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Enhancing the Quality of Digital Panoramic Radiographs with Median Filtering and Histogram Equalization Techniques

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A B S T R A C T

Digital panoramic radiographs often suffer from noise and reduced contrast, which can compromise diagnostic accuracy and treatment planning. Conventional enhancement methods rely on default Carestream software with manual adjustments, which may be inconsistent and time-consuming. This study aims to improve the quality of digital panoramic radiographs by applying Median Filtering (MF) to reduce noise and Histogram Equalization (HE) to enhance contrast using MATLAB R2022a. An analytical experimental design was conducted on 155 digital panoramic radiograph images, sampled from a total population of 254 images collected between July 2021 and July 2022 at the Dental Radiology Installation, Islamic Dental and Oral Education Hospital of Sultan Agung Semarang (RSIGMP-SA), using the Slovin formula. Radiograph files in DICOM format were converted to JPEG for analysis. Image quality was evaluated using Signal-to-Noise Ratio (SNR) and Contrast-to-Noise Ratio (CNR), and statistical significance was analyzed with the paired T-test in SPSS. The results indicated normal distribution for all parameters ($p>0.05$) and significant improvements in SNR and CNR after enhancement ($T=-14.426$ for SNR, $T=-41.673$ for CNR, $p<0.05$). These findings demonstrate that MF effectively enhances image sharpness, while HE improves contrast, resulting in clearer and more diagnostically reliable panoramic radiographs. The proposed approach provides a standardized and reproducible method for image quality improvement and offers potential support for clinical decision-making.

1. Introduction

Digital panoramic radiography is an extraoral radiographic technique that produces tomographic images of the facial structures of the maxilla, mandible, teeth, and supporting tissues on a computer screen [1]. A panoramic radiograph's quality is considered acceptable as a good image for diagnosis if it has good quality, including no noise and good contrast [2]. Image enhancement is a technique that aims to produce radiographs with improved visualization to provide as much information as possible in the radiographs [3].

Noise is a disturbance that can reduce the sharpness of the radiograph. Salt and pepper noise frequently appear on digital panoramic radiographs. As a result of memory corruption, bit errors during data transmission, and malfunctioning pixels, salt and pepper noise appears as black and white spots on radiographs. The median filtering technique is one of the image enhancement techniques for reducing noise on radiographs [4]. To replace noisy pixel values with the median values of the nearby pixels, the pixel values are first sorted in median filtering [5]. SNR (Signal to Noise Ratio) parameters can be used to assess improvements in radiograph quality. SNR is used to evaluate the noise-reduction performance of median filtering. Due to the radiograph's reduced noise, the SNR value increased after noise filtering was applied [6].

Contrast is another critical parameter affecting diagnostic quality, referring to the difference in grayscale levels between adjacent tissues on a radiograph [7]. Reduced contrast may result from sensor limitations or improper radiograph settings [8], making it difficult to distinguish between healthy and abnormal regions. Histogram equalization is a widely used method to enhance contrast by redistributing grayscale values, producing a more uniform histogram [9]. The improvement in contrast can be measured using the Contrast-to-Noise Ratio (CNR), which increases as tissue distinctions become clearer [10]. Enhancing contrast helps clinicians identify pathological regions more reliably and supports accurate clinical decision-making.

Based on these considerations, this study aims to apply the Median Filtering method for noise reduction and Histogram Equalization for contrast enhancement in digital panoramic radiographs. This research quantitatively evaluates image quality improvement using SNR and CNR parameters. The results of this study are expected to contribute to improving diagnostic image quality in dental radiology, particularly at the Islamic Dental and Oral Educational Hospital of Sultan Agung Semarang (RSIGMP-SA).

2. Research Method

This study employed a pre-post experimental design, a type of quasi-experiment, to evaluate the effect of image enhancement techniques on digital panoramic radiographs. The independent variables were the application of Median Filtering (MF) for noise reduction and Histogram Equalization (HE) for contrast enhancement. The dependent variables were Signal-to-Noise Ratio (SNR) and Contrast-to-Noise Ratio (CNR), which were measured before and after image processing.

2.1. Population and Sample

The population consisted of 254 digital panoramic radiograph files collected from patients between July 2021 and July 2022 at the Dental Radiology Installation, Islamic Dental and Oral Education Hospital of Sultan Agung Semarang (RSIGMP-SA). The sample size was determined using the Slovin formula, resulting in 155 radiographs selected from the population. Radiograph files that could not be opened or were corrupted were excluded from the study. All images were originally in DICOM format and converted to JPEG for processing. JPEG was chosen for compatibility with MATLAB R2022a, and care was taken to minimize compression artifacts by using high-quality, lossless settings. No additional resolution normalization was performed, as all images were captured with a standard panoramic radiograph resolution.

2.2. Image Enhancement Procedure

The image enhancement workflow consisted of the following steps:

1. Pre-processing: Conversion to grayscale when necessary to standardize input for the enhancement algorithms.
2. Median Filtering (MF): Applied with a 3×3 kernel to reduce salt-and-pepper noise while preserving edges.
3. Histogram Equalization (HE): Implemented as global HE to improve overall contrast. Both SNR and CNR values were measured before and after enhancement to quantify the effect.

2.3. Data Analysis

The normality of the SNR and CNR distributions was assessed using the Shapiro–Wilk test. After confirming normal distribution, the paired T-test was conducted to determine whether the application of MF and HE significantly improved image quality metrics.

2.4. Ethical Considerations

Ethical approval for this study was obtained from RSIGMP-SA under approval number 417/B.1-KEPK/SA-FKG/X/2022. Permission to use patient data was granted by hospital management to ensure privacy and confidentiality.

3. Result and Discussion

This study was conducted from November 2022 to January 2023 at the Sultan Agung Dental and Oral Islamic Education Hospital (RSIGMP-SA), Semarang. The normality test results for initial SNR, SNR after Median Filtering (MF), initial CNR, and CNR after Histogram Equalization (HE) indicated $p > 0.05$, confirming that the data were normally distributed and suitable for parametric analysis using the Paired T-Test.

The effect of Median Filtering on noise reduction was analyzed by comparing the SNR values before and after enhancement. The Paired T-Test results showed a calculated t value of -14.426 with $p = 0.000$, indicating a statistically significant increase in SNR and confirming that Median Filtering effectively reduces noise on digital panoramic radiographs (Table 1).

Table 1. Paired T-Test Results for SNR and CNR

Treatments	Calculated T Value	Sig. (2-tailed)
Intial SNR–SNR MF	-14.426	0.000
Initial CNR–CNR HE	-41.673	0.000

*H0 Significant >0,05

The distribution of SNR values before and after Median Filtering is presented in Table 2. Initially, the majority of SNR values (98 out of 155) were in the low range of 3–9, reflecting high noise levels in the original radiographs. After applying Median Filtering, most images shifted to higher SNR ranges, with the mean increasing from 8.54 to 10.39, indicating a clear reduction in noise and improvement in image quality.

Table 2. Distribution of Initial SNR and SNR after Median Filtering

Range Data	Initial SNR	Range Data	MF SNR
A (3–9)	98.00	A (4-10)	70.00
B (9–15)	53.00	B (10-15)	77.00
C (15–21)	4.00	C (15-22)	8.00
Total of Data	155.00		155.00
Mean	8.54		10.39

The improvement in SNR after Median Filtering can also be visually observed in panoramic images. Figure 1 shows the average SNR before and after Median Filtering, while Figures 2 and 3 present representative radiographs before and after noise reduction, respectively. Median Filtering successfully reduced salt-and-pepper noise while preserving edge details, providing clearer anatomical boundaries. Although effective, Median Filtering may not completely eliminate noise at object edges, as it primarily modifies the central pixel values within the filtering kernel.

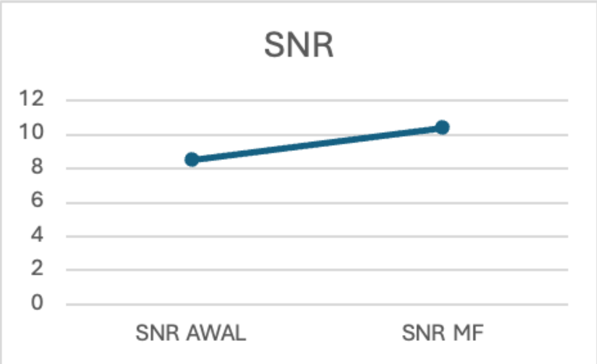

Figure 1. Average SNR before and after Median Filtering.

Figure 2. Initial Panoramic Radiographic Picture

Figure 3. Panoramic radiograph after Median Filtering.

The effect of Histogram Equalization (HE) on image contrast was evaluated using CNR values. The Paired T-Test showed a calculated t value of -41.673 with p = 0.000, demonstrating a significant improvement in contrast. The distribution of CNR values before and after HE is shown in Table 3. Initially, most CNR values were in the lower ranges (41 in 10–35, 55 in 35–55), indicating poor contrast. After HE, the distribution shifted to higher ranges, with the mean increasing from 49.50 to 121.85, confirming that HE significantly enhances image contrast.

Table 3. Distribution of Initial CNR and CNR after Histogram Equalization

Data Distribution	Initial CNR	Data Distribution	HE CNR
A (10-35)	41.00	A (34-100)	83.00
B (35-55)	55.00	B (100-200)	53.00
C (55–75)	40.00	C (200-300)	12.00
D (75-95)	15.00	D (300-400)	4.00
E (95-132)	4.00	E (400-500)	0.00
		F (500-600)	2.00
		G (600-732)	1.00
Total data	155.00		155.00
Average	49.50		121.85

Figure 4 illustrates the average CNR before and after Histogram Equalization, while Figure 5 shows a panoramic radiograph after contrast enhancement. HE improves visibility of anatomical structures by increasing the difference between regions of varying brightness, although it may shift the overall brightness toward mid-range values.

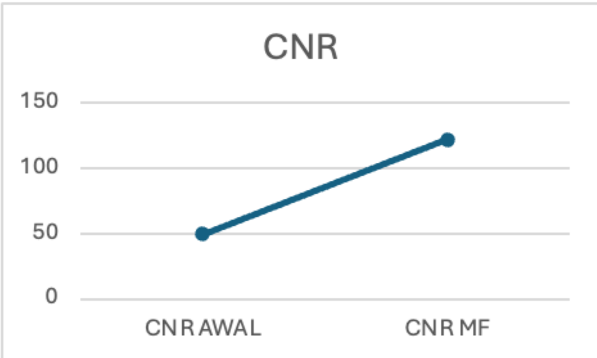

Figure 4. Average CNR before and after Histogram Equalization.

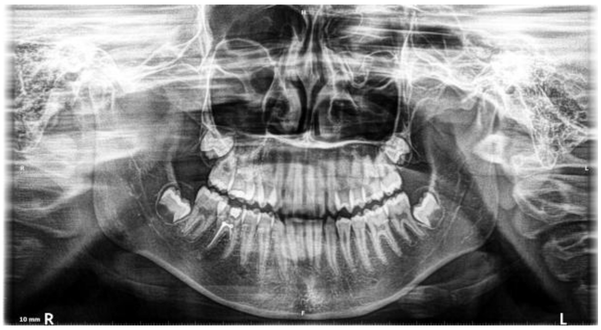

Figure 5. Panoramic radiograph after Histogram Equalization.

Overall, the combination of Median Filtering and Histogram Equalization significantly improved the quality of digital panoramic radiographs. The SNR increase after Median Filtering reflects effective noise reduction, while the CNR increase after Histogram Equalization indicates enhanced contrast and clearer object structures. MATLAB software facilitated the quantitative evaluation of these improvements by converting qualitative radiograph observations into measurable SNR and CNR values. These findings demonstrate that the proposed image enhancement techniques can effectively improve the diagnostic quality of digital panoramic radiographs.

3.1. Discussion

Median Filtering may be employed to reduce noise on digital panoramic radiographs, allowing the radiograph's noise to be decreased and the boundaries of objects on the radiograph to be seen clearly. Radiograph quality can be determined by comparing the SNR value before and after image enhancement with Median Filtering [11]. The noise in panoramic radiographs is salt and pepper noise. Salt and pepper noise are black and white spots on radiographs caused by memory damage, bit errors when sending data, and pixels that do not work [12]. The reduced noise on panoramic radiographs causes the SNR value to increase after image enhancement using Median Filtering, which means the Median Filtering SNR value is greater than the initial SNR. The noise in the radiograph causes the SNR value to be low; therefore, if the noise decreases, the SNR value will increase [13]. The advantages of Median Filtering are that it can be accessed in a variety of software, it is more practical and easier to use, especially in medical radiographs, and it can reduce noise without blurring the edges of panoramic radiograph objects, whereas the disadvantage of Median Filtering is that it’s not programmed to reduce noise on the radiograph's edges because Median Filtering only changes the pixel values in the middle of the matrix [14]. The improvement in SNR values after Median Filtering is evident from the data distribution and the average increase, which can be seen in Table 2 and the graphical representation in Figure 1, showing the effect of noise reduction on image quality.

Histogram Equalization is a contrast enhancement method that can make it more convenient to identify objects on radiographs. The purpose of Histogram Equalization is to increase the contrast and brightness values from low to high [15]. The degree of difference between two different areas on a radiograph is defined as contrast. Contrast can be beneficial for identifying various areas in the part to be observed; the higher the contrast value, the greater clarity of the object will be seen [16]. The Contrast-to-Noise Ratio (CNR) is a method for determining contrast acuity. The increased contrast level on the radiograph causes the CNR value to increase after image enhancement with the Histogram Equalization method. If the CNR value is low, the structure of the object on the radiograph cannot be seen clearly, and if the CNR value increases after image enhancement, the contrast is said to increase, allowing the structure of the object on the radiograph to be seen more clearly [17]. The Histogram Equalization method has the advantages of being accessible in a wide range of software, being more practical and simple to use, particularly in medical radiographs, and having the ability to provide a uniform distribution of colours [18]. Meanwhile, the Histogram Equalization method has the disadvantage of shifting the average value of radiograph brightness to the middle range of brightness values [15]. The improvement in CNR values after Histogram Equalization can be seen in Table 3 and visually represented in Figure 5, illustrating enhanced contrast and clearer visualization of anatomical structures.

MATLAB (Matrix Laboratory) is software that has many features and is referred to as the toolbox. A toolbox is a collection of MATLAB functions designed to help simplify the image enhancement process [19]. MATLAB can be used in medical imaging technology, particularly medical radiographs generated from digital radiographs. The MATLAB software used for image enhancement can convert qualitative analysis data into quantitative data by viewing or comparing the values of radiograph quality parameters such as SNR and CNR [20].

According to the findings of this study, there was a significant difference in SNR values before and after image enhancement was performed using the Median Filtering method on digital panoramic radiographs, implying that using the Median Filtering method to reduce noise on digital panoramic radiographs had an effect. According to the findings of this study, the SNR value corresponds to the radiograph quality. Increasing the SNR values after improving the quality of the radiographs indicates less noise, making the radiograph look smoother and better than initial radiographs [21].

According to the findings of this study, there was a significant increase in CNR values between before and after image enhancement using the Histogram Equalization method on digital panoramic radiographs, implying that there was an effect of using the Histogram Equalization method to increase contrast on digital panoramic radiographs. According to the findings of the study, the CNR value corresponds to the radiograph quality. Increasing the CNR values after improving the quality of the radiographs indicates that the contrast of the radiographs is better than the initial radiographs [22].

Overall, there is an improvement in sharpness after applying Median Filtering, and an improvement in contrast after applying the Histogram Equalization method to digital panoramic radiographs. The increase in SNR values on panoramic radiographs after Median Filtering indicates a reduction in radiograph noise, while the increase in CNR values after Histogram Equalization indicates an increase in contrast on the radiographs. These results are reflected in the relevant tables and figures, which summarize the quantitative changes and illustrate the visual improvements in radiograph quality.

4. Conclusion

The results of this study demonstrate that the application of Median Filtering (MF) and Histogram Equalization (HE) significantly enhances the quality of digital panoramic radiographs. Median Filtering effectively reduces noise, as evidenced by the increase in Signal-to-Noise Ratio (SNR), while Histogram Equalization improves image contrast, as indicated by the increase in Contrast-to-Noise Ratio (CNR). These improvements can potentially enhance the accuracy and reliability of dental radiology diagnoses by providing clearer visualization of anatomical structures.

However, this study has several limitations. The radiographs were converted to JPEG format, which may introduce minor compression artifacts, and the study did not compare MF with other noise reduction filters. Future research could explore alternative image formats and compare different filtering techniques to optimize radiograph enhancement further.

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