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Analysis of the Gray-Value Reproducibility and Noise of a Direct Digital Radiography System

Análise da Reprodutibilidade do Valor de Cinza e Ruído de um Sistema de Radiografia Digital Direto

Marcelo Lupion Poleti*[a]; Jaqueline Akemi Yamashita[b]; Marcelo Estevam[c]; Tânia Christina Simões[a]; Paulo Henrique Rossato[a]; Thais Maria Freire Fernandes[d]

[a]Instituto Federal do Paraná, Curso de Odontologia. PR, Brasil.
[b]Unopar, Curso de Odontologia. PR, Brasil.
[c]Instituto Federal do Paraná, Pró-Reitoria de Extensão, Pesquisa, Pós-Graduação e Inovação. PR, Brasil.
[d]UNOPAR, Programa de Pós-Graduação Stricto Sensu em Odontologia. PR, Brasil.
*E-mail: marcelo_poleti@yahoo.com.br
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Abstract

The digital radiograph represents a great advance in oral maxillofacial radiology because it incorporates informatics technology in the capture, interpretation, and archiving of radiographic images. Previous studies have demonstrated that it is possible to use gray values in bone lesion diagnosis and follow-up. However, these applications depend on radiograph system quality and exposure time. The aim of this study was to evaluate the gray-value reproducibility and noise produced by Dabi Atlante's IDA system, a direct digital radiography system. Radiographs were obtained in a standardized manner (70 kV, 7 mA, and 2.2-mm filtration) with a direct digital sensor and a stepwedge placed in a phantom at a 30-cm focus-film distance. Ten consecutive x-ray imaging series were completed at 0.10-s, 0.15-s, and 0.20-s exposure times. Gray values were analyzed in five regions of interest (ROIs): bone tissue (BT), soft tissue (ST), and three stepwedge steps (Step 1, Step 2, and Step 3). Mean gray values differed significantly across exposure times ($p < .05$) in all five ROIs. The ROI with the greatest gray-value variability (25.36%) and noise (9.46%) was ST. In conclusion, gray-value reproducibility and noise of the IDA system vary across areas with differing radiolucency. Thus, special attention is necessary for the diagnosis and follow-up of radiolucent lesions due to relatively high gray-value interference.

Keywords: Radiography, Dental, Digital. Reproducibility of Results. Diagnostic Imaging.

Resumo

A radiografia digital representa um grande avanço na radiologia bucomaxilofacial porque incorpora a tecnologia informática na captura, interpretação e arquivamento de imagens radiográficas. Estudos anteriores demonstraram que é possível usar os valores de cinza no diagnóstico e na proservação das lesões ósseas. No entanto, essas aplicações dependem da qualidade do sistema radiológico e do tempo de exposição. O objetivo deste estudo foi avaliar a reprodutibilidade do valor de cinza e o ruído produzido pelo sistema IDA da Dabi Atlante, um sistema de radiografia digital direto. As radiografias foram obtidas de maneira padronizada (70 kV, 7 mA e filtração de 2,2 mm) com um sensor digital direto e um penetrômetro colocados em um fantoma a uma distância de filme-foco de 30 cm. Dez imagens radiográficas consecutivas foram obtidas com tempos de exposição de 0,10-s, 0,15-s e 0,20-s. Os valores de cinza foram analisados em cinco regiões de interesse (ROIs): tecido ósseo (TO), tecido mole (TM) e três degraus do penetrômetro (Degrau 1, Degrau 2 e Degrau 3). Os valores de cinza médios diferiram significativamente entre os tempos de exposição ($p < 0,05$) em todos as cinco ROIs. A ROI com maior variabilidade do valor de cinza (25,36%) e ruído (9,46%) foi TM. Em conclusão, a reprodutibilidade do valor de cinza e o ruído do sistema IDA variam entre áreas com radiolucência diferente. Assim, atenção especial é necessária para o diagnóstico e proservação de lesões radiolucentes devido à interferência dos valores cinza relativamente alta.

Palavras-chave: Radiografia Dentária Digital. Reprodutibilidade dos Testes. Diagnóstico por Imagem.

1 Introduction

The digital radiograph represents a great advance in oral maxillofacial radiology because it incorporates informatics technology in the capture, interpretation, and archiving of radiographic images. Importantly, it eliminates technical, chemical processing errors and obviates the need for the conventional film, thereby reducing the production of environmentally toxic residues[1-15].

Previous studies have demonstrated that it is possible to use gray values in bone lesion diagnosis and follow-up[16,17]. However, the results obtained in such applications depend on radiograph system quality and exposure time. The physical and clinical outcomes of various radiograph systems have been evaluated[7-9,11,13,18-20].

However, to the best of our knowledge, empirical data are not yet available for the Advanced Digital Image System (IDA). Thus, the aim of this study was to evaluate the reproducibility of gray values and noise in the IDA system.

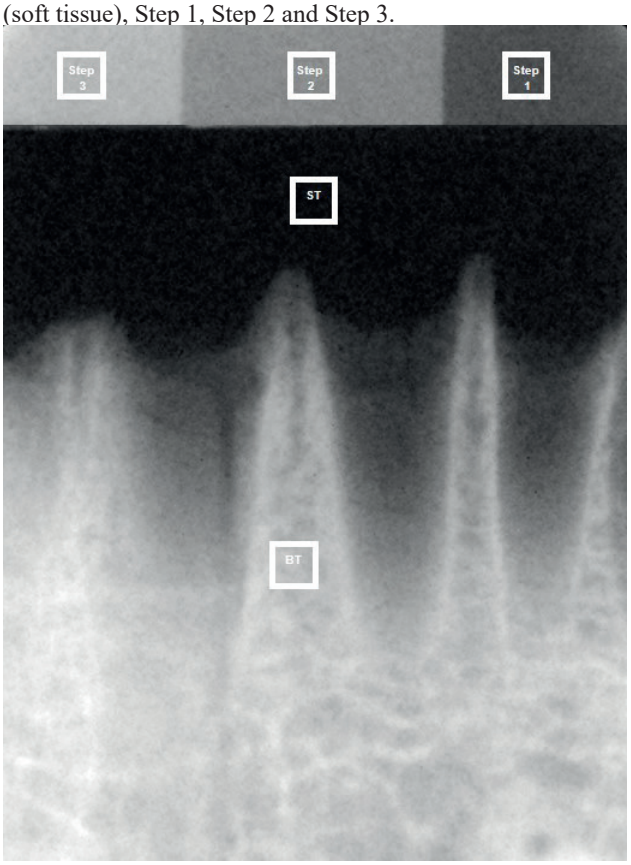
2 Material and Methods

A metal-oxide semiconductor sensor (periapical size; 36.03 mm × 25.83 mm; special resolution, 22 line pairs/mm) complementary to the IDA System (Dabi Atlante, Ribeirão Preto, SP, Brazil) was placed in a phantom with a soft tissue

simulator (acrylic) to standardize and attenuate radiation, respectively. A stepwedge with three thickness steps (0.2 mm, 0.4 mm, and 0.6 mm) was coupled to the sensor. Images were acquired by a dental x-ray machine (Yoshida Denatl MFG Co. Ltd, Tokyo, Japan) at 70-kV and 7 mA, with 2.2-mm filtration and a focus-sensor distance of 30 cm.

Ten consecutive radiographic images were obtained in the same position at each of the three exposure times (0.10 s, 0.15 s, and 0.20 s). The images were saved as TIFF files and viewed in a notebook computer with a 14-inch screen (Satellite, Toshiba, Tokyo, Japan) via ImageJ software (US National Institutes of Health, Bethesda, MD). The following five square (102 × 102 pixels) regions of interest (ROIs) were created: bone tissue (BT), soft tissue (ST), Step 1, Step 2, and Step 3 (Figure 1). The mean gray values of these ROIs were determined with the Image J measuring tool.

Figure 1 - Definition of the five ROIs: BT (bone tissue), ST (soft tissue), Step 1, Step 2 and Step 3.



Fonte: Authors.

Gray value reproducibility was calculated as [the greatest difference/(mean × 100)]. Noise was calculated as [standard deviation/(gray value × 100)]. Analyses of variance (ANOVAs) were performed in SPSS 22.0 software (IBM, Inc., Chicago, IL), with a significance criterion of $p < .05$.

3 Results and Discussion

Mean gray values differed significantly among exposure times within each ROI (Table 1).

Table 1 - Comparison of the pixel values in the different exposure times

ROIs	Exposure times						P
	0.10 s		0.15 s		0.20 s		
	Mean	SD	Mean	SD	Mean	SD	
BT	165.61[a]	5.16	174.42[b]	1.91	177.50[b]	2.75	0.000*
ST	59.46[a]	7.80	33.20[b]	3.14	28.33[b]	1.87	0.000*
Step 1	95.06[a]	4.76	70.02[b]	5.24	45.49[c]	3.94	0.000*
Step 2	92.66[a]	1.92	77.40[b]	4.84	52.99[c]	3.35	0.000*
Step 3	110.43[a]	6.09	100.08[b]	3.24	81.12[c]	4.02	0.000*

SD: standard deviation

*Different superscript letters show the significant difference at P < 0.05 level.

Source: Research data.

The pixel value reproducibility results are reported in Table 2. Gray value variability was higher in ST (25.36%) and lower in BT (1.38%).

Table 2 - Reproducibility of pixel values in the different exposure times

ROIs	Exposure times		
	0.10 s	0.15 s	0.20 s
BT	6.59	1.38	2.25
ST	25.36	16.93	11.89
Step 1	7.35	11.70	15.50
Step 2	3.03	11.87	10.93
Step 3	10.58	5.14	8.04

Source: Research data.

The noise data are reported in Table 3. Briefly, a relatively high level of noise was observed for ST (-0.15 s, 9.46%) and a relatively low level of noise was observed for BT (-0.15 s, 1.10%).

Table 3 - Noise in the different exposure times

ROIs	Exposure times		
	0.10 s	0.15 s	0.20 s
BT	2.07	1.10	1.55
ST	5.15	9.46	6.6
Step 1	5.01	7.48	8.66
Step 2	2.07	6.25	6.32
Step 3	5.15	3.24	4.96

Source: Research data.

This study makes an important contribution of revealing limitations of the IDA system. The results demonstrated that the noise and pixel-value reproducibility of the IDA system can vary according to ROI and exposure time, similar to the results obtained for the Digora system by Freitas[1]. Similar to previous studies[1,2,20], we found the highest gray values in the most radiopaque regions (BT and Step 3) and the lowest gray values in the most radiolucent regions (ST and Step 1). Meanwhile, although pixel-value variability of the IDA was greater in high radiolucence ROIs (25.36 %), it remained lower than that observed previously[1] for the Digora system (75%).

With respect to clinical importance, diagnosis and follow-up can be compromised by gray values, particularly in

radiolucent lesions. On the other hand, IDA data variability was lower , and thus most accurate, in radiopaque lesions.

Noise, which represents artefactual fluctuation of pixel intensity, was higher for ST than BT, regardless of exposure time. Meanwhile, it was shown in this study that, within a particular ROI, noise magnitude can vary with exposure time. These results are consistent with Rubira-Bullen et al.[2] findings for digital radiographic images.

4 Conclusion

In conclusion, the reproducibility of gray values and the noise of IDA systems can vary among the areas of differing radiolucency. Thus, special attention is necessary for the diagnosis and follow-up of radiolucent lesions due to relatively high gray-value interference.

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