

Tolerance of image enhancement brightness and contrast in lateral cephalometric digital radiography for Steiner analysis

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Abstract. Image enhancement brightness and contrast can be adjusted on lateral cephalometric digital radiographs to improve image quality and anatomic landmarks for measurement by Steiner analysis. To determine the limit value for adjustments of image enhancement brightness and contrast in lateral cephalometric digital radiography for Steiner analysis. Image enhancement brightness and contrast were adjusted on 100 lateral cephalometric radiography in 10-point increments (-30, -20, -10, 0, +10, +20, +30). Steiner analysis measurements were then performed by two observers. Reliabilities were tested by the Interclass Correlation Coefficient (ICC) and significance tested by ANOVA or the Kruskal Wallis test. No significant differences were detected in lateral cephalometric analysis measurements following adjustment of the image enhancement brightness and contrast. The limit value of adjustments of the image enhancement brightness and contrast associated with incremental 10-point changes (-30, -20, -10, 0, +10, +20, +30) does not affect the results of Steiner analysis.

1. Introduction

Cephalometric radiography is a standardized and reproducible form of skull radiography known mostly for its usefulness in producing the same geometry of image quality for pre-treatment analysis and treatment evaluation. Cephalometric radiography is used extensively in orthodontics to assess the relationships of the teeth to the jaws and the jaws to the rest of the facial skeleton [1]. The main clinical indications of cephalometric radiography can be considered under two major headings: orthodontics and orthognathic surgery. Cephalometric radiograph is used in orthodontic treatment to obtain an initial diagnosis and to determine the presence of any abnormalities in the underlying skeletal and/or soft tissue. It is also used for treatment planning, to monitor the treatment progress, and to assess the treatment results. In orthognathic surgery, it is used for preoperative evaluation of skeletal and soft tissue patterns, to assist in treatment planning, and to conduct postoperative appraisals of the results of the surgery and long-term follow-up studies [1].

Cephalometric radiography of the jaws has two main radiographic projections: lateral cephalometric and postero-anterior cephalometric. Each projection has its own purpose and indication [1]. Lateral cephalometric radiography is used mostly for orthodontic analysis, diagnosis, treatment planning, and evaluation of treatment results, but it can also be used to assess facial growth and development. By contrast, postero-anterior cephalometric radiography of the jaws can produce radiography images of the skull bone from the mediolateral side, which can be useful for assessment of facial asymmetries and for postoperative evaluation in orthognathic surgery [2,3]. Overall, lateral cephalometric radiography is the most widely used in dentistry. It is utilized for skeletal measurement, dental measurement, and soft tissue anatomy, including the measurement of lines, planes, angles, and lengths. These uses require accurate



diagnostic information from the lateral cephalometric radiograph.

Analysis of lateral cephalometric radiography requires angle measurements, which can be obtained by landmark identification. One type of lateral cephalometric analysis is Steiner analysis, which is most frequently used in orthodontic treatment plans because it focuses on the angle measurement as well as showing the relationships between each measurement. In addition, it provides a normal reference point of specific measurement, which is very useful for treatment planning [4]. This type of analysis is now facilitated by today's highly developed computer technology, which has advanced the use of digital radiography in the dental radiology field. One of the advantages of digital radiography is its convenience in moving the interpretation to the computer and displaying it as a better image with some adjustment choices, such as panning, zooming, grayscale inversion, length and angle measurement, and windowing [5].

The utilization of digital radiography technology can increase image clarity through image enhancement settings that can increase contrast, optimize brightness, and reduce blur and noise [3]. One advantage of cephalometric digital radiography, as revealed by research by Chen YJ *et al.*, is the ability to increase the reliability of cephalometric analysis by adjusting the image enhancement settings, which can simplify landmark identification [6]. One form of image enhancement is brightness and contrast adjustment. Research by Shahidi *et al.* verified that images can be enhanced by brightness and contrast adjustment to increase the quality of the radiograph image and to provide reliability for landmark identification. Image quality enhancement and landmark identification reliability can enhance the cephalometric analysis, thereby improving the diagnosis and treatment plan [7].

Digital radiography images that have been enhanced by brightness and contrast adjustment can only increase the accuracy of some limited landmark identifications. Therefore, brightness and contrast adjustment must be considered very carefully, based on the radiograph image quality, prior to the enhancement [3, 8]. However, the progression in the development of digital radiography in this era had led to overuse of image enhancement, especially brightness and contrast, by many operators. This could have deleterious effects on the interpretation of the radiographic results, so knowledge of the tolerance limit of image enhancement is needed, especially with respect to brightness and contrast adjustment, to ensure that enhancements do not change the interpretation of lateral cephalometric radiographs.

2. Materials and Methods

This is a cross-sectional study. One hundred samples were taken from lateral cephalometric digital radiographs in patients' medical records in teaching dental hospital at Faculty of Dentistry, Universitas Indonesia. Samples were chosen based on inclusion criteria. Samples were grouped into three groups (light, medium, and dark) based on brightness level of the secondary data. Brightness and contrast adjustments were done in 10-point increments (-10, -20, -30, 0, +10, +20, +30) on each sample from every group, using the *Digora software program*. Lateral cephalometric tracing was done on each sample using *Autocad for Windows* software. All measurement was all made within a two month span. Reliability tests of the lateral cephalometric radiograph tracing results were performed by two observers with an Interclass Correlation Coefficient (ICC). The tests were done to compare the tracing results of lateral cephalometric radiographs for every adjustment made in the study. Multivariate analysis was also conducted using a data processing application. Data with a normal distribution were analyzed by one-way ANOVA to determine any significant differences. The Kruskal Wallis test was used to determine statistical significance for data that did not show a normal distribution.

3. Results and Discussion

3.1 Results

In this study, image enhancement brightness and contrast adjustments were analyzed in 10-point increments. The adjustments were done six times for brightness and contrast, three times to determine the upper limit value, and three times to determine the lower limit value, on 100 data samples.

Different codes were assigned for every adjustment made in this study. For example, brightness adjustments to -10, -20, and -30 were coded as B-10, B-20, and B-30, respectively, while brightness

adjustments to +10, +20, and +30 were coded as B+10, B+20, and B+30, respectively. Similarly, contrast adjustments to -10, -20, and -30 were coded as C-10, C-20, and C-30 and adjustment to +10, +20, and +30 were coded as C+10, C+20, and C+30, respectively. ANOVA was used in this study to determine statistically significant differences in the measurement results between brightness and contrast adjustments in the dark, medium, and light radiograph groups (Table 1 and 2).

Table 1. Significant values of brightness adjustment

Light		Medium		Dark		Parameter
Sig. Increase	Sig. Decrease	Sig. Increase	Sig. Decrease	Sig. Increase	Sig. Decrease	
*	0.982	0.981	0.587	0.992	0.347	Sella-Nasion-A point (SNA) Angle
0.986	0.956	*	*	0.983	0.897	Sella-Nasion-B point (SNB) Angle
*	*	*	*	0.913	0.966	A point-Nasion-B point (ANB) Angle
0.979	0.947	0.972	0.935	0.082	0.049	Mandibular Plane Angle
*	0.995	*	0.966	0.983	0.891	Maxillary (Sella Nasion-Incisor) SN-I Angle
0.971	0.879	0.768	*	0.993	0.729	Mandibular SN-I Angle
0.921	*	0.884	0.955	0.888	0.959	Maxillary-mandibular I Angle

*= Data without a normal distribution

Table 2. Significant Values of Contrast Adjustment

Light		Medium		Dark		Parameter
Sig. Increase	Sig. Decrease	Sig. Increase	Sig. Decrease	Sig. Increase	Sig. Decrease	
0.615	*	0.991	0.662	0.985	0.872	SNA Angle
0.967	0.846	*	*	0.904	0.969	SNB Angle
*	*	*	*	*	*	ANB Angle
0.995	0.940	0.997	0.929	0.066	0.081	Mandibular Plane Angle
0.866	0.921	*	0.734	0.895	0.876	Maxillary SN-I Angle
0.918	*	*	0.620	0.802	0.685	Mandibular SN-I Angle
0.896	0.937	0.976	0.946	0.894	0.808	Maxillary-mandibular I Angle

*= Data with a normal distribution

The ANOVA data presented in tables 1 and 2 show that decreasing or increasing the brightness and contrast had no statistically significant effects on the light, medium, or dark radiograph groups ($p > .05$). The results of the Kruskal Wallis test for data that did not have a normal distribution are shown in tables 3 and 4.

Table 3. Significant Values of Brightness Adjustment

Light		Medium		Parameter
Sig. Increase	Sig. Decrease	Sig. Increase	Sig. Decrease	
0.996	*	*	*	SNA Angle
*	*	0.919	0.941	SNB Angle
0.954	0.942	0.868	0.801	ANB Angle
*	*	*	*	Mandibular Plane Angle
0.943	*	0.973	*	Maxillary SN-I Angle
	*	*	0.721	Mandibular SN-I Angle
*	0.975	*	*	Maxillary-mandibular I Angle

*= Data with a normal distribution

Table 4. Significant Values of Contrast Adjustment

Light		Medium		Dark		Parameter
Sig. Increase	Sig. Decrease	Sig. Increase	Sig. Decrease	Sig. Increase	Sig. Decrease	
*	0.894	*	*	*	*	SNA Angle
*	*	1.00	0.658	*	*	SNB Angle
0.704	0.953	0.845	0.683	0.638	0.792	ANB Angle
*	*	*	*	*	*	Mandibular Plane Angle
*	*	0.955	*	*	*	Maxillary SN-I Angle
*	0.937	0.672	*	*	*	Mandibular SN-I Angle
*	*	*	*	*	*	Maxillary-mandibular I Angle

*= Data with a normal distribution

The Kruskal Wallis test results shown in tables 3 and 4 confirm that decreasing or increasing the brightness and contrast had no statistically significant effects on the light, medium, or dark radiograph groups ($p > 0.05$)

3.2 Discussion

This study was conducted with 100 samples of secondary data from lateral cephalometric radiographs that were grouped into light, medium, and dark radiograph groups. This grouping was done to avoid any imbalance in brightness level differences in the groups, which was predicted to affect the measurement results. A previous study on the effects of radiograph quality on diagnosis concluded that a dark group, which had the lowest level of brightness, could still be diagnosed correctly [9], while a medium group, which had the optimal level of brightness, could have a perfect diagnosis. Similarly, a light group, which had the highest level of brightness, could still provide a correct diagnosis [9].

The number of samples in the groups in the present study varied from 11 radiographs in the dark group to 38 radiographs in the medium group and 51 radiographs in the light group. Before the study was started, a preliminary experiment was conducted on some radiographs from each group to determine the increments of brightness and contrast adjustment that would show visually significant differences. This preliminary experiment was done by subjective observation and viewing the sharpness of the anatomic details present on the radiographs from each group. This experiment determined that several adjustments would be needed, in 10-point increments.

In this study, the ANOVA, a parametric test of normally distributed data, indicated no statistically significant differences for the measurement results between each group ($p > 0.05$), so that a tolerance limit for brightness and contrast adjustment could not be determined. Similarly, the Kruskal Wallis test, a non-parametric test conducted on the data that did not have a normal distribution, showed no

statistically significant difference for the brightness and contrast adjustments for each group ($p > 0.05$). This lack of significant differences rendered between-group comparisons unnecessary. Again, the tolerance level for brightness and contrast adjustment could not be determined for the dark, medium, and light groups.

The test results presented here indicate that any differences in brightness and contrast adjustment in the dark, medium, or light radiograph groups are not statistically significant. This means that any differences between the measurement results for the various angles (SNA, SNB, ANB, mandibular plane, maxillary SN-I, mandibular SN-I, and maxillary-mandibular SN-I angles) also were not statistically significant. The results from this study still did not allow a determination of the tolerance level for brightness and contrast adjustment on lateral cephalometric radiographs. A previous quantitative study by Guneri *et al.* on the effects of increasing the brightness and contrast levels indicated that a radiograph's original mean gray values (MGV) will not change until the contrast has been increased to +50, so it is better to take a second radiograph rather than doing an image enhancement of more than +50 points. Conversely, brightness adjustment to +50 showed no MGV change on the radiograph. However, the measurements performed in that study did not reveal the anatomic landmark change radiographically and were conducted only on intraoral radiographs [10]. The results of the present study are aligned with research by Guneri *et al.* because the brightness and contrast adjustment to +30 conducted in the present study did not affect the measurement results of lateral cephalometric radiograph analysis [10].

A study by Purnamasari showed that brightness and contrast adjustment from -10 to +10 on periapical digitized radiographs of apical periodontitis lesions and early apical abscess lesions did not change the interpretation [11]. These results differ from the results of the present study, as a limit value for brightness and contrast adjustment could not be determined here because the measurement results showed no statistically significant results. A study by Oshagh M *et al.* concluded that the identification of anatomic landmarks, such as the nasion and menton, could be more reliable on the horizontal dimension after performing an image enhancement. The A point and the pogonion point could also be more reliably identified on the vertical dimension. Other anatomic landmarks, such as the sella, ANS, and B point, had no changes in their reliability [7]. This agrees with the results of the present study, which showed no change in the measurements because the anatomic landmark reliability was constant or even increased after performing the image enhancements. Therefore, the brightness and contrast adjustment did not affect the measurement results of the SNA, SNB, and ANB angles.

Oshagh *et al.* also concluded that a variation often occurs when determining the gonion point [7]. A study by Chien *et al.* also indicated that the variations that result in errors in determining the gonion point happen vertically [12]. Another study by Durao *et al.* also showed a high variation in determining the gnathion point, because no detailed explanation was provided for the gnathion point location [13]. These studies confirmed that anatomic point determination will affect the measurement of the mandibular plane angle because this angle is established based on the gonion and gnathion points. However, the present study showed that the brightness and contrast have no effect on the measurement results of the mandibular plane angle, although variation is possible when determining these anatomic points. The present study differs from other previous studies in some factors. The first difference is a potential internal bias factor, because the observers became familiar with performing the lateral cephalometric analysis on the same sample after a couple of times. This possibility could give rise to unreliable measurement results. The second potential cause is the monitor screen used in this study. A study by Butt *et al.* explained the effect of the monitor screen display on digital radiography quality by drawing attention to the view held by radiologist experts that a significant connection exists between monitor screen display and the diagnosis that will be made. The monitor screens that are usually used to decide a diagnosis are of two types: primary grade and secondary grade. Primary grade is a monitor screen that is used in medical interpretation to determine a diagnosis that has to have high image quality. By contrast, secondary grade is a monitor screen that is used simply to view medical images without deciding a diagnosis [14]. In this study, the monitor screen was not tested to confirm that it fits the primary grade standard. Consequently, the monitor screen quality used in this study might also have

affected the determination of landmark identification, which would also affect the measurement results of lateral cephalometric radiograph analysis.

Assessing the monitor screen quality, in terms of the consistency and tolerance limit of the image clarity deemed still acceptable, can be done using the Society of Motion Picture and Television Engineer (SMPTE) pattern test and a guideline called the Digital Imaging and Communications in Medicine (DICOM), part 14: Greyscale standard display function standard. These tests can be done to separate the monitor screen grades that can be used for medical diagnosis from those that can be used for nonmedical purposes. In the present study, the monitor screen used by the two observers was not subjected to any assessment. However, the conclusion is valid that lateral cephalometric analysis can be affected by the monitor screen quality.

4. Conclusion

The results of this study support the conclusion that brightness adjustments made in 10-point increments (-10, -20, -30, +10, +20, +30) in lateral cephalometric radiography do not affect the results of Steiner analysis. Similarly, contrast adjustments made in 10-point increments (-10, -20, -30, +10, +20, +30) in lateral cephalometric radiography also do not affect the results of Steiner analysis. Advanced research is required on brightness and contrast adjustment to identify the limit value of tolerance that is acceptable for lateral cephalometric radiography. The use of primary data is also important to ensure the control needed to produce the same image on all the sample data. More research is also required that focuses on image enhancements other than brightness and contrast.

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