up. For both assessment methods, a single investigator was assigned to score all of the obtained records from all the patients. Patients data and follow-up timing was blinded from the assigned investigator (O.G). Radiographic assessment was done with the aid of Orthopantomogram (OPG), using the orthostate device for standardization (Orthophos E Dentsply Sirona Charlotte, NC USA)[21]. USG assessment was done by using Philips Hd5 Ultrasound System (Koninklijke Philips/ATL N.V) with a linear transducer to identify and evaluate the dynamic bone callus formation process and assess the extent of fracture healing by detecting the changes in the fracture gap through monitoring the changes in the echogenicity appearance of the fracture gap[22]. Regarding the USG examination operation, the linear transducer was coupled to the extra-oral skin using ultrasonic conductive gel then positioned correctly at the level of the fracture site to examine it in the transverse plane, taking care to be away from the surgical wound without causing additional discomfort to the patients till the fracture site is viewable on the device monitor. Ultrasound examination of the fracture site was performed by the same operator, with the same ultrasound device each time (Figure 1).

For both the OPG-FHA and USG-FHA, the "Moed Scoring Index" was utilized for qualitative assessment of the investigated modalities, along with the quantitative scoring[23]. Moed criteria is based on the creation of a continuous callus, and the clarity of the fracture line criteria. The scoring standard included four levels, each level is assigned to an ascending score value (Figure 2). The Friedman test with its post hoc test was performed to analyse differences in fracture scores at different time intervals. Wilcoxon Sign rank test was used to compare "Moed Scoring Index" fracture outcome between OPG and USG. All tests were two tailed and the significance level was set at p value ≤0.05. Data were analysed using IBM SPSS (V 23, Armonk, NY, USA).

Fracture Healing Assessment modalities correlation and data agreement

In an attempt to analyse the linear relationship between the OPG and USG FHA modalities, correlation between Moed scores was assessed using Spearman correlation coefficient (ρ)[24]. The ρ values range from -1 to 1, where a ρ score =1 means a perfect positive association and a ρ score of -1 means a perfect negative correlation[24]. Degree of agreement between the two investigated FHA raters was examined using Cohen's kappa coefficient (κ)[25, 26]. The κ ranges from 0 to 1, where any report below 0.5 is poor agreement and those above 0.9 are excellent agreement[25, 26]. Significance level was set at p value ≤0.05.

RESULTS

The study was conducted on 40 patient suffering from mandibular fractures, The age range was (22-46 years) with mean age of 32.40 ± 7.56 years, and male-to-female ratio of 2.3:1. Demographic analysis of the study is presented in Table 1. An uneventful clinical follow-up was reported in 72.5% of the cases, with normal occlusal analysis. On the other hand, complications were reported in 11 patients (27.5%). Only 2 cases (5%) reported occlusal disharmony at the early follow-up period. Both patients required a minor selective griding in order to attain harmonious occlusion, which was achieved in the subsequent follow-up session. Wound dehiscence was reported in 1 case, where an intraoral approach was utilized. Wound debridement, irrigation, and strict care showed allowed the wound to close by secondary intention by the end of the clinical follow-up period. Hardware failure 2 (5%) due to postoperative infection at the second postoperative week as the patients were not follow the oral hygiene instructions nor the medications the two cases underwent non-union at the 8^{th} postoperative week.

Fracture Healing Assessment

The "Moed scoring index" was utilized for Fracture Healing Analysis (FHA) in a regular intervals analysis. In the OPG-FHA, a mean score of 1.00 ± 0.00 was reported in the first two follow-up sessions (P=1.000). A mean value was of 1.98 ± 0.16 was reported at the 4^{th} postoperative week, which plateaued in the 8th week. A statistical significant increase was reported in the 12^{th} postoperative week when compared to the previous follow-up period, reporting a mean score of 2.95 ± 0.32 ($P<0.0001^*$) (Table 2). In the USG-FHA, a statistically significant increase in the mean score was reported in the 2^{nd} postoperative week ($P=0.033^*$). A similar increase was reported in the 4^{th} postoperative week, however the difference between the subsequent follow up periods was statistically insignificant (P=0.080). In the 8^{th} postoperative week, a statistically significant increase was reported when compared to the previous follow-up session ($P=0.006^*$). Lastly, the difference between the 12^{th} and 8^{th} postoperative weeks was statistically insignificant (P=1.00) (Table 3).

Using both FHA modalities and across the follow-up period a statistically significant increase in the mean

Moed score was reported (P<0.0001*). Excluding the first FHA follow-up session, comparison between the two FHA modalities showed a highly statistical significant difference in all of the investigated follow-up periods (P<0.0001*) (Table 4, Figure 3).

Figure 1. Ultrasonographic examination manoeuvre.

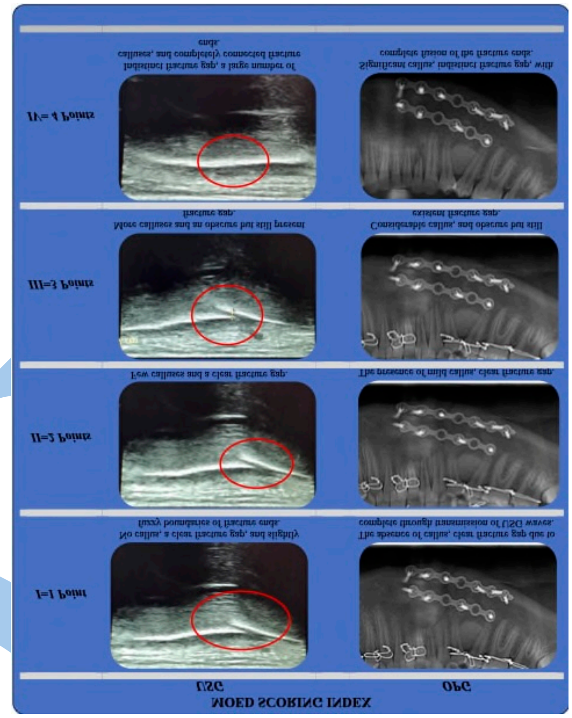

Figure 2. Moed Scoring Index qualitative depiction and quantitative scoring description.

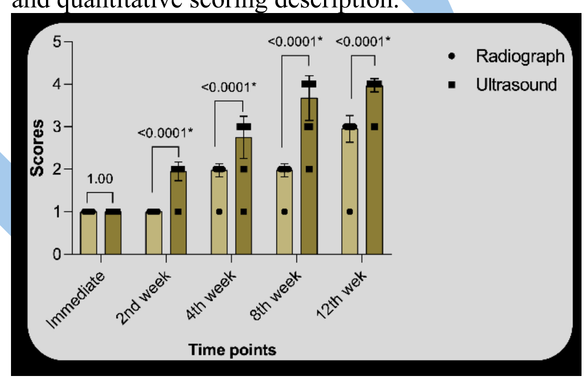

Figure 3. Bar graph illustrating the comparison between OPG-FHA and USG-FHA Moed Scoring Index values at different follow-up intervals.

Analysis of liner relationship between the OPG and USG FHA modalities revealed a near perfect positive correlation using the Spearman's rho coefficient, indicating a strong association between both investigated FHA modalities (ρ=0.884). Degree of agreement between OPG-FHA and USG-FHA was nearly non-existent, as the kappa coefficient reported a κ =0.041 value (P=0.226) (Table 5).

Table 1: Demographic data of the study.

		n= 40 patients.
Age: Mean ± SD		32.40 ± 7.56
Gender: n (%)	Males.	28 (70%)
	Females.	12 (30%)
Fracture etiology: n (%)	RTA.	28 (70%)
	Fall from height.	5 (12.5%)
	Violence.	7 (17.5%)
Fracture location: n (%)	Unilateral body fracture.	16 (40%)
	Bilateral body fracture.	4 (10%)
	Angle fracture.	2 (5%)
	Symphyseal.	2 (5%)
	Parasymphyseal.	11 (27.5%)
Associated fracture: n (%)	No.	25 (62.5%)
	Yes.	15 (37.5%)
	- Body fracture.	3 (20%)
	- Condylar head.	5 (33.3%)
	- Subcondylar.	1 (6.7%)
	- Ramus.	1 (6.7%)
	- Angle fracture.	2 (13.3%)
	- Dentoalveolar.	3 (20%)
Associated injury: n (%)	No.	35 (87.5%)
	Yes.	5 (12.5%)
	- Chin.	2 (5%)
	- Cheek.	1 (2.5%)
	- Lip soft tissue.	2 (2.5%)
Incision type: n (%)	Intra oral.	34 (85%)
	Extra oral.	6 (15%)
Complication occurrence: n (%)	No.	29 (72.5%)
	Yes.	11 (27.5%)
	- Occlusal discrepancies.	2 (5%)
	- Neurosensory disturbances.	2 (5%)
	- Nonunion.	1 (2.5%)
	- Infection.	3 (7.5%)
	- Dehiscence.	1 (2.5%)
	- Hardware failure.	2 (5%)

n, number; RTA, Road Traffic Accident.

Table 2: OPG-FHA Moed Scoring Index at different follow up intervals.

	24h	**2nd week**	**4th week**	**8th week**	**12th week**	**Test (p valu**
Mean SD.	1.00 0.00	1.00 0.00	1.98 0.16	1.98 0.16	2.95 0.32	156.00 (<0.00)
Min Max.	1.00 1.00	1.00 1.00	1.00 2.00	1.00 2.00	1.00 3.00	
P0		1.00	<0.00 *	<0.00 *	<0.00 *	
			<0.00 *	<0.00 *	<0.00 *	
				1.00	<0.00 *	
					<0.00 *	

OPG-FHA, Orthopantomogram-Fracture Healing Analysis; Test: Friedman test; *Statistically significant difference at p value≤0.05.

Table 3: USG-FHA Moed Scoring Index at different follow up intervals.

	24h	2nd week	4th week	8th week	12th week	Test (p value
Mean SD.	1.00 0.00	1.95 0.22	2.75 0.49	3.68 0.53	3.98 0.16	152.4 (<0.0 1*)
Min Max.	1.00 1.00	1.00 2.00	1.00 3.00	2.00 4.00	3.00 4.00	
P0		0.033	<0.00 *	<0.00 *	<0.00 *	
			0.080	<0.00 *	<0.00 *	
				0.006	<0.00 *	
					1.00	

USG-FHA, Ultrasonographic-Fracture Healing Analysis; Test: Friedm test; *Statistically significant difference at p value≤0.05.

Table 4: Comparison between OPG-FHA and USG-FH Moed Scoring Index values at different follow- intervals.

		OPG-FHA	USG-FHA	Test (p value)
24h	Mean ± SI Min – Max	1.00 ± 0.00 1.00 - 1.00	1.00 ± 0.00 1.00 - 1.00	0.00 (1.00)
2nd week	Mean ± SI Min – Max	1.00 ± 0.00 1.00 - 1.00)	1.95 ± 0.22 1.00 – 2.00	6.164 :0.0001*
4th week	Mean ± SI Min – Max	1.98 ± 0.16 1.00 – 2.00)	2.75 ± 0.49 1.00 – 3.00	5.568 :0.0001*
8th week	Mean ± SI Min – Max	1.98 ± 0.16 1.00 – 2.00)	3.68 ± 0.53 2.00 – 4.00	5.774 :0.0001*
12th week	Mean ± SI Min – Max	2.95 ± 0.32 1.00 – 3.00)	3.98 ± 0.16 3.00 – 4.00	6.252 :0.0001*

OPG-FHA, Orthopantomogram-Fracture Healing Analysis; USG-FI Ultrasonographic-Fracture Healing Analysis; Test: Wilcoxon sign Rank t *Statistically significant difference at p value≤0.05.

Table 5: Correlation and reliability between OPG-FH and USG-FHA Moed Scoring Index values.

	Radiographic vs Ultrasound	
Correlation (ρ)	Spearman’s rho (p value)	0.884 (<0.0001*)
Reliability (κ)	Kappa Coefficient (p valı	0.041 (0.226)

*Statistically significant difference at p value≤0.05

DISCUSSION

Fracture healing management is primarily concerned with the anatomical reduction, segment fixation, and immobilization. Bone healing monitoring lacks mentioning in the literature, with majority of the publication focusing on patient ability of prompt return to work and the long term radiographic assessment of the healing [16, 17]. The intent of this study was the sequential monitoring of mandibular fractures management with the utilization of different modalities.

The utilized fracture management modality was open reduction and internal fixation with 2.0-miniplates according the popularized biomechanical principles mandated by Champy. Mandibular fracture management with mono-cortical 2.0-miniplates permits a functionally-stabilized fixation modality. This fixation scheme does not require a period of mobilization while utilizing a small plate configuration. In an investigation of mandibular fracture management, Ellis reported that functionally-stabilized fixation modality is the most contemporary and commonly utilized fracture management choice[27]. Al-Moraissi and Ellis reported that manging mandibular fracture following the Champy's lines of osteosynthesis reported the least complication rate and a predictable healing pattern[28]. Standardization of the utilized plates and plating technique allowed validation of the outcome stated in this study, as it avoided any confounding factors and selection bias.

The study included the analysis of fracture healing in recent non-comminuted fracture lines affecting adult patients of age. Clark et al documents an age-related changes in fracture healing outcomes in various groups. A conception of poor healing in old patients is clearly evident, with several culpable factors especially the lack of proper bone vascularization [29]. The mean reported age in the study was 32.40 ± 7.56 years, with a male predominant demography and a male-to-female ratio of 2.3:1. This demographic analysis report that most of the patients were in their third decade of life, which is vibrant and active stage of life. This make them liable to altercations, active work, and make them susceptible to fractures and traumatic events. This could be correlated with the male predominance found in this study. Similar outcome is reported by Shah et al, where in their 7-year audit reported a mean age of 39.5 years and a male predominance but with a higher ratio[30].

The study was conducted on 40 patients suffering from mandibular fracture, with no location predilection. The main intent in this study is to assess the applicability and the validity of USG in monitoring fracture healing progress, as a non-ionizing modality. Limiting the fracture location would not give the study information regarding the use on other mandibular fracture locations. The USG-FHA reported a near perfect positive correlation when associated with the results of the commonly utilized OPG-FHA (ρ=0.884). Chen et al conducted a similar comparative FHA study in rabbit model. They reported a similar correlation between USG and OPG (ρ=0.892).

The positive outcome in this study may call future studies with the utilization of USG as a FHA modality with specification of the mandibular fracture location. The most prevalent mandibular fracture in this study was unilateral body fracture (n=16), followed by Parasymphyseal fracture (n=11). The outcome comes in contrast to those reported by Saravanan et al, where in their investigation regarding the prevalence of mandibular fracture reported Parasymphyseal mandibular fracture as the leading anatomical location[31].

The overall complication rate reported in this study was 27.5%, where only two cases requiring change in the fracture management modality (5%). Perez and Ellis clarified that complications in those suffering mandibular fractures could be classified into anatomical, hardware, and patient complications[32]. They reported that hardware-complication could reach 16% in cases with mandibular fracture[32]. Achieving a immobility across the fracture segment is of paramount importance, espcially in the early stages of healing, in order to attain an uninterrupted bone healing[33]. Functionally-stabilized fixation modality achieve this level of immobilization during the bone healing period[2]. The encouraging outcome in this study is an added evidence to the practicality of this fixation scheme.

The Moed scoring index was utilized for FHA with both the OPG and USG. The score represent an ascending levels of bone healing [21, 22]. Morshed report the merit of the Moed score in quantitative representation of USG-FHA, along with the qualitative depiction[34].

The earliest sign of change in bone radiographic appearance on the OPG was on the 4th postoperative week, and the subsequent change was on the 12th postoperative week. Nardi et al report that the utilization of OPG in mandibular fractures is confronted by many obstacles in the detection of the fracture, however its mainly used a recurring radiographic modality for the follow-up assessment[9]. Son etl al reported the utilization of deep learning to improve the performance of OPG in mandibular fracture detection[35]. Functionally-stabilized osteosynthesis promotes a direct fracture healing of the gap type, where it differs from contact healing by the fact that bony union and haversian remodelling do not occur concurrently [36]. Gap Direct healing is attained when the gap between the bone segments is less than 1 mm, with anatomical reduction and uninterrupted stability. This process require a secondary ostium reconstruction to reorient the direction of the lamellar bone from perpendicular to parallel orientation [36]. The main biological process occurs at a time range of 7-9 days post-trauma, and radiographic changes usually require 3-8 weeks to be observed [37].

The OPG-FHA findings in this study is consistent with the biological pattern attained with Functionally-stabilized osteosynthesis. Despite that, this monitoring technique is usually considered with the latter phases of fracture bone healing. OPG is a respectable modality in assessing the final outcome of the mandibular fracture management, and detecting unusual bone healing complication. However, dynamic monitoring is difficult to be performed with OPG or other ionizing modalities as they require unsafe exposure to radiation.

Akashi et al investigated the sequential evaluation of bone consolidation using a quantitative score. They documented that OPG provided an adequate two-dimension analysis modality [38]. USG could analyse the lower border of the mandible along with the outer surface analysis, along with any overlap in fracture anatomical reduction, which could be easily misidentified in the topographic radiographic analysis. On the other hand, USG-FHA reported an ascending level of Moed score with each consecutive follow-up period. Difference between each period was statistically significant. Changes in Moed score was reported in the second postoperative week. A similar outcome was reported by Chen et al in his analysis of dynamic monitoring of bone healing in rabbit model[21]. Early analysis of the bone healing physiological process is of an overriding importance for the investigation of the success of the fracture osteosynthesis. One of the advantages of USG that there is no ultrasonographic errors or disturbances in the images from the plates and screws, therefore ultrasonography is very helpful in the evaluation of bone healing process as reported in the study of Miura et al [39].

Accurate detection of the physiological require a physiological scanning protocol, which has its own risks and unapplicable for consecutive weekly scans. Although being an anatomical modality, USG allowed early detection of FHA and bone healing. Alternation in the resonance and changes in outline are easily to be detected with USG with no need of frequent harming radiation. The operator dependent nature of the USG device is one of the recurring complications of ultrasound as regular radiographic investigation modalities. Gadicherla et al conducted a meta-analysis on the reliability, sensitivity, and specificity of USG in facial fractures. They reported that a high degree of inter and intra examiner reliability could be obtained with USG[40, 41].

USG utilized changes in the outline and bone resonance to monitor bone healing. On the other hand, radiographic analysis depends on the radiation attenuations and amount of absorbed radiation by different tissues for FHA. Difference in both modalities is evident in the reported degree of agreement in this study. The degree of agreement between OPG-FHA and USG-FHA was nearly non-existent (κ =0.041).

The repeatable nature of FHA may affect the total patient radiation exposure, which generates concerns about the overall administered dosage. Despite its limitation, USG allowed a repeatable, Sequential, and dynamic bone healing monitoring with no dosage apprehensions. It's a reliable modality with linear association with the conventional technique, all while providing earlier chronological assessment.

CONCLUSION

Ultrasonography sounds to be significantly efficient and safe alternative to conventional radiography with high rates of sensitivity in the monitoring of mandibular fractures healing. Moreover, In the early phases of bone healing monitoring, USG is quite useful for identifying bone healing problems earlier than the radiography.

Declarations:

- **Ethics approval and consent to participate**

Ethical approval was granted by the Fayoum University Ethics committee, (FU-SCSRE- EC 2310). An ethical approval statement was added to the manuscript. All patients signed informed consent before the start of the treatment protocol. All methods were carried out per Helsinki Declaration guidelines. Clinical trial number: not applicable

- **Consent for publication**

All of the involved subjects signed an informed consent for the utilization of their radiographic records for scientific purposes.

- **Availability of data and materials**

All data generated or analysed during this study are included in this published article.

- **Competing interests**

The authors declare that they have no conflicts of interest.

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• **Authors' contributions**

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List of abbreviations

- **κ:** Cohen's kappa coefficient.
- **OPG:** Orthopantogram.
- **ρ:** Spearman's rho coefficient.
- **FHA:** Fracture Healing Analysis.
- **USG:** Ultrasonogram.
- **κ:** Cohen's kappa coefficient.

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