The limit values for brightness and contrast adjustment in digital panoramic radiography

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Abstract. There is an overall lack of studies about digital panoramic radiography. The application of image enhancement techniques is still being done based on the operator's preferences, since there is no objective limitation. The aim is to evaluate the limit values of the brightness and contrast adjustment in digital panoramic radiography. Digital panoramic radiographs were divided into three groups (dark, medium, and light), and the contrast and brightness adjustments were done using Digora for Windows. The static evaluations were done using three criteria: 1 if the image had lower quality, 2 if there was no difference and 3 if the image had better quality. The radiographic changes differed in each group depending on the initial imaging conditions. The brightness adjustment limit values in the dark and medium groups were -10 and +20, respectively, and -20 and +10 in the light group. The contrast adjustment limit values in all of the groups were -10 and +10.

1. Introduction

Panoramic radiography is an important technique in dentistry that is used to create a single tomographic image of the facial structure, which includes the dental arch, maxilla and mandible, and other supporting structures. This technique is most useful clinically for defining a diagnosis that requires a wide view of the jaw. Several examples of the use of panoramic radiography are for the evaluation of trauma, the third molar location, tooth development (especially in mixed dentition), temporomandibular joint (TMJ) pain, and growth anomalies [1].

Although panoramic radiography is widely used, it still has some drawbacks. For example, errors occur if the produced image layer is not appropriate to the original shape and size, resulting in a distorted image. In addition, poor images can result from the wrong head position, ghost images, processing faults, and patient movement [2]. The most common fault is excess distortion and disproportion resulting from an incorrect patient position. The three most important things to remember in order to achieve an optimum radiograph wth correctly interpreted diagnostic information are the correct patient position, exposure parameters, and image processing [3].

Panoramic radiographs can be created using conventional and direct digital imaging techniques [4]. When compared to the conventional technique, the digital panoramic technique has some advantages, including a lower dose of absorbed radiation in the patient (the sensitivity results in a shorter exposure time), computerized data saving to simplify the consultation and communication with the patient, and the ability to reprocess the images [5].

The main advantage of this technique is image reprocessing by adjusting the contrast and density of the radiograph, which decreases the need for retaking the images due to errors in the technique and

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exposure [6]. Image enhancement is done in the hope of creating a better quality image than that of the original radiograph. This can be achieved by increasing the contrast, optimizing the brightness, sharpening the image, and reducing the noise. These are applied subjectively depending on the observer's preference to improve visualization; therefore, they do not increase the accuracy of the interpretation. When adjusting the brightness and contrast, a histogram tool or changing gamma value can be used to gain better contrast, in both darker and lighter areas. Sharpening and smoothing the image can increase the quality by reducing the blur or noise [1].

Intraoral digital radiography has become commonplace in dentistry, in contrast with digital panoramic radiography, which is a newer technology [7]. Since the release of digital panoramic radiography, there has been a lack of scientific research done on the subject. Studies about the image enhancement effects in digital panoramic radiography have been conducted, stating that there is a significant increase in the diagnostic quality due to contrast enhancement; however, smoothing and sharpening the enhancement did not affect the results [8].

To date, there has been no objective evaluation conducted, since most of the image enhancement techniques were applied based on the observer's subjective preferences [4]. In certain diagnostic laboratories, the radiographic density was changed due to excessive brightness and contrast settings, which changed the diagnostic information. Research about the score limits of the brightness and contrast with regard to how they may change the diagnosis remain limited [9].

The image enhancement process may not increase the diagnostic quality. Furthermore, increasing the rate of contrast in the digital radiographic diagnostic score is still controversial [1]. Nevertheless, limit values are needed for adjusting the brightness and contrast of panoramic radiographs, without changing the diagnostic results, while simplifying the interpretation. Based on the above information, this study aimed to ascertain the limit values of the brightness and contrast adjustments to increase panoramic radiographic quality. The values should not change the normal anatomical structural information in the panoramic radiograph itself, nor the diagnostic information.

2. Materials and Methods

This was a cross-sectional descriptive analytical study performed at the Exclusive Pavilion of the Dental and Oral Health Hospital and Radiology Department, Faculty of Dentistry, at the University of Indonesia from June 2016 until September 2016. The samples used were digital panoramic radiographs taken from patients' medical records at the hospital that complied with the inclusion criteria. The samples were divided into three groups (groups A, B, and C) according to the brightness of the existing panoramic radiographs. The radiograph were classified according to the following visual observations: low brightness (dark) but able to be diagnosed in group A, moderate brightness but able to be diagnosed in group B, and high brightness (bright) but able to be diagnosed in group C.

This study began by choosing appropriate digital radiographs that complied with the inclusion criteria, then a quality evaluation was performed for each radiograph. The image enhancement was done via the following adjustments: brightness -10 (B1), brightness -20 (B2), brightness -30 (B3), brightness +10 (B4), brightness +20 (B5), brightness +30 (B6), contrast -10 (C1), contrast -20 (C2), contrast -30 (C3), contrast +10 (C4), contrast +20 (C5), and contrast +30 (C6). Following the image enhancement, the radiographs were interpreted, a score was given, and that score was compared to the original. The scores were assigned as follows: 1 for a worse quality radiograph, 2 for an unchanged radiograph, and 3 for a better quality radiograph. The data was later processed and analyzed to obtain limit values for the image enhancement (brightness and contrast). The data from the first and second observers, along with the data compiled from the first and second observations, underwent interobserver and intraobserver reliability testing using Cohen's kappa coefficient test. The Kolmogorov-Smirnov test was used to evaluate the normality. The Wilcoxon signed-rank test was used to determine the statistical differences between the radiographs before and after the brightness and contrast image enhancements.

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3. Results and Discussion

3.1 Results
In this study, each radiograph in the image enhancement settings (B1, B2, B3, B4, B5, B6, C1, C2, C3, C4, C5, and C6) for groups A, B, and C was compared with the original radiograph, which was assumed to have a score of 2 (no change in the radiograph).

3.1.1 Panoramic radiographic change analysis: group A
According to Table 1, the brightness adjustment values were -10 for the lower limit and +20 for the upper limit. The contrast adjustment values were -10 for the lower limit and +10 for the upper limit. After remineralization with aquades, cow milk, and soy milk there was significant increase in enamel hardness ($p < 0.05$). The increase in enamel hardness from aquades or soy sauce immersion showed a significant result ($p < 0.05$).

Table 1. Panoramic radiographic change frequency: group A

Settings		Changed to worse (1)		Unchanged (2)		Changed to better (3)		p-value [a]
		Total	Percentage (%)	Total	Percentage (%)	Total	Percentage (%)	
Lower limit	B1	1	8	6	50	5	42	0.059
	B2	11	92	0	0	1	8	0.004
	B3	12	100	0	0	0	0	0.001
Upper limit	B4	0	0	10	83	2	17	0.157
	B5	5	42	5	42	2	17	0.257
	B6	11	92	0	0	1	8	0.004
Lower limit	C1	0	0	11	92	1	8	0.059
	C2	12	100	0	0	0	0	0.004
	C3	12	100	0	0	0	0	0.001
Upper limit	C4	2	17	5	42	5	42	0.157
	C5	12	100	0	0	0	0	0.257
	C6	12	100	0	0	0	0	0.004

[a] Wilcoxon test results

3.1.2 Panoramic radiographic change analysis: group B
According to Table 2, the brightness adjustment values were -10 for the lower limit and +20 for the upper limit. The contrast adjustment values were -10 for the lower limit and +10 for the upper limit.

Table 2. Panoramic radiographic change frequency: group B

Settings		Changed to worse (1)		Unchanged (2)		Changed to better (3)		p-value[a]
		Total	Percentage(%)	Total	Percentage (%)	Total	Percentage (%)	
Lower limit	B1	0	0	20	43	27	57	0.000
	B2	22	47	2	4	23	49	0.881
	B3	42	89	0	0	5	11	0.000
Upper limit	B4	0	0	46	98	1	2	0.317
	B5	10	21	34	72	3	6	0.052
	B6	46	98	1	2	0	0	0.000
Lower limit	C1	2	4	45	96	0	0	0.157
	C2	45	96	2	4	0	0	0.000
	C3	47	100	0	0	0	0	0.000
Upper limit	C4	4	9	9	19	34	72	0.000
	C5	46	98	0	0	1	2	0.000
	C6	47	100	0	0	0	0	0.000

[a]Wilcoxon test result

3.1.3 Panoramic radiographic change analysis: group C

According to Table 3, the brightness adjustment values were -20 for the lower limit and +10 for the upper limit. The contrast adjustment values were -10 for the lower limit and +10 for the upper limit.

Table 3. Panoramic radiographic change frequency: group C

Settings		Changed to worse (1)		Unchanged (2)		Changed to better (3)		p-value[a]
		Total	Percentage (%)	Total	Percentage (%)	Total	Percentage (%)	
Lower limit	B1	1	3	18	49	18	49	0.000
	B2	8	22	2	5	27	73	0.001
	B3	19	51	0	0	18	49	0.869
Upper limit	B4	1	3	35	95	1	3	1.000
	B5	25	68	11	30	1	3	0.000
	B6	36	97	1	3	0	0	0.000
Lower limit	C1	4	11	33	89	0	0	0.046
	C2	36	97	1	3	0	0	0.000
	C3	37	100	0	0	0	0	0.000
Upper limit	C4	2	5	11	30	24	65	0.000
	C5	27	73	0	0	10	27	0.005
	C6	36	97	0	0	1	3	0.000

[a]Wilcoxon test result

3.2 Discussion

This study was done with 96 digital panoramic radiographs as samples, which were classified into groups A, B, and C, according to the following visual observations: low brightness (dark) but able to be diagnosed in group A, moderate brightness but able to be diagnosed in group B, and high brightness (bright) but able to be diagnosed in group C [10]. The classification was done visually, and not using an aluminum step wedge for a mean grey value (MGV) of the radiograph [11]. The brightness value can also be obtained in those radiographs in which the data were in numeric or binary formats by representing the brightness value in pixels as integers with proportional values [12]. The classifications were done with secondary data, and the X-ray conditions were unknown during imaging; therefore, these panoramic radiographs had certain differences before changing the image settings.

Digora for Windows was used to adjust the brightness and contrast since it has a wider scale than Adobe Photoshop. It was previously shown that the changes in the brightness and contrast values were similar between Adobe Photoshop and Digora for Windows. However, the largest and smallest units for the brightness and contrast adjustments in Adobe Photoshop have not been able to create differences in cortical bone, which may change the panoramic radiographic images.

This study was done by two observers doing two observations each. Each evaluation was done objectively on the radiographs as a whole by observing the region of interest, including the mental foramen, border of the maxillary sinus, and mandible's inferior border. The scores were given as follows: 1 for a worse radiograph, 2 for an unchanged radiograph, and 3 for a better radiograph. The observations were done using different times, places, and monitors. There were no large sensitivity variations for each observer using the different types of monitors, although there was no significant difference between the monitors; therefore, there was no clear relationship between the diagnostic accuracy with regard to the resolution and monitor's price [13]. Based on previous research, there was no difference in determining the diagnosis between standard liquid crystal display (LCD) monitors and monitors specifically designed to evaluate digital radiographs [14]. One proven factor in diagnostically determining an affected carious lesion was the level of environmental light [light exposure, measured in lux (lx)] in the room where the digital radiographs were read. According to the American Association of Physicists in Medicine (AAPM), the environmental light must be <50 lx (very dim) during a radiographic evaluation using a standard monitor. The diagnostic accuracy for dentinal lesions was significantly much higher in environmental light <50 lx (dark room) when compared with using a covered or coverless monitor in environmental light >1000 lx (bright room) [14,15].

In order to obtain the limit values for the brightness and contrast adjustments, a Wilcoxon signed-rank test was done while considering the frequency and distribution of the changes in the panoramic radiographic results. In group A, the tolerance level of the lower limit brightness was -10; that is, when setting the brightness to -20, about 92% of the radiographs were changed to a worse quality. The upper limit level was +20; that is, when setting the brightness to +30, about 92% of the radiographs were changed to a worse quality. However, in the contrast adjustment, the lower limit value was -10 and the upper limit value was +10; that is, when setting the contrast to -20 and +20, 100% of the radiographs were changed to a worse quality. In group B, the tolerance level of the lower limit of the brightness was -10; that is, when setting the brightness to -20, about 47% of the radiographs were changed to a worse quality. The upper limit level was +20; that is, when setting the brightness to +30, about 98% of the radiographs were changed to a worse quality. However, in the contrast adjustment, the lower limit value was -10 and the upper limit value was +10; that is, when setting the contrast to -20 and +20, 96% and 98% of the radiographs were changed to a worse quality. Finally, in group C, the tolerance level of the lower limit of the brightness was -20; that is, when setting the brightness to +30, about 51% of the radiographs were changed to a worse quality. The upper limit level was +10; that is, when setting the brightness to +20, about 51% of the radiographs were changed to a worse quality. However, in the contrast adjustment, the lower limit value was -10 and the upper limit value was +10; that is, when setting the contrast to -20 and +20, 97% and 73% of the radiographs were changed to a worse quality. In this research, the panoramic radiograph was described as worse if there was cortical bone discontinuity and spreading radiolucency.

This study was done qualitatively by assessing the radiographs with regard to specific criteria. This was different from the previous research that was done in a quantitative study by measuring the MGV of the objects [11]. That research suggested that in brightness adjustment, there was no error when the brightness score was changed; the bright and dark shadows will move in the same direction. Brightness was defined as a bright MGV level in the radiograph, scaled between black and white, so that the higher the brightness level, the brighter the image. When the brightness level was changed, all of the pixel scores moved in the same direction (towards white or black), resulting in the same distance between the initial and end values. In this study, the brightness tolerance was different, following the initial state of the radiograph. However, the main problem occurred in the contrast adjustment. The contrast represents the difference between the brightest and darkest grey shadows in the image. As a linear function, all of the pixel scores were stretched as the contrast was increased, all of the dark shadows became darker, and all of the bright shadows became brighter. In previous research, the MGV score was maintained until the contrast was increased to 50 units, or in other words, a contrast increased by 50% of the initial data would not distort the original radiodensitometry data, but when the contrast was decreased, originality was significantly lost [11]. In this study, the contrast levels in each group were not tolerated after the -10 and +10 settings; above the limit value, the radiographic quality was worse.

Research about the tolerance limit values of the brightness and contrast has been done using digitized periapical intraoral radiographs and Adobe Photoshop imaging software. That research was done on teeth with apical periodontitis lesions and early apical abscesses, resulting in a lower limit of -5 and upper limit +5 for apical periodontitis, and -10 and +5, respectively, for early abscesses [16]. Another study using radiographs with chronic apical abscesses and apical granulomas obtained tolerance limit values of -10 and +10 [17]. Nevertheless, the adjustment of the limit levels will create more diagnostic information without changing the diagnostic interpretation.

In this research, there were some limitations, such as the unknown initial state of the X-ray, non-homogenous samples, and the fact that an aluminum step wedge was not used as a control standard. The unknown initial state of the X-ray resulted in different brightness values in the end result radiographs, with no way to determine the limit value in general. Moreover, the panoramic radiographs taken at the Exclusive Pavilion Dental and Oral Health Hospital, Faculty of Dentistry, at the University of Indonesia were not homogenous, even with a single operator and device. An aluminum step wedge was used as the quality control standard, and to observe the grayscale or contrast level of the radiograph. The radiographs could have been classified according to the level of contrast, if the aluminum step wedge had been used for all of the radiographs. In this research, each panoramic radiograph was classified according to the brightness level observed. Further studies are needed with larger sample sizes and the ability to control the X-ray exposure conditions and samples. Additional studies to compare the brightness and contrast settings in image enhancement programs specifically for radiographs may complement this research.

4. Conclusion

The brightnesstolerance limits of the digital panoramic radiographs from the dark group had -10 as a lower limit value and +20 as an upper limit value. The values for the contrast were -10 as a lower limit and +10 for an upper limit. The brightnesstolerance limits of the radiographs from the moderate group had -10 as a lower limit and +20 as an upper limit. The values for the contrast were -10 for the lower limit and +10 for the upper limit. The brightnesstolerance limits of the radiographs from the bright group had -20 as a lower limit and +10 as an upper limit. The values for the contrast were -10 as a lower limit and +10 for an upper limit. A determination of the brightness and contrast values could not be achieved due to the different initial states of the X-ray.

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