Email and instant messaging applications as platforms for remote oral radiology consultation in maxillofacial fractures

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Objective. The present study aimed to test the reliability and diagnostic efficacy of the evaluation of radiographs transmitted by e-mail and through instant messaging in the diagnosis of maxillofacial fractures.

Study Design. Screening of radiographs of 150 patients by a senior maxillofacial radiologist was performed as the gold standard method for the assessment of fractures by using a workstation monitor. The radiographs were sent to the Gmail accounts of 2 observers, who used their laptop computers to independently evaluate the radiographs for fractures. The same radiographs were sent to the smartphones of the observers via WhatsApp Messenger and were evaluated on the smartphone screens. Intra- and interobserver reliability, sensitivity, specificity, positive predictive value, negative predictive value, and accuracy were calculated.

Results. The reliability of the observers' diagnoses for both modalities ranged from 0.96 to 1.00 compared with the gold standard. Intra- and interobserver reliability ranged from 0.85 to 0.98. Measures of diagnostic efficacy ranged from 93.5% to 100% for images sent by Gmail and from 95.2% to 99.9% for radiographs transmitted through WhatsApp Messenger.

Conclusions. The present study demonstrated that email and instant messaging applications can be reliable tools for the assessment of maxillofacial fractures by radiologists located at remote sites. (Oral Surg Oral Med Oral Pathol Oral Radiol 2021;131:241−246)

In recent years, the world has witnessed widespread technologic innovations that have transformed the practice of dentistry. This has led to the emergence of teledentistry, in which electronics and telecommunications are used to provide oral health care, patient education, diagnosis, and treatment advice over distances. Progress has been made in the use of personal computers and smartphones enabled with software that can aid in diagnosis and follow-up care. The extensive use of smartphones among health care professionals and patients has significantly improved the exchange of clinical records. This has been made possible by software applications, including email, WhatsApp, Viber, WeChat, Facebook Messenger, Telegram, Signal, Line, Skype, and others.[1]

Advances have been made in the imaging technology housed within smartphones. Numerous instant messaging services that offer real-time transmission of texts, photographs, and videos over the Internet at the touch of a button are now available. These provide superior prospects for the use of teledentistry as a modality for virtual consultations. Smartphones have all the requirements for teledentistry. They can capture, store, and transfer images to a distant location, where they can be viewed without any change in resolution. Smartphones are also very efficient, cost−effective, and user friendly.[2]

Gmail, a free email service developed by Google, offers a considerable amount of storage, permitting transmission of large files as attachments. Larger files can also be inserted into Google Drive.[3,4] WhatsApp Messenger, a cross-platform mobile messaging application with over a billion active users worldwide,[5] is an extensively used instant messenger that allows users to send and receive text messages, images, and audio and video files via smartphones with Internet capability.

The efficacy and utility of free messaging applications have been demonstrated in various clinical settings for diagnosing oral diseases. Few studies have tested the efficacy of WhatsApp for remote consultation in telemedicine. In the field of dentistry, it has been evaluated for histopathologic diagnosis in oral pathology practice and as a remote screening model for potentially malignant oral disorders.[6] However, no studies have evaluated the role of free messaging

Statement of Clinical Relevance

This study is clinically relevant because remote primary health care centers may have provisions for acquiring radiographs but may not have an expert radiologist to interpret them. This necessitates sharing radiographic images via email and/or instant messaging platforms.

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applications in the radiographic diagnosis of maxillofacial fractures.

Hence, the objectives of the present study were (1) to determine observer agreement in fracture diagnosis on images transmitted by Gmail and viewed on a laptop monitor and by WhatsApp and viewed on 2 smartphones; and (2) to calculate the sensitivity, specificity, positive predictive value (PPV), negative predictive value (NPV), and accuracy of the observers' diagnoses for each modality in comparison with the gold standard of images viewed on a desktop workstation. The null hypotheses stated that there would be no significant differences in observer agreement between the email and instant messaging applications and the gold standard desktop workstation and no significant differences in measures of diagnostic efficacy.

MATERIALS AND METHODS

This diagnostic accuracy study was carried out by retrieving extraoral images from the archives of the Oral Radiology department. The institutional ethics committee approved the conduct of the study (IEC: 655/2019). Radiographs acquired between March 2019 and September 2019 were included in the study.

Sample size was calculated on the basis of the expected kappa of 0.9 and the lowest limit of kappa of 0.6. The sample size was estimated to be 149 with power of 80%, alpha of 5%, and expected proportion of 90%.[7]

In total, 150 patient radiographs (representing 1950 sites), with no technical errors or artifacts obscuring the areas of interest, were screened by a senior maxillofacial radiologist for the assessment of fractures by using a workstation monitor. This was considered the gold standard to evaluate the presence of fractures. Of the 150 images, 75 were panoramic radiographs and 75 were skull radiographs, including 33 posteroanterior skull projections, 33 submentovertex projections, and 9 paranasal sinus projections (Table I). Radiographs with and without any evidence of fractures were included.

Radiographs were acquired with a Planmeca 2-D S3 unit (Planmeca Oy, Helsinki, Finland) and viewed on the workstation monitor by using Planmeca Romexis dental imaging software. They were anonymized to safeguard patient confidentiality before the radiographic images were sent electronically. The images were simultaneously sent to the Gmail (Google LLC, subsidiary of Alphabet Inc., Mountain View, CA) accounts of observer A and observer B, who were trained and experienced maxillofacial radiologists. These images were opened by the observers by using HP ProBook 440 G4 laptop computers housing an Intel processor (Intel Core i5-7200 U CPU @ 2.50 GHz) with the Microsoft Windows 10 Enterprise operating system (display resolution of 1366 × 768 pixels and installed physical memory of 4.00 GB RAM). The observers independently analyzed the radiographs on their laptops with 50% brightness in a room with ambient light.

Table 1. Radiographs included in the study

Type of radiograph	Number of radiographs included
Panoramic radiograph	75
Posteroanterior skull radiograph	33
Submentovertex radiograph	33
Paranasal sinus radiograph	9

The senior radiologist sent the same 150 radiographs to both observers via WhatsApp Messenger (version 2.20.40; WhatsApp Inc., Mountain View, CA). The images on WhatsApp were viewed by the observers on their smartphones. Observer A viewed the images on a smartphone equipped with the iOS operating system with software version 13.3.1; a 6.1-inch (diagonal) all-screen LCD (liquid crystal display); 1792 × 828 pixel resolution at 326 PPI (pixels per inch); 1400:1 contrast ratio (typical); and 50% display brightness in ambient light. Observer B viewed the images on a smartphone equipped with the Android 9.0 (Pie): MIUI 11 operating system; a 6.3-inch IPS (in-plane switching) LCD capacitive touchscreen display; 1080 × 2340 pixel resolution at approximately 409 PPI density; 19.5:9 contrast ratio; and 50% display brightness in ambient light. The observers viewed panoramic images in landscape mode and the other extraoral radiographic images in portrait mode on their respective smartphones. They used the zoom feature on their smartphones for better visualization, whenever required. The observers independently viewed the images and recorded their detailed interpretations and radiologic diagnoses of the presence or absence of fractures in a specially designed proforma, which indicated the 1950 anatomic sites to be evaluated. After a period of 3 weeks, the observers reanalyzed the radiographs on both platforms, and the data were recorded for calculation of intraobserver reliability.

The data obtained for each of the 1950 sites, as evaluated on the laptop computer and the 2 smartphones, were entered into a Microsoft Excel spreadsheet (Microsoft Corp., Redmond, WA) and were statistically analyzed by using SPSS software version 20 (IBM, Armonk, NY). Intra- and interobserver reliability were assessed by using kappa statistics. The observers' findings were used to calculate the sensitivity, specificity, PPV, NPV, and accuracy of their diagnoses as rendered on laptop computers and smartphones, along with the interpretation of the senior radiologist on the desktop workstation, which was the gold standard. Significance of differences was established at $P < .05$.

Fig. 1. Evidence of fractures as indicated by the arrows in the posteroanterior skull radiograph, submentovertex radiograph, paranasal sinus radiograph (top row, left to right), and the panoramic radiograph.

RESULTS

Of the 150 radiographs, 131 showed evidence of fractures (Figure 1), and 19 presented no evidence of fractures, as diagnosed by the senior radiologist. There were 43 radiographs with evidence of multiple fractures. In total, 186 of the 1950 sites had fractures and 1764 did not. The region-wise distribution of the 186 fractures is presented in Figure 2.

The intraobserver reliability kappa values for Gmail for observers A and B were 0.85 and 0.92, respectively. For WhatsApp, the kappa values were 0.85 and 0.96, respectively. Interobserver reliability kappa values for Gmail and WhatsApp were 0.95 and 0.98, respectively, indicating substantial agreement.[7]

The kappa values for Gmail images viewed on the laptop computers for observers A and B in comparison with the gold standard were 1.00 and 0.95, respectively. Likewise, the kappa values for the WhatsApp images viewed on the smartphones for observers A and B in comparison with the gold standard were 0.97 and 0.96, respectively (Table II). The reliability values in all cases indicated almost perfect agreement.[7]

Sensitivity, specificity, PPV, NPV, and accuracy were calculated, and the results are presented in Table III. These values of diagnostic performance ranged from 93.5% to 100% for images sent by Gmail and examined on laptop computers. The range was 95.2% to 99.9% for diagnoses of the radiographs sent by WhatsApp and examined on smartphones.

DISCUSSION

Electronic mailing services began in the 1970s, and tremendous advances in the technology have been made over the past 4 decades. This has enabled uninterrupted communication among personnel in all fields. Email has facilitated the exchange of medical records among health care professionals and patients and has also been applied for teleconsultations. The efficacy of e-mail services as a platform for remote consultations has been evaluated in nuclear telecardiology [8] and telepathology.[9] Jacobs et al.[10] performed a study to compare the diagnostic efficacy of planar radiographs and that of images sent through a telemedicine system. Panoramic and occipitomental radiographs were

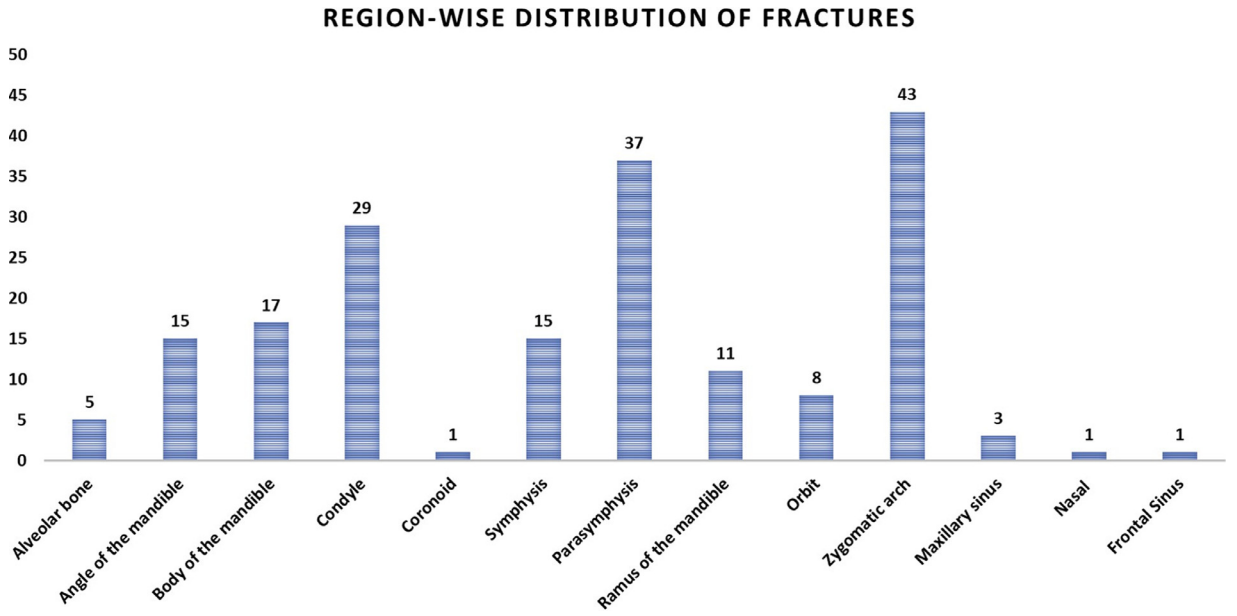

Fig. 2. Region-wise distribution of fractures.

transmitted over a teleradiology link, and the images were viewed on a laptop computer. The authors concluded that the telemedicine system was an acceptable tool in the diagnosis of most facial fractures.

Instant messaging services accessible on smartphones are also one of the most fruitful and significant technologic innovations of the modern era. One of the most popular applications is WhatsApp Messenger. The easy and instantaneous transfer of text, images, and videos through this messaging application has made it a valuable tool for teleconsultations and referrals to experts in the clinical practices of medicine and dentistry. This is possible only because of the exceptionally sophisticated and efficient smartphones that are currently available.

The usefulness of mobile phone instant messaging services as a communication tool has been studied in diverse specializations in medicine and dentistry. Petruzzi et al.[5] conducted a study in southern Italy and demonstrated the efficacy of smartphone use for patient referrals to specialized oral pathology and medical centers. Similarly, a study was performed by Sarode et al.,[11] who demonstrated the efficacy of the WhatsApp application for obtaining second opinions on histopathologic diagnoses in an oral pathology practice. Vinayagamoorthy et al.[2] demonstrated the feasibility of using a remote sensing model as a free messaging application tool in the preventive screening of potentially malignant oral disorders in a rural area of India.

Some research has been conducted to evaluate the effectiveness of instant messaging services in interpreting radiographs. Stahl et al.[12] and Giordano et al.[13] reported the reliability of smartphone-based teleradiology for the diagnosis of thoracolumbar spinal fractures and tibial plateau fractures, respectively.

However, there are no documented studies on using email and instant messaging services for sharing patient radiographs for evaluation of maxillofacial

Table 2. Observer reliability regarding the presence or absence of fractures measured in kappa values compared with the gold standard

		Gold standard		
		Present	*Absent*	*Kappa (SE)*
Gmail				
Observer A	Present	186	0	1 (0)
	Absent	0	1764	
Observer B	Present	174	3	0.95 (0.01)
	Absent	12	1761	
WhatsApp				
Observer A	Present	178	2	0.97 (0.01)
	Absent	8	1762	
Observer B	Present	177	3	0.96 (0.01)
	Absent	9	1761	

SE, standard error.

Table 3. Sensitivity, specificity, positive predictive value, negative predictive value, and accuracy in percentage

	Sensitivity	*Specificity*	*PPV*	*NPV*	*Accuracy*
Gmail					
Observer A	100	100	100	100	100
Observer B	93.5	99.8	98.3	99.3	99.2
WhatsApp					
Observer A	95.7	99.9	98.9	99.5	99.5
Observer B	95.2	99.8	98.3	99.5	99.4

NPV, negative predictive value; *PPV,* positive predictive value.

trauma. Thus, the present study is the first to test the reliability of free messaging applications in obtaining diagnoses of maxillofacial fractures. This study is also recognizably distinct because the radiographic images were shared on 2 different platforms (Gmail and WhatsApp), viewed on 2 different kinds of programmable devices (laptops and smartphones), and evaluated for any differences. The need for this kind of a study stems from the fact that in many countries, remote primary health care centers in rural areas and towns and most dental clinics may only have the facility for acquiring radiographs but may not have an expert consultant maxillofacial radiologist available to provide interpretations of the images. This necessitates sharing radiographic images with expert radiologists at a distant location via instant messaging platforms.

In this study, the interpretation of radiographs with the use of a workstation desktop monitor was considered the gold standard. Dental imaging software (Planmeca Romexis; Planmeca, Helsinki, Finland) installed with the viewer and ambient viewing conditions make the diagnosis at the workstation superior to any other setup and has fewer confounding errors. Moreover, the powerful image enhancement tools aid in clearer analysis to achieve the correct radiographic diagnosis. In this investigation, we found that the diagnoses rendered through the use of the online platforms were on par with the gold standard, with measures of diagnostic performance ranging from 93.5% to 100%.

Images delivered through Gmail may be occasionally resized but usually retain their image quality without significant degradation. Moreover, the images sent through Gmail were viewed on laptop screens that were bigger than smartphone screens. In the present study, the reliability (kappa) of Gmail for observers A and B in comparison with the gold standard indicated almost perfect agreement. These findings confirm the results of the study conducted by Tually et al.,[8] who made a preliminary assessment of Internet-based nuclear telecardiology to support the clinical management of cardiac disease in a remote community. The authors concluded that there were no clinically significant variations in scan findings when comparing Internet-based image results with the formal diagnoses that were derived from conventional displays on fixed nuclear medicine−processing workstations. The results of the present investigation were also in accordance with the study conducted by Settakorn et al.,[9] who assessed the diagnostic performance of a pathologist in examining photomicrographs sent as email attachments. The authors reported acceptable diagnostic efficacy with this form of telepathology.

Images shared via WhatsApp are usually compressed by the WhatsApp server for easy sharing through faster download even at a low Internet speed. However, this image compression may compromise the quality and resolution of the radiograph. Moreover, the images sent via WhatsApp were viewed on the small screens of smartphones. Despite these limitations in technology, the results of the present study showed that the reliability measures of the interpretations of observers A and B when using WhatsApp Messenger in comparison with the gold standard were 0.97 and 0.96, respectively, indicating almost perfect agreement. These findings were in agreement with the study conducted by Kapıcıoğlu et al.,[14] who evaluated the reliability of WhatsApp for diagnosing and classifying type 1 and type 2 pediatric supracondylar fractures, and Stahl et al.,[12] who demonstrated near-perfect agreement among interpretations of radiographs of pediatric limb fractures viewed with smartphone screens. The present study also revealed substantial interobserver agreement in diagnoses made with both the Gmail and WhatsApp systems.

The results of the present study demonstrated that e-mail and instant messaging applications are impressively effective in obtaining accurate diagnoses of fractures from maxillofacial radiologists located at remote sites. With more than half of the world's population having smartphones and being connected by the Internet, the results of the present research have even more applicability during pandemics or epidemic outbreaks, as at present with the COVID-19 pandemic.[15] This is especially important for health care settings at primary and secondary care levels, where local medical resources may have limited technical expertise for making diagnoses; electronic data-sharing platforms can facilitate collaboration with experts at remote locations.[16]

The present study has some limitations. The observers used smartphones with excellent resolution to view images sent through WhatsApp and had very good Internet access. However, smartphones with less advanced features may hinder the ability to view images clearly, and slower Internet connectivity could impact the ability to send and receive messages instantly. Nonetheless, with ever-evolving smartphone technology, these difficulties may be overcome in the near future.

Another issue of concern is the possibility of exposure of sensitive information and patient data to the service provider, who has the capacity to retrieve these data. With growing awareness of cybercrimes, an innovative, secure free-messaging application may be developed to curb this problem. WhatsApp has recently incorporated a default end-to-end encryption feature to ensure data privacy, which is a small but significant step in the right direction.[17,18] The Health Insurance Portability and Accountability Act of 1996 in the United States ensures protection of the privacy of

patient health records and data. This enables uninterrupted 2-way communication between health care professionals and patients, resulting in better patient care. Secure transmission of protected patient data also paves the way for health research and quality improvement initiatives.[19]

CONCLUSIONS

Electronic transmission of radiographic images through email and instant messaging applications promises to be an invaluable technologic tool in modern dentistry. It can be instrumental in enhancing patient care by enabling effective and proficient team communication. The present study demonstrated that fractures were identifiable on radiographs transmitted through these platforms, and the high kappa values suggest that the diagnostic task was relatively easy to perform. However, we believe that future studies should evaluate diagnostically difficult radiographic images of maxillofacial fractures and different jaw lesions, which are frequently shared among clinicians for a second opinion. Future smartphones and applications may be even better equipped and more sophisticated to handle image sharing and could contribute immensely to teledentistry.

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