Description of Quality Enhancement of Panoramic Conventional Radiography

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Abstract

Development of negative panoramic-based radiograph system into digital imaging often getting the unexpected quality. There are many methods of the quality improvement process (enhancement) thus needs to be assessed. The objective of this research was to obtain the best quality improvement method based on an objective radiograph quality analysis.

This research was a comparative descriptive research with as much as 30 samples of analogue panoramic radiograph taken with the purposive sampling method from data of Dental Hospital of Faculty of Dentistry Universitas Padjadjaran (RSGM). The next stage was the digitalization process using a scanner with mode settings as follows: transmission; intensity resolution of 8-bit and spatial resolution of 800 dpi; Intel® Pentium Dual Core 2 GHz PC Processor; 4 GB RAM; Scanner; So Epson® Perfection V700; Software; LED LCD Screen. The program file setting was set in the *.tif format. Enhancement of the radiograph quality was performed by using the software, each was using the Contrast Stretching (SC) method, Adaptive Histogram Equalization (AHE), Histogram Equalization (HE), and Contrast Limited Adaptive Histogram Equalization (CLAHE). The objective assessment was using the variables as follows: mean; standard deviation; peak signal to noise ratio (PSNR); root mean square error (RMSE); average difference (AD); normalized absolute error (NAE); and structural content (SC).

From the measurement results obtained the values of Mean, SD, PSNR, RMSE, AD, NAE, and SC with the CLAHE method were 106.17; 47.27; 17.11; 35.56; 9.29; 0.1679; and 1.2252 consecutively.

The CLAHE method was the best quality improvement method because the ability to overcome the limitations of the AHE method by limiting the increase in brightness and contrast thus maintained the object details.

Experimental article (J Int Dent Med Res 2018; 11(3): 857-865)

Keywords: Enhancement, Objective quality, Panoramic digitalization.

Received date: 28 April 2018 **Accept date:** 06 June 2018

Introduction

Conventional panoramic radiograph with negative film results is the early device generation still widely used to date. For visualization and interpretation, the negative film of the radiograph is placed on the source of the viewer.[1-3]

The contrast difference in radiograph is determined by the level of transmitted light from the viewer to the film negative, as well as the visual perception. The ability to differentiate the soft and hard tissue radiographs and the occurrence of abnormalities in patients are mostly determined by the visualized contrast ranges on the radiograph. Dental Hospital of Faculty of Dentistry Universitas Padjadjaran is provided with a direct digital imaging x-ray panoramic device. The advantage over conventional devices is that the final radiograph obtained from the device is already presented in a digital radiographic format of DICOM (Digital Imaging and Communications in Medicine). The contrast range of digital format can be corrected as necessary through a radiograph processing.[4-6] As in the conventional device, the contrast quality of the negative film is determined mostly by the film washing process, and the contrast range cannot be corrected. The visualization will require digitalization. The result of indirect digitalization is

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a good image range. Many developed methods are depending on the radiograph film type produced. The contrast range of the radiograph negative film is still varied and differ from the digital radiographic contrast range. In some cases, it may cast a doubt on the interpretation outcome.[5,6] The development of a negative-based panoramic x-ray dental radiograph system into digital imaging radiograph is performed to improve the quality of various methods, in order to get the best method for visualizing and interpreting the dental radiograph image easier, clearer, and more accurate.[7,8] The objective of this study was to obtain the best quality improvement method based on the radiographic quality analysis objectively using a Direct Digital Imaging as the standard reference.

Materials and methods

This research was a comparative descriptive research with purposive sampling method. The research was conducted towards as much as 30 conventional panoramic radiographs, with radiograph inclusion criteria were in the good state of brightness and complete. Radiographs were produced by Dentomaxillofacial Radiology Installation of Dental Hospital of Faculty of Dentistry Universitas Padjadjaran, Indonesia. Digitalization process was performed using the Epson® Perfection V700 Scanner; PC with Intel® Pentium processor Dual Core 2 GHz and 4 GB RAM; Software; LED and LCD Screen of 42LV350; and Windows® XP Professional SP2 operating system. Digitalization procedure was performed by setting up the Epson® Scan program firstly, with the transmission mode scanner, 8-bit intensity resolution, 800 dpi spatial resolution, and radiograph *.tif file format. The computation process was then performed using specific software. The radiograph histogram was analyzed by performing an enhancement to improved the quality of each radiograph using the methods of Contrast Stretching (SC), Adaptive Histogram Equalization (AHE), Histogram Equalization (HE), and Contrast Limited Adaptive Histogram Equalization (CLAHE).[9-11]

Objective assessment of radiographic statistical characteristics

At this stage, comparisons were made objectively based on the radiographic statistical characteristics.[11,12] Mean

$$\overline{x} = \frac{1}{N}\sum_{i=1}^{N} x_i$$

with the $\overline{x}$ value was the pixels average value; the N value was the pixels number; and the x_i value was the gray level value on the-i pixels.

Standard deviation was counted as follows:

$$\sigma = \sqrt{\frac{1}{N}\sum_{i=1}^{N}\left(x_i - \overline{x}\right)}$$

The PSNR represented the quality of a radiograph objectively by comparing the noise to its peak signal.

$$PSNR = 20\log 10\left(\frac{255}{\sqrt{MSE}}\right)$$

with MSE was the Mean Square Error value defined with the formula as follows:

$$MSE = \frac{1}{n_x n_y}\sum_{0}^{n_x-1}\sum_{0}^{n_y-1}\left[r(x,y)-t(x,y)\right]^2$$

with the n_x and n_y value were the number of rows and columns of the radiograph matrix respectively; the $r(x,y)$ value was the pixel gray level value of original radiograph; and the $t(x,y)$ value was the pixel gray level value of enhanced radiograph.

The Root Mean Square Error (RMSE) is the square root of the MSE, used to measure the average amount of errors on an enhancement radiograph based on the original radiograph. Mathematically, the RMSE value is defined according to the equation as follows:

$$RMSE = \sqrt{\frac{1}{n_x n_y}\sum_{0}^{n_x-1}\sum_{0}^{n_y-1}\left[r(x,y)-t(x,y)\right]^2}$$

The Average Difference (AD) shows the value of the average differences between the pixel values and defined according to the equation as follows:

$$AD = \frac{1}{n_x n_y}\sum_{0}^{n_x-1}\sum_{0}^{n_y-1}\left|r(x,y)-t(x,y)\right|$$

Meanwhile, the Normalized Absolute Error (NAE) is defined according to the equation as follows:

$$NAE = \frac{\sum_{0}^{n_x-1}\sum_{0}^{n_y-1}\left|r(x,y)-t(x,y)\right|}{\sum_{0}^{n_x-1}\sum_{0}^{n_y-1}\left|r(x,y)\right|}$$

The Structural Content (SC) is defined according to the equation as follows:

$$SC = \frac{\sum_{0}^{n_x-1}\sum_{0}^{n_y-1}\left|r(x,y)\right|^2}{\sum_{0}^{n_x-1}\sum_{0}^{n_y-1}\left|t(x,y)\right|^2}$$

Results

Contrast Streching (CS)

The radiographic contrast range could be widened, or the brightness level was shifted to the white grey level to made the radiograph image appears brighter, as seen in Figure 1.

Histogram Equalization (HE)

Histogram equalisation was a radiographic quality improvement method of global spatial domains. The output pixel value at the radiographic coordinates was the result of the histogram equalisation operations, depending on all the pixel input values of the radiograph.

Adaptive Histogram Equalization (AHE)

In the adaptive histogram equalisation process, the process included the selection of the local neighbourhood of each pixel radiograph, calculation, and equalisation of the histogram neighbourhood. Then the pixel value mapping as the centre of the neighbourhood based on the localised histogram that has been equalised.

Contrast Limited Adaptive Histogram Equalization (CLAHE)

The contrast limited adaptive histogram equalisation method was the development of the adaptive histogram equalisation method. In this method, there was a parameter for the boundary value of the histogram so that the increasing contrast in the radiograph background would not be excessive although operated locally.

Objective assessment of radiographic statistical characteristics

Statistical characteristics used in this study were including the mean, standard deviation, peak signal to noise ratio (PSNR), root mean square error (RMSE), average difference (AD), normalised absolute error (NAE), and structural content (SC), as shown in Table 1.

Discussion

The radiographic quality improvement methods were divided into two types, namely frequency and spatial based methods. The Fourier transformation is used In the frequency-based radiograph quality improvement method, whilst the pixel radiograph operation is used in the spatial-based method. In this study, the panoramic radiograph quality improvement method used was the spatial-based method. There are three types of spatial-based radiographic quality improvement methods to be evaluated, based on the point operation, global operation, and local operation. The quality improvement methods were included the contrast stretching, histogram equalisation, adaptive histogram equalisation, and contrast limited adaptive histogram equalisation.[11,12] The contrast stretching method could widen the contrast range or shifted the brightness level to the white grey level to make the radiograph appeared brighter. The contrast stretching method includes an enhancement method with point-operational properties. This operational property enables the output pixel value in the radiographic coordinates as the result of the contrast stretching operation depends on the pixel value of the radiograph input at the same coordinates. Generally, there is a similarity in the histogram distribution between the contrast stretching (CS) and histogram equalisation (HE) image, also, between the contrast limited adaptive histogram equalisation - uniform (CLAHE-uniform) and contrast limited adaptive histogram equalisation–exponential (CLAHE-Rayleigh) processed images.[9,11,12] Figure 1 showed the comparison between original radiograph with enhanced radiograph by the contrast stretching method with the grey-level distribution in the range of 5-222, widened into 5-255. The radiograph resulted in a visually better brightness level. Objectively, the brightness change as the processing result of the contrast stretching method can be observed from the change in the mean value of the radiograph pixel from 84.65 to 138.82. Overall, the brightness level of the panoramic radiograph area was increasing. However, there was a shortcoming in the processing results with contrast stretching method, which were changes in the local contrast and reduction of the radiograph object details.[13,14]

Histogram equalization is a radiographic quality improvement method with global spatial domains. The output pixel value at the radiographic coordinates was the results of the histogram equalization operation, depends on all the radiograph pixel input values. When the radiographic histogram is parsed, all the radiograph pixel values are redistributed in such ways that some pixel values will get closer as a result of histogram equalization operation.[6,7]

In the histogram equalization operation, the contrast will increase at the dominant grey level range (peak area of the histogram). The number of pixels in the black value range is close to 0, and in the grey value range was approximately 255, as shown in Figure 2. The histogram ranges were increasing due to the equalization process, resulting in darker obscure areas, and brighter vivid areas on the radiograph, thus, the object detail became invisible and local contrast was decreasing.

Adaptive Histogram Equalization (AHE), has a different output from the histogram equalisation operation result, which depends on the overall (global) radiograph pixel value. In adaptive histogram equalisation, the output pixel values coordinates are depending on the environment of the radiograph pixel value at the same local coordinate. The process of adaptive histogram equalisation method includes the selection of local neighbourhood of each pixel radiograph, calculation, and equalisation of the histogram neighbourhood.[6,7] The pixel value mapping at the centre of the neighbourhood is based on the localised histogram. Due to the local properties, the uniformity effect of the illumination when digitising or during the x-ray exposure are able to be minimised thus the adaptive histogram equalisation method is better in maintaining the local contrast. Also, the local operation within the adaptive histogram equalisation method is resulting in relatively slight changes in the radiograph grey level.[11,12] This will give a more natural impression than the histogram equalization processing radiograph. In the histogram equalization method, the equalisation of the histogram distribution that operates globally increases the variation of the excessive grey levels. However, there is still a shortcoming of the adaptive histogram equalisation method, which is the noise presence due to an increasing background contrast level.[12] Contrast Limited Adaptive Histogram Equalization (CLAHE) method is a development of the adaptive histogram equalization method.

Generally, there are similarities in the histogram distribution between the contrast stretching (CS) and the histogram equalisation (HE) image. Also, between the contrast limited adaptive histogram equalization-uniform (CLAHE-uniform) and the contrast limited adaptive histogram equalization-exponential (CLAHE-exponential). In the contrast limited adaptive histogram equalisation-Rayleigh (CLAHE-Rayleigh), the parameters for boundary values in the contrast background of radiograph histogram was not excessive though operated locally. The expected histogram distribution criteria can be adjusted based on an evaluation of the original radiograph contrast range prior to the enhancement operation. Based on the histogram distribution, it appeared that with the contrast limited adaptive histogram equalisation method, the grey-dominated area of the panoramic radiograph and the shape of the original radiographic distribution could be maintained.[11] The disadvantages of previous adaptive histogram equalisation methods have also been accommodated. Another advantage of the contrast limited adaptive histogram equalisation method was seen in the grey level areas of the objects which approaching 255 (white degree).[6] Due to the limitation of the contrast increases and a local operation, distribution in the grey range was close to 0, and the increase was not excessive, close to 255, thus, the detail of the object in the darkest and brightest area of the radiograph remains visible and local contrast was able to be maintained (Figure 1). There was a correlation of various statistical characteristics towards the quality improvement parameters, which were the Mean, Standard Deviation, RMSE, and AD, that showed smaller values after the enhancement methods that provided better radiograph quality. The PSNR, NAE, and SC parameters tend to have a better value.[12] Therefore, it can be concluded that each image quality improvement method used affected the histogram distribution changes from the original image.

Conclusions

The CLAHE-Rayleigh method was the best radiograph enhancement method because it could overcome the limitations of the AHE method by limiting increases in the brightness and contrast so that the object detail could be maintained. A successful brightness and contrast improvement at the right values will retain both local and original contrast. The quality of the radiographic result should be examined by a phantom to see the x-ray output homogeneity, and also as a repeatable test sample without worrying about the x-ray radiation negative side effects.

Acknowledgements

The authors wish to thank Dr. Madhav VNV and Dr. Rahul, Dept. of Prosthodontics, Bharati Vidyapeeth University, Dental College & Hospital, Pune, for their guidance and help.

Declaration of Interest

The authors report no conflict of interest and the article is not funded or supported by any research grant.

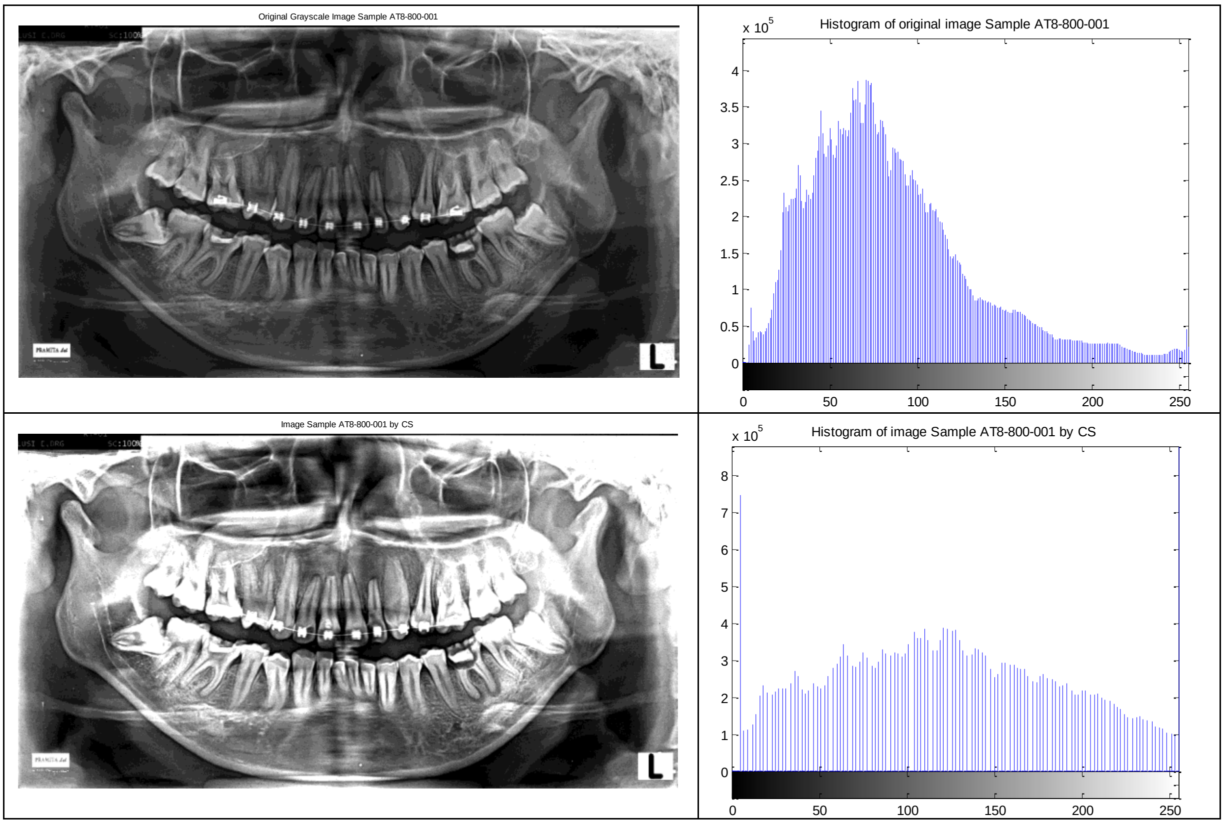


Figure 1. Radiograph and histogram before and after the process with contrast stretching (CS) method: (a) original radiograph and (b) enhanced radiograph.

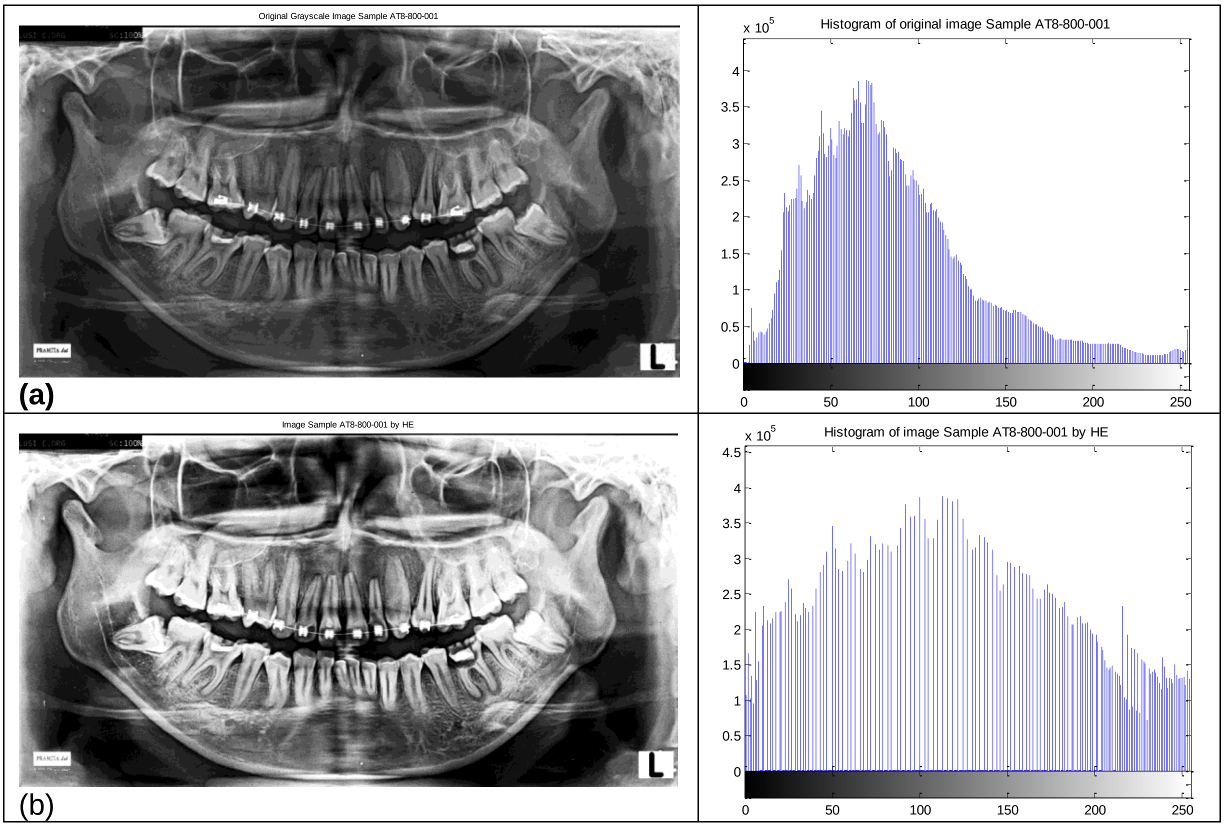


Figure 2. Radiograph and histogram before and after the process with histogram equalisation method: (a) original radiograph and (b) enhanced radiograph.

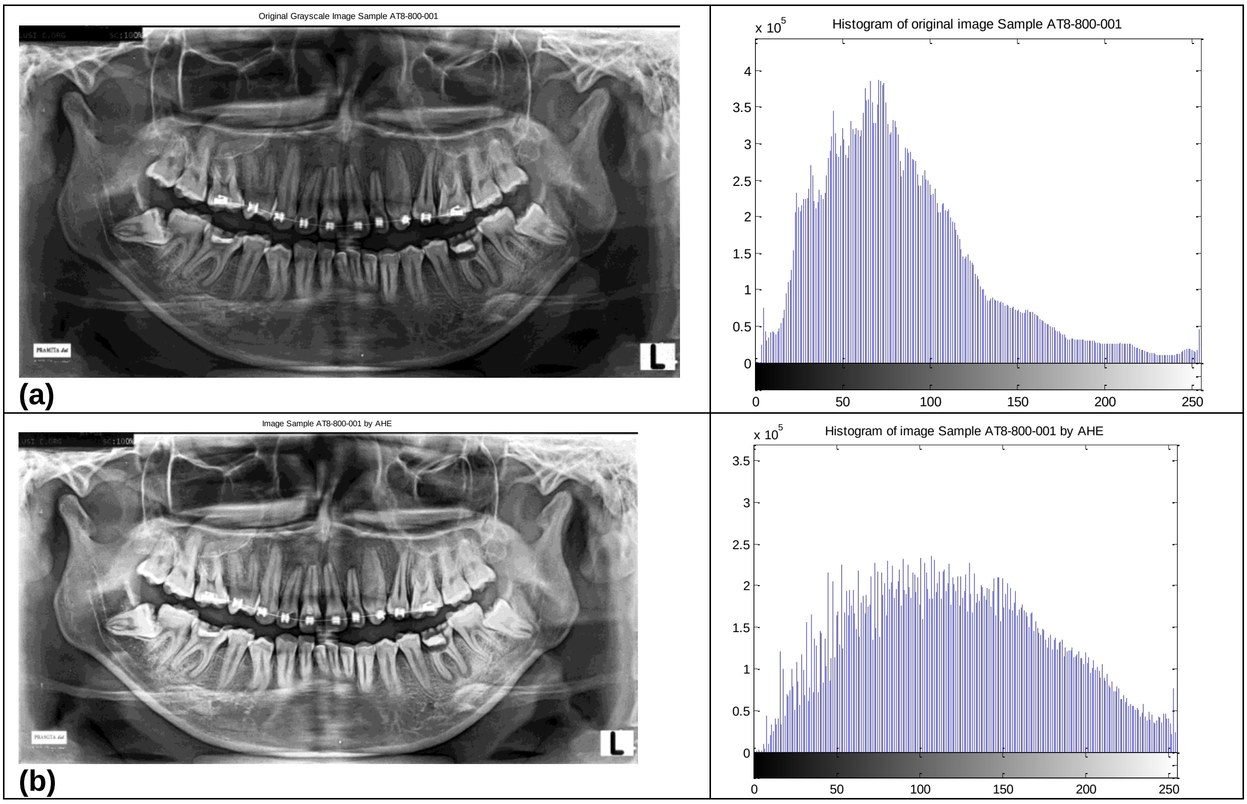


Figure 3. Radiographs and histograms before and after the process using adaptive histogram equalisation method: (a) the original radiograph and (b) enhanced radiograph.

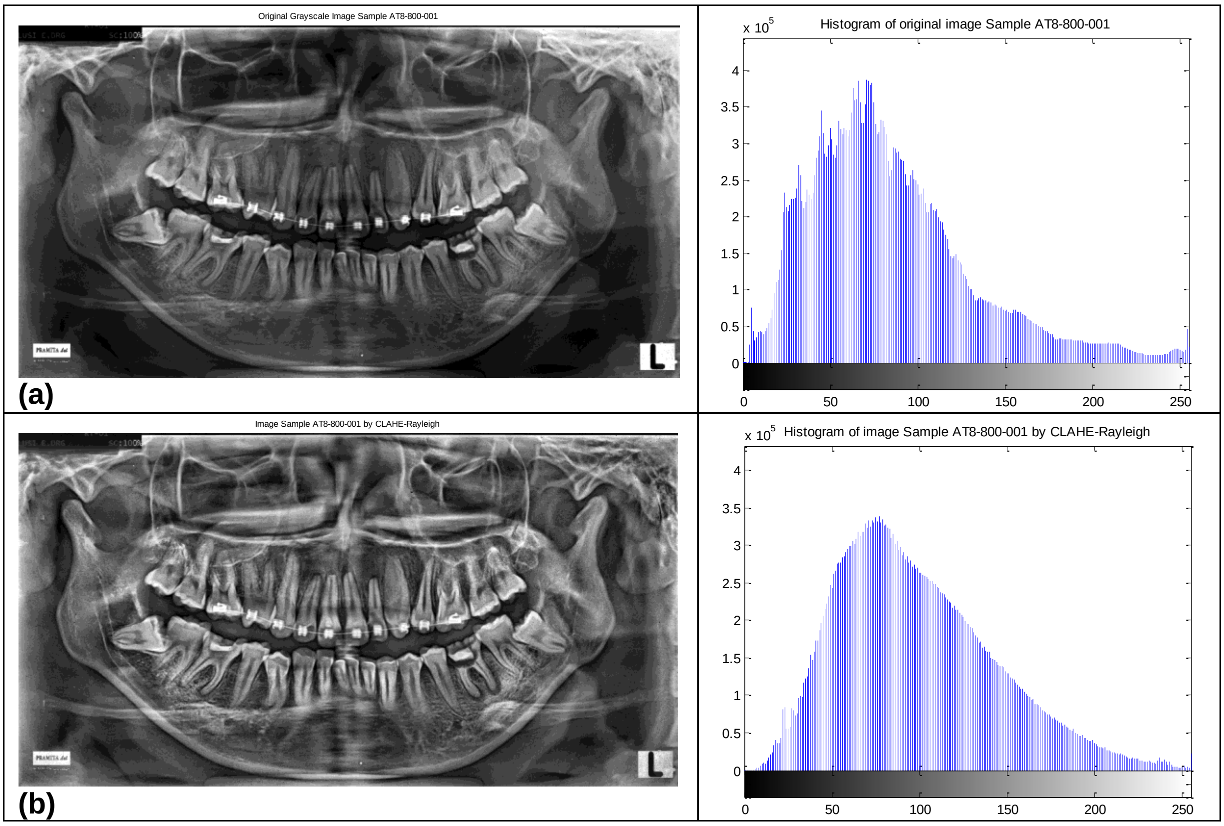
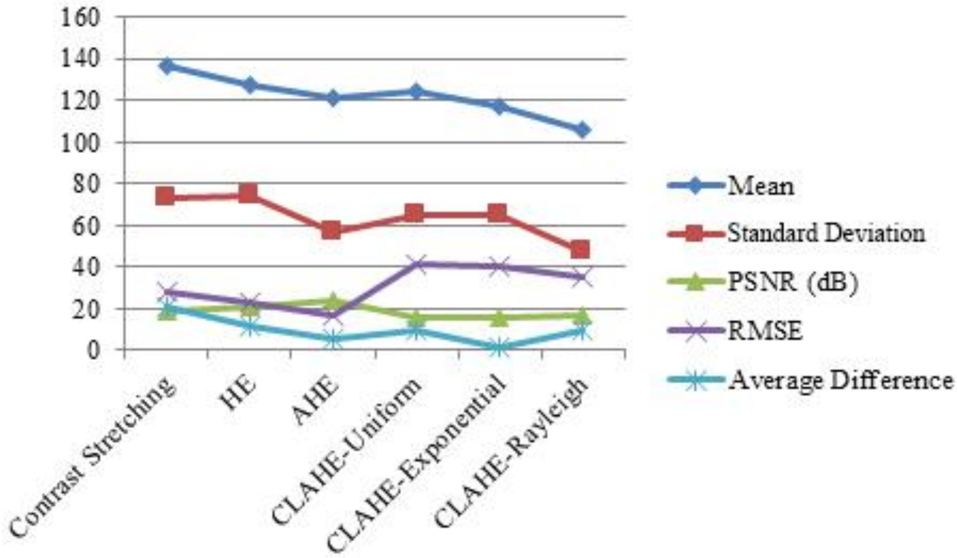


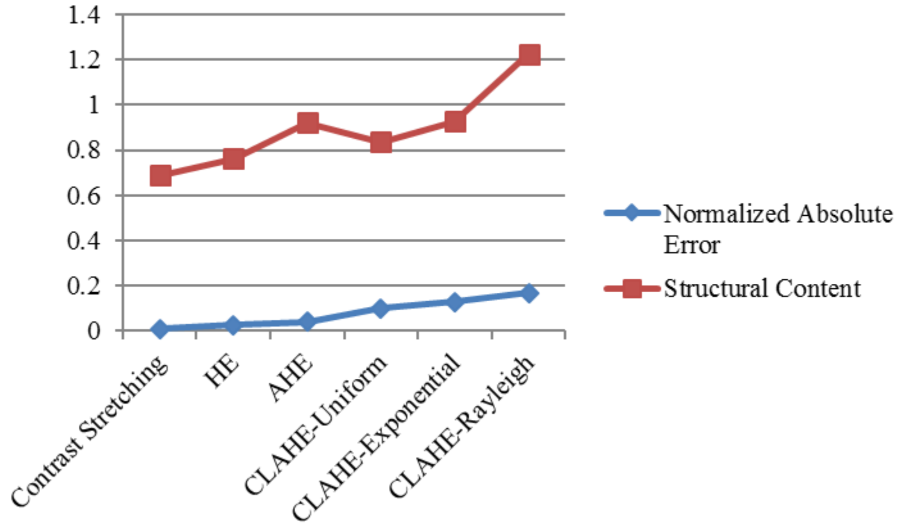
Figure 4. Radiograph and Histogram Before And After The Process Using The CLAHE Method: (A) The Original Radiograph And (B) Enhanced Radiograph.

	Mean	Standard Deviation	PSNR (dB)	RMSE	Average Difference	Normalised Absolute Error	Structural Content
Original Radiograph	115.46	56.71	20.1	24.05	21.01	0.009	0.7120
Contrast Stretching	136.81	73.25	19.28	27.69	21.35	0.0103	0.6871
HE	127.51	73.92	20.92	22.93	12.05	0.0269	0.7618
AHE	121.30	56.98	23.53	16.99	5.84	0.0399	0.9214
CLAHE-Uniform	124.75	65.14	15.88	40.98	9.29	0.0986	0.8356
CLAHE-Exponential	117.07	64.64	16.10	39.94	1.61	0.1278	0.9253
CLAHE-Rayleigh	106.17	47.27	17.11	35.56	9.29	0.1679	1.2252

Table 1. The Average Result of Objective Assessment of Quality Improved Panoramic Radiograph (Enhanced Radiograph).



Graph 1. The Average Values of: Mean, SD, PSNR, RMSE, and AD Found in the CS, HE, AHE, and CLAHE (Uniform, Exponential, and Rayleigh) Methods.



Graph 2. Structural Content (SC) Results from Various Panoramic Radiograph Enhancement.

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