JOURNAL MEDICAL INFORMATICS TECHNOLOGY
medinftech.org ISSN 2988-7003 (online)

Differences in Contrast Quality of Digital Panoramic Radiographs Before and After Contrast Stretching

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ARTICLE HISTORY

Received: 29 October 25
Final Revision: 14 March 26
Accepted: 28 March 26
Online Publication: 31 March 26

KEYWORDS

Contrast Stretching, Contrast-to-Noise Ratio (CNR), Digital Panoramic Radiography, Image Enhancement, Signal-to-Noise Ratio (SNR).

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DOI

10.37034/medinftech.v4i1.115

A B S T R A C T

Digital panoramic radiography is widely used for diagnosis and treatment planning because it provides comprehensive information on dental and maxillofacial anatomical structures in digital form that can be directly visualized on a computer screen. However, the quality of panoramic radiographs may decrease due to noise, inadequate density, and low contrast, which can affect diagnostic interpretation. The contrast stretching method can be applied to address this problem by increasing image contrast and reducing noise, thereby improving the visibility of objects and anatomical boundaries in radiographic images. This study aimed to determine the effect of the contrast stretching method on the quality of digital panoramic radiographs. A quantitative experimental analysis was conducted using retrospective digital panoramic radiograph data from patients at RSIGMP UNISSULA. A total of 155 digital panoramic radiograph images from July 2021 to July 2022 were selected using the Slovin method. Image quality enhancement was quantitatively evaluated using the Signal-to-Noise Ratio (SNR) and Contrast-to-Noise Ratio (CNR) parameters. The obtained data were analyzed using a paired t-test after fulfilling the normality assumption. The results showed significant differences in both SNR and CNR values before and after processing, with a significance value of 0.000 ($p < 0.05$). Both parameters increased after contrast stretching, indicating improved image contrast and reduced noise in digital panoramic radiographs. These findings demonstrate that contrast stretching is an effective and practical method for improving radiographic quality, which may support radiographers in achieving clearer diagnostic images and provide useful insight for medical imaging system developers in designing image enhancement modules.

1. Introduction

Digital panoramic radiography is one of the extra-oral radiographs that is used to determine diagnoses and treatment plans because it can depict all teeth and tooth tissue completely in one film, stored in digital file form that can be directly seen on a computer monitor screen [1]. The quality of the panoramic radiograph is said to be acceptable as a good image (acceptable) for diagnosis, that is, if it has good quality. Panoramic radiographs are of good quality if they have all the information needed and meet several aspects [2]. The quality aspects assessed in a radiograph include that there is no noise and has good density and contrast [3]. Image enhancement is a method that can be used to produce radiographs with better visualization than the original radiographs [4]. Recent studies also emphasize that improving radiographic image quality is essential to support diagnostic accuracy and clinical decision-making [5].

Noise is a disturbance that can reduce the sharpness of radiographic images. The noise is caused by bit errors and pixels that don't work [6], [7]. Meanwhile, contrast is the degree of density difference between two parts in a radiographic image. The contrast itself expresses a distribution of light and dark in the image [8]. Contrast helps in identifying the characteristics possessed by each image in the inspection section such as scratches, breaks and others. High contrast can make objects look easier [9]. Noise in the radiograph and poor contrast can occur in digital panoramic radiographs. Previous studies have shown that dental panoramic radiographs often suffer from low contrast and noise, which can affect interpretation accuracy [10]. Therefore, image enhancement techniques are required to overcome these limitations.

One of the image enhancement methods that can be used to reduce noise and increase contrast on radiographs is the contrast stretching method [11]. Contrast stretching is a method used to obtain a new image that has better contrast than the original image. Contrast Stretching aims to make the contrast to a higher value increase and reduce noise so that the noise on the radiograph can be reduced and objects and the boundaries of objects on the radiograph can be seen properly. The mechanism is by making it wide or making a narrow range of pixel intensity values and reducing noise. Parameters for measuring radiograph quality improvement can use SNR and CNR [12]. In addition, contrast enhancement techniques have been widely applied in dental radiography to improve image detail, edges, and overall visual quality [10].

Radiographic quality assessment can be done by comparing the SNR and CNR values before and after image enhancement is performed. Signal Noise Ratio (SNR) is used to see the image quality that is determined after an image enhancement is performed [13]. Factors that cause an increase in the SNR value after image enhancement due to reduced noise on panoramic radiographs so that the SNR value will increase more than the initial SNR. Increasing the SNR value means that noise reduction can improve image quality [12].

Contrast to Noise Ratio (CNR) is a relative indicator of the contrast quality of an image. The factor that causes the CNR value to increase after image enhancement is due to the increased contrast level on the radiograph. An increase in the CNR value indicates that the contrast increases which causes the structure of the object on the radiograph to be seen more clearly [14]. The stretch contrast method has the advantages of being simple, accessible in several applications, and easy to implement and can represent a good visual image of the original image [15]. Despite the rapid development of advanced techniques such as deep learning-based enhancement, conventional methods remain relevant due to their efficiency and practicality in clinical environments with limited computational resources [5].

However, studies that specifically examine the application of contrast stretching in dental panoramic radiographs remain limited. Therefore, based on the description that has been presented, the authors are interested in knowing more about the use of the Contrast Stretching method to reduce noise and increase contrast on digital panoramic radiographs. It is hoped that the results of this study can provide input to the Islamic Dental and Oral Educational Hospital of Sultan Agung Semarang (RSIGMP-SA) related to improving the quality of radiographs.

2. Research Method

This study used a quantitative experimental method with comparative analysis before and after treatment. Data collection was carried out through observation of digital panoramic radiographic images at the Dental Radiology Installation of the Islamic Dental and Oral Education Hospital of Sultan Agung Semarang (RSIGMP-SA). The dependent variable in this study was the quality of digital panoramic radiographic images, while the independent variable was image enhancement using the contrast stretching method.

The study population was digital panoramic radiograph image files in JPEG format for several patients at the Islamic Dental and Oral Education Hospital Sultan Agung Semarang from July 2021 – July 2022. The samples were obtained from retrospective secondary data using the Slovin formula, resulting in 155 digital panoramic radiograph images. The inclusion criteria were panoramic radiographs with complete anatomical coverage, good file readability, and no severe motion artifacts. The exclusion criteria included image files that could not be opened, corrupted files, incomplete anatomical structures, and images with severe distortion.

The research procedure was carried out in several stages. First, permission was obtained from the management of the Dental Radiology Installation because the study involved retrospective patient image data. Ethical approval was obtained from the institutional ethics committee under approval number [insert number]. The initial stage involved measuring the Signal-to-Noise Ratio (SNR) and Contrast-to-Noise Ratio (CNR) values before image enhancement. Next, the radiographic images were processed using the Python programming language with contrast stretching coding to improve contrast and reduce noise. After processing, the SNR and CNR values were re-measured to compare image quality before and after enhancement. The processed images were also visually compared using panoramic radiograph displays before and after processing.

The obtained data were tested for normality using the Kolmogorov–Smirnov test. Because all variables showed normal distribution ($p > 0.05$), the analysis was continued using the paired t-test to compare SNR and CNR values before and after the contrast stretching process on the same image samples.

3. Result and Discussion

This research was conducted from February to June 2023 at the Dental Radiology Installation at the Islamic Dental and Oral Education Hospital of Sultan Agung Semarang (RSIGMP-SA). Based on the data obtained, a normality test was carried out using the Kolmogorov–Smirnov method to determine whether the data were normally distributed. The results showed that the SNR before processing, SNR after processing, CNR before processing, and CNR after processing had Asymp. Sig. values of $p > 0.05$, indicating normal distribution. Therefore, the analysis was continued using the paired t-test.

Table 1. Paired T-Test Results

		Mean (dB)	*Paired T Test Sig.*
Pair 1	SNR Before Process (N = 155)	867,74 ± 196,87	0,000
	SNR After Process (N = 155)	1.167,50 ± 326,88	
Pair 2	CNR Before Process (N = 155)	578.552,74 ± 136.070,90	0,000
	CNR After Process (N = 155)	646.283,30 ± 180.616,81	

Table 1 presents the comparison of mean SNR and CNR values before and after the application of contrast stretching. The mean SNR increased from 867.74 ± 196.87 before processing to 1167.50 ± 326.88 after processing. This increase indicates that the processed panoramic radiographs had a better signal representation relative to background noise, suggesting improved image clarity and reduced noise interference.

A similar trend was observed for the CNR values. The mean CNR increased from 578552.74 ± 136070.90 before processing to 646283.30 ± 180616.81 after processing. The higher CNR value after enhancement indicates improved differentiation between adjacent anatomical structures, which is essential for clearer visualization of teeth, bone, and surrounding tissues in panoramic radiographs.

The paired t-test significance value of 0.000 ($p < 0.05$) for both SNR and CNR confirms that the observed improvements were statistically significant. These results indicate that the contrast stretching method had a measurable positive effect on both noise suppression and contrast enhancement..

Table 2. Data distribution of SNR values before and after processing

Data distribution	SNR Before Process	Data distribution	SNR After Process
Range Data		Range Data	
A (100-600)	10,00	A (100-600)	3,00
B (600-1.100)	127,00	B (600-1.100)	65,00
C (1.100-1.600)	18,00	C (1.100-1.600)	75,00
D (1.600-2.100)	0,00	D (1.600-2.100)	10,00
E (2.100-2.600)	0,00	E (2.100-2.600)	2,00
Total data	155,00		155,00
Average	867,74		1.167,50

Table 2 shows the frequency distribution of SNR values before and after contrast stretching. Before processing, the majority of radiographs (127 out of 155 images) were concentrated in the 600–1100 range, indicating moderate image quality with noticeable noise levels.

After processing, the distribution shifted toward higher ranges. The number of images in the 1100–1600 range increased substantially from 18 images to 75 images, while additional images also appeared in the 1600–2100 and 2100–2600 intervals. At the same time, the number of images in the lower 100–600 range decreased from 10 images to only 3 images.

This distribution shift demonstrates that contrast stretching consistently improved the signal quality of most radiographs, moving them from moderate to higher SNR categories. The increase in average SNR from 867.74 to 1167.50 further supports this improvement.

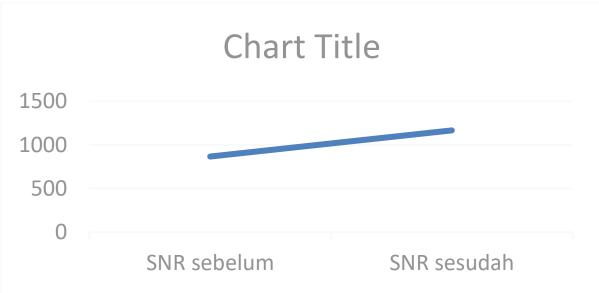

Figure 1. Graph of average SNR value tabulation before and after processing

The shift in SNR distribution is further supported by the graphical comparison shown in Figure 1, where the average SNR value after contrast stretching is visibly higher than before processing. This graph confirms that the enhancement process consistently improved signal quality and reduced noise in most digital panoramic radiographs.

Table 3. Data distribution of CNR values before and after processing

Data distribution	SNR Before Process	Data distribution	SNR After Process
Range Data		Range Data	
A (100.000-400.000)	11,00	A (100.000-400.000)	11,00
B (400.000-700.000)	120,00	B (400.000-700.000)	94,00
C (700.000-1.000.000)	24,00	C (700.000-1.000.000)	44,00
D (1.000.000-1.300.000)	0,00	D (1.000.000-1.300.000)	6,00
Total data	155,00		155,00
Average	578.552,74		646.283,30

Table 3 presents the distribution of CNR values before and after processing. Before enhancement, most radiographs (120 images) were grouped within the 400000–700000 range, indicating moderate contrast differentiation between anatomical structures.

After contrast stretching, the number of radiographs in the 700000–1000000 range increased from 24 images to 44 images, and 6 images reached the highest range of 1000000–1300000, where previously no images were found. Meanwhile, the frequency in the lower-middle range decreased from 120 to 94 images, indicating a clear upward shift in contrast quality.

This finding suggests that contrast stretching improved the visibility of boundaries between teeth, jawbone, and surrounding anatomical regions. The increase in average CNR from 578552.74 to 646283.30 quantitatively confirms better contrast discrimination after processing.

A similar pattern can be observed in Figure 2, which illustrates the increase in the average CNR value after processing. The higher post-processing average indicates better contrast differentiation between anatomical structures, supporting the effectiveness of the contrast stretching method in improving radiographic visibility.

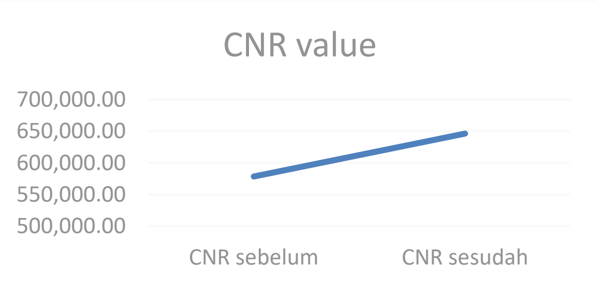

Figure 2. Graph of average CNR value tabulation before and after processing

The visual comparison between Figure 3 and Figure 4 demonstrates that the panoramic radiograph after contrast stretching exhibits clearer anatomical boundaries, improved grayscale separation, and better visibility of dental and osseous structures. In particular, the cortical bone margin, tooth roots, and interdental regions appear more distinct after processing, supporting the quantitative increase in SNR and CNR values.

Figure 3. Panoramic radiograph before processing

Figure 4. Panoramic radiograph after processing

3.1. Discussion

The results of this study showed that the application of the contrast stretching method significantly improved the quality of digital panoramic radiographs, as indicated by the increase in both SNR and CNR values. Contrast stretching is a method used to obtain a new image with better contrast than the original image by expanding the range of pixel intensity values [12]. This mechanism increases grayscale separation, allowing the boundaries between anatomical structures such as teeth, roots, cortical bone, and surrounding tissues to become more visible.

The increase in Contrast-to-Noise Ratio (CNR) after processing indicates that the contrast difference between adjacent anatomical regions became clearer. Higher CNR values suggest better object discrimination and improved visibility of anatomical structures, which is essential in dental panoramic radiography for diagnostic interpretation [14]. This finding is also visually supported by Figure 4, where the processed panoramic radiograph shows clearer cortical margins, more distinct tooth roots, and improved contrast separation compared with Figure 3.

In addition to CNR improvement, the increase in Signal-to-Noise Ratio (SNR) indicates that the signal component became more dominant relative to background noise after processing. Although contrast stretching primarily focuses on contrast enhancement, the redistribution of intensity values can also improve perceived signal clarity, thereby increasing the SNR value. However, several images showed less pronounced improvement, which may be caused by residual noise that was not sufficiently reduced, such as bit errors and malfunctioning pixels in the digital detector system [11].

Compared with other image enhancement methods, such as histogram equalization and median filtering, contrast stretching offers a more controlled grayscale enhancement. Histogram equalization can improve global contrast but may produce excessive brightness redistribution in certain regions, which can reduce anatomical realism. Meanwhile, median filtering is effective in suppressing impulsive noise but may reduce fine edge details in the trabecular bone and root regions. The contrast stretching method has the advantage of being simple, easily accessible in several applications, easy to implement, and capable of preserving the overall visual representation of the original image [16]. However, one limitation is the possibility of reduced image detail due to saturation, especially when the histogram does not contain a clear peak value [16].

The use of Python in this study also supported the image enhancement process effectively. Python is widely used in medical imaging applications because it provides flexible algorithm implementation and efficient quantitative evaluation of image quality parameters such as SNR and CNR [17]. Through Python-based contrast stretching coding, the image contrast was enhanced while background noise was relatively reduced, resulting in improved radiographic visibility after processing.

Overall, based on both quantitative analysis and visual comparison, the findings confirm that the contrast stretching method has a significant positive effect on improving contrast quality and reducing noise in digital panoramic radiographs. The increased SNR and CNR values after processing indicate that the radiographic images became clearer and more diagnostically useful than the initial images.

4. Conclusion

Based on the research findings, it can be concluded that there are significant differences in the contrast quality of digital panoramic radiographs before and after the application of the contrast stretching method. The method was proven to improve radiographic image quality through increased contrast and reduced noise, as demonstrated by the higher SNR and CNR values after processing. These findings indicate that contrast stretching is effective in enhancing the diagnostic visibility of digital panoramic radiographs at the Islamic Dental and Oral Education Hospital of Sultan Agung Semarang (RSIGMP-SA). Practically, this method can assist radiographers in obtaining clearer radiographic images for more accurate diagnostic interpretation and may also serve as a reference for medical imaging system developers in designing simple image enhancement modules for dental radiography applications. For future research, it is recommended to use a larger dataset, include more diverse patient image characteristics, and compare contrast stretching with other enhancement methods such as histogram equalization and median filtering to determine the most effective technique for improving digital panoramic radiograph quality.

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