ORIGINAL ARTICLE

Comparison of Subjective Image Quality of Digital and Printed Dental Radiographs

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ABSTRACT

Background: To assess if there is loss of diagnostic information in radiographs when printed on various mediums compared to on-screen digital image and to determine which medium is better for printing radiographs when needed.

Methods: A cross-sectional study was conducted at Public Sector Medical University, Karachi from June 2023 to November 2023. This study examined the diagnostic quality of digital panoramic radiographs (OPGs). According to the inclusion and exclusion criteria for dental radiographs, an OPG was selected from the database of patients reporting to the daily OPD of the University. This image was presented on a monitor and printed on various mediums, including conventional film, glossy paper, and plain matte paper. 75 dental professionals from Karachi, Pakistan, evaluated the clarity of anatomical components and analyzed media outcomes for diagnostic accuracy.

Results: The panoramic image displayed on monitor (image a) had the highest subjective image quality followed by (in descending order) image printed on radiographic film (image b), inkjet images printed on glossy paper (image c) and plain paper (image d) (p value= 0.00). However, the differences among the nominal variables with the radiographic images were non-significant (p value > 0.05)

Conclusion: Digital monitors are the preferred method for viewing radiographic images due to their superior image quality. When digital display is unavailable, radiographic film is essential for maintaining diagnostic clarity. If paper printing is required, glossy inkjet paper is recommended.

Keywords: *Radiographs, Printed radiographs, Digital radiographs, Plain paper, Inkjet paper, Conventional film, Photo paper*

Introduction

Radiographs are indispensable for accurate diagnosis and effective treatment planning in dentistry.[1] Historically, conventional film-based radiographs were the standard, but advancements in technology have led to the increasing adoption of digital radiographs, offering several advantages, including time efficiency, image manipulation capabilities, and reduced radiation exposure[2,3]. Digital radiographs align with the ALARA principle, ensuring radiation doses are kept as low as reasonably achievable[4]. Additionally, they facilitate the seamless exchange of radiographic images among dental practitioners[2,3], thereby promoting multidisciplinary patient care.

While digital radiography has become a routine practice globally and has significantly contributed to advancements in artificial intelligence (AI) for dentistry[5], aiding in the detection of radiographic abnormalities beyond human perception,[6] challenges persist in certain regions. Dental professionals in developing countries often encounter difficulties in transferring digital radiographic images between practices due to technological limitations[7]. Many dental hospitals in these regions continue to rely on conventional radiographic techniques, primarily due to a lack of access to modern digital equipment[8]. In such contexts, the printing of digital radiographic images on physical media becomes necessary for the transfer of diagnostic information between practitioners[9,10].

A variety of media are available for printing digital images, including plain paper, glossy inkjet paper, and conventional radiographic film[11]. Printed images are generally more cost-effective than radiographic films[12], leading to their widespread use, particularly for record-keeping and sharing diagnostic information. However, concerns have been raised about the potential loss of diagnostic accuracy in printed radiographs[9]. While previous studies have explored the comparative advantages and limitations of digital and conventional radiographs, as well as their printed versions on different media[3,10] there is a lack of research specifically evaluating the diagnostic accuracy of printed radiographs in Pakistan, where their use is prevalent due to cost considerations.

This study seeks to evaluate the quality and diagnostic efficacy of radiographs printed on various media (conventional film, glossy inkjet paper, and standard office paper) compared to their onscreen digital counterpart. The objective is to determine the most suitable medium for printing radiographs when physical copies are required for image transfer between dental practitioners. The null hypothesis is that no significant difference exists in the diagnostic accuracy of radiographic images printed on different media.

Methodology

This analytical cross-sectional study was conducted at a public sector university from June 2023 to November 2023 after approval from the institutional ethical review board (JSMU/IRB/2022/-612). Digital panoramic radiographs (OPG) were obtained from the digital database of the radiology department of the institute of those patients reporting in the specified time of three

months from June 2023 to August 2023 and having given written informed consent for using their record of OPG for the study. OPGs collected in the above-mentioned time period were assessed by Principal investigator to select one radiograph in accordance with the following inclusion criteria; patient with age ranging from 19-35 years, written informed consent, presence of permanent dentition, 3rd molar present (impacted or erupted), an overall number of teeth present should be 24 with a minimum of five teeth present in each quadrant, one to four carious teeth, at least one tooth with caries extending to pulp, apical radiolucency associated with at least one tooth, and all the above mentioned landmarks are clearly visible to the observer on digital image. Radiographs not meeting the inclusion criteria were excluded.

A digital image of the selected radiograph with sufficient brightness and contrast was transferred to a flash drive after converting it to JPEG format. The image was viewed using Microsoft Photo Editor software on a 17-inch color monitor display (Image A) by the observers. Conventional radiographic film (image B) was also obtained for the selected digital radiograph. Afterward, the image was also printed using the ink-jet printer (Epson L3150) on 2 hard copies: glossy paper (image C) and plain regular matt paper (image D).

A Sample size of seventy-eight participants was calculated using "WHO" sample size calculator by keeping the confidence interval (1- α) at 99%, and absolute precision (margin of error) at 0.05, using the study of Gerrard et al[9] as reference. Out of seventy-eight participants who filled the questionnaire, three were excluded due to incomplete forms. Finally, seventy-five participants were included in the study. Participants belonging to four different teaching hospitals in Karachi were randomly selected fulfilling the inclusion criteria: Consultants (Oral and Maxillofacial surgeon, Orthodontist, Prosthodontist, Periodontist, Operative/ endodontics) having work experience of minimum 1year, General dental practitioner having work experience of 3 or more years and Postgraduate student in the fourth year of residency. Undergraduate and Postgraduate students in their first, second, and third year, house officers, and general dental practitioners with work experience of less than 3 years were excluded from the study. After taking consent, the participants were requested to individually assess the digital radiograph and its printed images by filling an electronic questionnaire.

An electronic questionnaire was designed consisting of five sections (first section comprising of seven questions regarding demographics whereas, each of the other four sections comprised of ten questions). The questionnaire was provided to the participants on a 10inch tablet screen on which they were required to rank the subjective quality of the anatomical landmarks on each image on a Likert scale, this scale employing five points from (1: very poor 2: poor 3: uncertain 4: good 5: very good) according to The Visual Grading System (VAS) used by Molander et al[13], clarity in visualisation of various anatomical structures was scored (Table 1) on four images; digital screen (A), radiographic film (B), glossy paper (C), plain paper (D). Figure 1-2.

Table 1. *Anatomical Landmarks (Items in the questionnaire to be rated on a scale of 1 to 5)*

No.	Item
1	Partially impacted right mandibular 3rd molar
2	Mental foramen
3	Mandibular canal
4	Lower and anterior border of maxillary sinus
5	Interproximal bone level between tooth no x and y
6	Lamina dura
7	TMJ anatomy
8	Extent of caries of tooth no X
9	Apical radiolucency with tooth no Z
10	Rate the overall quality of image

Value of Cronbach's alpha= 0.9

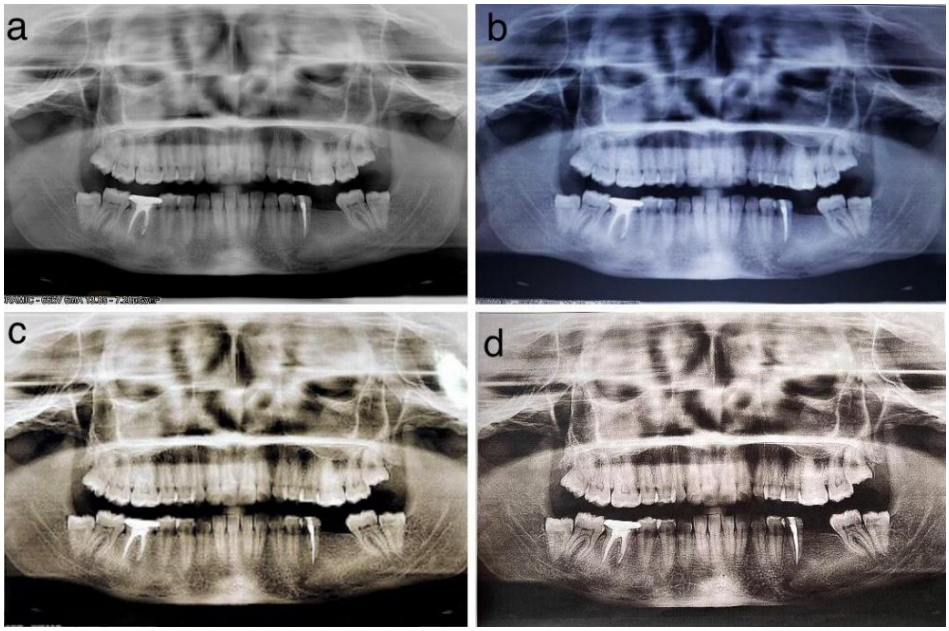

Figure 1(a-d); *Digital image, radiographic film, glossy paper, plain paper*

Each image was assigned a sequential label, and the observers were kept unaware of the specific print medium used. An illuminator was also provided for better visualization of conventional film radiograph. The images were evaluated one after the other in a quiet room with no time limit given to the observer.

Statistical package for social sciences (SPSS) version 24 was utilized for statistical analysis. The kappa statistics were used to determine inter-observer variability. Nonparametric tests, median, and interquartile ranges were used to describe the qualitative variables and frequency distribution of the categorical data was determined. Wilcoxon's sign rank test and Kruskal-Wallis test were used to test for significant differences in median scores among groups. The level of significance was kept at less than 0.05[12]

Results

The reliability of the questionnaire was checked through Cronbach's alpha (0.93). Out of total 75 participants, 43(57.3 %) were females and 32(42.6%) were males with age ranging from 20 to 50 years. The majority of the participants were post graduate residents (57.3%). Most of the participants were from the department of operative dentistry followed by prosthodontics and maxillofacial surgery respectively (Figure 2).

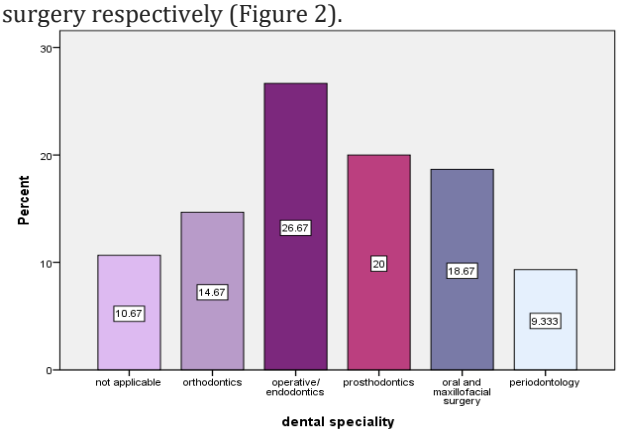

Figure 2: *Distribution of different dental specialties*

A summary of the distribution of different variables among the participants is presented in Table 2.

Table 2: *Descriptive statistics*

Variable	Category	Frequency (Percentage)
Institute	A	40 (53.3%)
	B	13 (17.3%)
	C	16 (21.3%)
	D	06 (08%)
Age	20-30 years	47 (62.7%)
	31-40 years	23 (30.7%)
	41-50 years	3 (4.0%)
	>50 years	2 (2.7%)
Experience	<3 years	23 (30.7%)
	3-6 years	27 (36.0%)
	7-10years	15 (20.0%)
	>10 years	10 (13.3%)
Level of education	General dentist	19 (25.3%)
	Post grad resident	43 (57.3%)
	Consultants	13 (17.3%)

Median and interquartile ranges were used to describe the agreement among the raters. Most respondents indicated Image A as very good quality (Mdn= 5, IQR = 0), whereas, opinion seems to be divided about image D (Mdn=3, IQR= 2)

Wilcoxon's Sign Rank test revealed significant differences between the modalities (p value= 0.00). Thus, the null hypothesis, which asserts no difference in the radiographic quality across various print media, is rejected. The panoramic image displayed on monitor (image A) exhibited the most superior quality followed (in descending order) by the radiographic film (image B), inkjet images printed on glossy paper (image C) and plain paper (image D) (p value= 0.00). Kruskal-Wallis's test statistics to observe the differences among the nominal variables with the radiographic images were non-significant (p value > 0.05) for most of the categories except for clinical experience, dental specialty and institute. (Table 3).

Table 3. *Wilcoxon Sign Ranks test*

Comparison	Rank Type	N	Mean Rank	Sum of Ranks	Test statistics
image2 - image1	Negative Ranks	35[a]	20.29	710.00	
	Positive Ranks	4[b]	17.50	70.00	0.000*
	Ties	36[c]			
	Total	**75**			
image3 - image1	Negative Ranks	56[d]	28.50	1596.00	
	Positive Ranks	0[e]	.00	.00	0.000*
	Ties	19[f]			
	Total	**75**			
image4 - image1	Negative Ranks	70[g]	35.50	2485.00	
	Positive Ranks	0[h]	.00	.00	0.000*
	Ties	5[i]			
	Total	**75**			

**Significant p value significant 0.000 (<0.05)*

Discussion

The present study, titled "Comparison of Subjective Image Quality of Digital and Printed Dental Radiographs," was conducted to evaluate and compare the perceived image quality of digital radiographs and their printed counterparts among dental professionals, and to assess whether the mode of display influences diagnostic interpretation. According to the findings of this study, it has been demonstrated that the image displayed on a monitor has been rated to have superior image quality. This contrasts with the findings of prior studies[9,11] which indicated that direct thermal printing[11] and printed radiography[9] were considered the best modalities.

Previously, several studies have reported conflicting results regarding diagnostic image quality. For instance, Gijbels[11] found that direct thermal prints have superior diagnostic quality than panoramic images displayed on a computer monitor However, this finding is limited by the methodology used. The study relied on image editing software not specifically designed for radiographic diagnostics. The actual format of the photographic image (OFL, Agfa, Belgium) was changed into TIFF (Tagged Image File Format) to approximate the image quality typically found in dental imaging software. This conversion was necessary because the OFL format is primarily used by advanced software in medical field and does not reflect the standard practices in typical dental offices. Therefore, the superiority of thermal prints over radiographic film cannot be proven.

Also in the study of Gerrard et al[9], it can be seen that they preferred printed radiographs over digital images because high-resolution printed images, such as inkjet photos and radiography film, are preferred by observers due to their ease of viewing without pan and zooming. The authors argued that office monitors' LCD matrix has a low resolution of 100 dots per inch, but high-end printers can print up to several thousand dots per inch. Another argument stated by Stephen P Knight et al, in film-screen radiograph, there were limited options for altering an image[14]. Advancements in Digital Radiography (DR) address these concerns by offering versatile post-processing tools, such as brightness, contrast, magnification adjustments, and specialized filters, enhancing diagnostic accuracy[14-16].

In this study, consultants, general dentists, and residents were requested to compare image A with three other printed images (images B, C, and D). The results consistently favored the image displayed on the monitor followed by radiographic film and inkjet images printed on glossy paper. The lowest scores were given to images printed on plain office paper. Contrary to this, Gerrard et al reported that printed image of radiographs has a higher potential to evaluate anatomical components as compared to digital images, but this was only observed for images printed using an expensive inkjet printer on photographic paper or film[9]. Low inter-rater reliability was observed in previous studies as the observers were not well-trained to interpret radiographs consistently. This lack of consistency can lead to discrepancies in the interpretation of findings and ultimately impact the accuracy of the results[17]. The present study excluded less experienced dental surgeons to avoid error in the interpretation of the radiographic image and more experienced dental professionals were approached including postgraduates in their final year of residency which ensured a higher level of expertise among the observers, increasing the reliability of our findings. By including only experienced professionals, we aimed to minimize the potential discrepancies in interpretation and improve the overall accuracy of our study results.

In the study Ajmal et al, they demonstrated that the best way to differentiate the subjective image quality of dental radiographs is to look at the image details of root canal fillings, enamel, dentin, DEJ, and simulated apical pathologies[18]. Whereas the objective of this study is to grade and assess the subjective image quality rather than to assess the specific landmarks or determine whether or not a pathology was present when examining the quality of images. Thus, this approach allowed a more comprehensive assessment of the subjective image quality on different printing media. Although, the results showed that digital radiographs are the preferred option, they are not particularly common among dentists for a variety of reasons. Despite the availability of computers in almost every workplace, Dental practitioners still favor paper prints of digital radiographic images. This could appear a little out of date because, in theory, a computer monitor should be used to assess digital image files. However, there are several situations in which inexpensive hardcopies might be helpful. One straightforward example is for referral purposes. Not all picture software will support files transferred in popular formats (JPEG, TIFF) due to various density algorithms. Hence at many teaching hospitals, digital radiographs are used but for the transfer of radiographs, plain paper is most commonly utilized as it is budget-friendly and cost-effective for patients, but doing so results in a loss of diagnostic efficacy to a much greater extent[9], therefore it has been emphasized that whenever possible, radiograph referrals should be made through digital radiography in a proper manner or if they need to be transferred via printed media, a suitable printing medium should be used. As depicted by our study, glossy paper shows better subjective image quality as compared to plain paper, which is in line with the previous study Frieda Gijbels et al[11].

This study emphasizes the importance and precision of digital radiograph images when displayed on a monitor. Conversely, a significant loss of diagnostic information occurs when radiographs are printed on hard copy media, with plain paper exhibiting the poorest quality. The study recommends glossy paper prints using a high-quality inkjet printer to facilitate accurate diagnosis and efficient treatment planning; this simple investment can lead to better patient outcomes and raise the overall standard of care in dental practices.

Despite its strengths, this study has several limitations that should be acknowledged. The assessment was based on subjective perception of image quality rather than objective diagnostic accuracy, which may introduce observer bias despite acceptable inter-observer agreement. In addition, the absence of a formal calibration exercise prior to data collection may have contributed to variability in responses. Potential differences in clinical experience and training among participants could also have influenced the consistency of interpretations. Furthermore, the sample size was slightly reduced due to incomplete responses, and no adjustment was made to compensate for these dropouts.

Conclusion

Digital monitors should be the preferred method for viewing radiographic images, given their superior subjective image quality. When digital display is not an option due to technical limitations or other constraints, printing on radiographic film remains essential to maintain diagnostic clarity. If printing on paper becomes necessary, the findings of this study suggest that glossy inkjet paper is the optimal choice. It offers a superior balance of image quality and diagnostic reliability compared to plain paper, ensuring that diagnostic accuracy is not compromised

Ethics approval:

Approval from the institutional ethical review board Ref. No. JSMU/IRB/2022/-612 Dated: 09-05-2022.

Data Availability: Data supporting the findings are available upon reasonable request.

Financial support and sponsorship: None

Conflict of interest: The authors declare that they have no conflict of interest.

Informed consent:

Written informed consent was taken from each of the participants of study

Authors' Contribution:

SFA & MK: Conception & design, data collection, data analysis, manuscript writing
MK: Data analyis, manuscript writing
MH: Data analysis and interpretation and reviewed final manuscript.
MKK: Ensured accuracy and integrity of data and revised manuscript before submission.

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