

# Effects of Image Compression on Linear Measurements of Digital Panoramic Radiographs

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This study aimed to evaluate the accuracy of panoramic radiographs obtained by digital system based on charge coupled device (CCD) and a phosphor storage plate (PSP) system with two different file formats, JPEG irreversible type and BMP. Linear measurements of artificial bony defects were made in dry mandibles with a digital caliper. Measures of digital panoramic radiographs were taken in ImageJ<sup>®</sup> software. Each measurement was performed twice by an experienced examiner. The intra-rater agreement was considered very strong (Pearson's correlation coefficient of 0.97). There was no significant difference between the linear measurements of dry mandibles, considered the gold standard, in relation to measurements obtained from digital radiographs ( $p=0.47$ ). The error of these measures for the CCD was 1.04 mm (9.97%) for JPEG images and 1.03 mm (9.99%) for those with BMP format. For the PSP images, these values were 1.48 mm (14.94%) and 1.43 mm (14.43%), respectively. Although there was no statistical difference between the images with JPEG and BMP format, for both digital systems ( $p=1.00$  for CCD and  $p=0.98$  for PSP system), errors made on radiographs obtained by PSP system were significantly higher than those of CCD ( $p<0.05$ ). The size of the files saved in JPEG was also significantly lower ( $p=0.005$ ) compared with the files saved in BMP. It may be concluded that the digital radiographs, both saved in JPEG and BMP formats, are accurate, regardless the used digital system, and JPEG images are more suitable for teleradiology.

Key Words: image compression, digital image, panoramic radiography

## Introduction

Digital radiographs are increasingly common in the health area. In dentistry, there are various systems, software and file formats used to produce, edit and save the images, respectively. There are three main types of digital systems, with different sensors: the phosphor storage plate (PSP) (1), charged-couple device (CCD) (1) and complementary metal-oxide-semiconductor (CMOS) (2).

Although digital radiographic systems have many advantages, they produce large amounts of image data, which require storage media and hamper transmission. These problems can be reduced with the image compression (3). The filing of digital images is an understudied field. There are several formats for digital files. Some of them perform image compression with loss of information, accepted as a source of depreciation of image quality, but then decrease the size of files facilitating their transmission and storage.

This study aimed to evaluate the linear measurements accuracy of digital panoramic radiographs (obtained by CCD and PSP systems) with two different file formats (JPEG irreversible type and BMP).

## Material and Methods

All the experimental procedures in this study were

approved by the Ethics in Research Committee of the Dental School (Universidade Federal da Bahia, Salvador, BA, Brazil). Ten human dry mandibles were randomly selected from the collection of the Radiology Department of the same institution. As inclusion criteria, the jaws should be intact, regardless the presence or absence of teeth. In these jaws were produced four standardized circumferential bony defects, two on each side of the jaw, obtaining 40 defects.

Dental panoramic radiographs were obtained with a CCD system (Kodak 8000C<sup>®</sup>; Carestream Health, Rochester, NY, USA) at the Radiology Department of the Dental School, Universidade de São Paulo, Bauru, SP, Brazil. Other radiographs were made with a PSP system (VistaScan<sup>®</sup>, Durr Dental AG, Bietigheim-Bissingen, Germany) associated to conventional X-ray panoramic device (Rotograph Plus<sup>®</sup>, Villa Sistemi Medicali, Buccinasco, MI, Italy), at Dental School, Feira de Santana State University, Feira de Santana, BA, Brazil. The images were exported and saved in BMP and JPEG formats.

Linear measurements (greater height and greater width of each bony defect) were performed with ImageJ<sup>®</sup> software (National Institute of Mental Health, Bethesda, MD, USA) with its own electronic rule, after image calibration.

Corresponding measurements were performed with a digital caliper in the dry mandibles. The measurements were made twice by an examiner, with an interval of seven days between assessments. These data were recorded for statistical analysis.

To evaluate the intraobserver agreement was applied the Pearson's correlation coefficient. To evaluate the accuracy of linear measurements, considering the dry mandibles measurements as gold standard, was used ANOVA followed by Dunnett's post hoc test. To compare the dimensional error of the measures in the different groups, was used ANOVA followed by Tukey's post hoc test. To compare the sizes between the two file formats, the Wilcoxon test was applied. The significance level was set at 5%.

## Results

Eight linear measurements were performed (four horizontal and four vertical) on the ten panoramic radiographs saved in BMP and on ten others saved in JPEG, from each digital radiographic system (CCD and PSP). Each measurement was performed twice, totaling 640 measures. In addition, there were 160 measures in dry mandibles, considered the gold standard. The results showed that

the intraexaminer correlation was very strong (Pearson's correlation coefficient of 0.97).

There was no significant difference between the measurements of dry mandibles and the measurements obtained from digital radiographs ( $p=0.47$ , ANOVA and Dunnett's post hoc test) (Table 1). The means of absolute and relative errors of these measures (ANOVA and Tukey's post hoc test) on CCD images were 1.04 mm (9.97%) for JPEG images and 1.03 mm (9.99%) for BMP format. For PSP images these values were 1.48 mm (14.94%) and 1.43 mm (14.43%), respectively. Although there was no statistical difference between the images with JPEG and BMP formats, for both digital systems ( $p=1.00$  for CCD and  $p=0.98$  for PSP), errors on radiographs obtained by PSP system were significantly higher than those by CCD ( $p<0.05$ ) (Table 2).

Regarding the file sizes (in kB), in the CCD system, the images saved in BMP format were on average 75% greater than the images saved in JPEG format ( $p=0.005$ ). In the PSP system, panoramic images saved in BMP were on average 76% greater ( $p=0.005$ ) (Table 3).

## Discussion

Radiographic digital systems, compared to radiographs obtained on films, allow image post-processing, including enhancement, subtraction, compression and image storage. These possibilities facilitate the transmission of data over the Internet, allow the discussion of cases with other professionals and improve diagnostic capability (4). Digital radiographic images can be saved in different file formats, the most common being the Tagged Image File Format (TIFF), the Bitmap - standard Windows® (BMP) and the Joint Photographic Experts Group (JPEG) (5).

The standardized procedures and evaluation of different variables, such as file formats and software, are important to avoid bias

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Table 1. Means of linear measurements performed on dry mandibles and digital panoramic radiographs with two file formats, obtained by different digital systems

Radiographic device	Digital system	Mean of linear measurements (mm)			p value
		JPEG	BMP	dry mandibles	
PSP system Rotograph Plus® (60 kV, 10mA, 17 s)	VistaScan® (250 dpi)	9.98	10.08	10.21	0.47
CCD Kodak 8000C® (60kV, 3,2mA, 13.2 s)	Kodak 8000C® (250 dpi)	9.68	9.73		

PSP= phosphor storage plate; CCD= charge coupled device.

Table 2. Means of absolute errors of linear measurements performed on digital panoramic radiographs with two file formats, obtained by different digital systems

Panoramic device	Digital system	Mean of absolute errors of linear measurements (mm)	
		JPEG	BMP
PSP system Rotograph Plus® (60 kV, 10mA, 17 s)	VistaScan® (250 dpi)	1.48a	1.43a
CCD Kodak 8000C® (60kV, 3,2mA, 13.2 s)	Kodak 8000C® (250 dpi)	1.04b	1.03b

PSP= phosphor storage plate; CCD= charge coupled device. Numbers followed by different letters = statistical difference ( $p<0.05$ ).

Table 3. Means of the files size, according to file format and digital radiographic system

Panoramic device	Digital system	Mean of files size (kB)	
		JPEG	BMP
PSP system Rotograph Plus® (60 kV, 10mA, 17 s)	VistaScan® (250 dpi)	808.8 <sup>a</sup>	3404.4 <sup>b</sup>
CCD Kodak 8000C® (60kV, 3.2mA, 13.2 s)	Kodak 8000C® (250 dpi)	73.4 <sup>c</sup>	2962 <sup>d</sup>

PSP= phosphor storage plate; CCD= charge coupled device. Numbers followed by different letters = statistical difference ( $p <0.05$ ).

and provide reliable data. This study analyzed panoramic radiographs obtained from CCD and PSP systems, saved with JPEG or BMP formats.

The uncompressed image files, as the BMP or TIFF formats, are very large and occupy great storage space in the computer. In hard disks, the data transfer is very slow. Compressed digital images may reduce storage requirements and facilitate data transmission over the Internet. For this compression, specific algorithms are used. The JPEG file is one of the most common algorithms used in digital technology and determines a compression "lossy". Compression "lossy" removes spatial frequencies and certain gray values that occur less frequently in the image. This process may reduce the size of the digital file and result in irreversible loss of information (6).

In this study, both JPEG as BMP formats were accurate regardless the used digital system, since there was no statistical difference between the measurements of dry mandibles and measurements of panoramic radiographs ( $p=0.47$ ). Nevertheless, the errors between radiographs and dry mandibles were less or equal to 1 mm in only 52.5% of the JPEG CCD images and in 55% of BMP CCD images. For PSP images, these values were 38.8% and 43.8%, respectively. On the other hand, 13.8% of errors were bigger than 2 mm from CCD images (both JPEG and BMP). These values were 18.8% and 21.3%, respectively for PSP images. These differences may have impact on the diagnosis in Dentistry, particularly in Implantology.

This result agrees with the study of Xavier et al. (7) who compared the formats TIFF and JPEG on intraoral radiographs for detecting caries lesion and did not report differences. Noujeim et al. (4) also did not find differences for the diagnostic accuracy in the detection of root fracture of periapical images saved in three different file formats (TIFF, JPEG medium file and JPEG small file). Comparing TIFF, BMP and JPEG file formats in simulated external root resorption, Gegler et al (5) did not find differences. Wenger et al (6) investigated the effects of JPEG compression on digital cephalometric image quality. The results show that there is no statistically significant difference among 60%, 70%, 80%, 90%, 98% JPEG compression and uncompressed TIFF images.

In the assessment of anatomical structures, studies have revealed conflicting results with those found here. Accord to Yasar et al. (8), during JPEG compression some information was lost and there was a statistically significant difference between TIFF and JPEG compressed images for mandibular cortical width, fractal dimension and density. Yasar et al. (9) found that the anatomical structures evaluated had better visibility in TIFF images than JPEG images, except for mandibular canal and mental foramen. They concluded that while JPEG compressed images offer

high inter and intra-observer agreements, the visibility of anatomical structures are better in TIFF images except for some structures.

For diagnosis in endodontics, the study by Siragusa and McDonnell (10) revealed that a JPEG lossy compression, six times smaller than the original TIFF, is compatible with diagnostic applications. Evaluating videomicroscopic image quality, saved in TIFF and JPEG formats, Seidenary et al. (11) found that the assessment of morphological details on dermatoscopic diagnosis of melanocytic lesions were higher when TIFF images were considered. Nonetheless, there was no significant difference in the diagnostic accuracy between uncompressed images and the compressed ones. Despite loss in image quality, a good diagnostic accuracy can be obtained with a compression factor of 30 in videomicroscopic images.

Comparing the linear distances between panoramic radiographs obtained by two different digital systems (CCD and PSP), it was observed that the error of the measurements was higher in the PSP system images. It is noteworthy that in this study both digital systems produced panoramic radiographs with the same space resolution (250 dpi). The PSP system is an indirect method of image acquisition, in which it is necessary to transfer the information stored in the phosphor plate to the computer. It might affect image quality. According Almeida et al. (1), images obtained from PSP system show a wide dynamic range. A large grey scale implies on a smaller contrast. In this study, high contrast would facilitate to identify the defect limits to make the measurements. Therefore, this can explain the inferior performance of PSP images in the present study.

Pittayapat et al. (12) compared the image quality between a PSP system and a CMOS receptor and found better results from PSP system. Adversely, Hintze (13) revealed a superior caries diagnostic accuracy in digital radiographs obtained from CCD, compared with PSP images.

Although there is no statistical difference in the measurements between the two file formats of images, it is noteworthy that the size of the JPEG files are statistically smaller than the size of the BMP files, which makes it the first type of advantageous image for filing and transmission over the internet.

## Resumo

Este estudo teve como objetivo avaliar a acurácia de radiografias panorâmicas digitais obtidas por sistema digital baseado em dispositivo acoplador de carga (DAC) e por sistema de placa de fósforo (PF) com duas diferentes extensões de arquivo (JPEG e BMP, sendo o primeiro do tipo compactador irreversível). Medidas lineares de defeitos ósseos foram realizadas em mandíbulas secas com paquímetro digital. As medidas correspondentes nas radiografias panorâmicas digitais foram realizadas no software ImageJ®. As medidas foram realizadas duas vezes por um examinador. A concordância intraexaminador foi considerada muito

forte (coeficiente de correlação de Pearson de 0,97). Não houve diferença significativa entre as medidas lineares das mandíbulas secas, consideradas padrão-ouro, em relação às medidas obtidas das radiografias digitais ( $p=0,47$ ). Os erros absolutos e relativos dessas medidas para o DAC foram de 1,04 mm (9,97%) para as imagens JPEG e de 1,03 mm (9,99%) para aquelas com extensão BMP. Para o sistema digital com PF esses valores foram de 1,48 mm (14,94%) e 1,43 mm (14,43%), respectivamente. Apesar de não ter havido diferença estatística entre as imagens com extensão JPEG e BMP, para ambos os sistemas digitais ( $p=1,00$  para DAC e  $p=0,98$  para a PF), os erros das medidas realizadas nas radiografias obtidas pelo sistema de PF foram significativamente maiores que os erros do DAC ( $p<0,05$ ). O tamanho dos arquivos salvos em JPEG também foram significativamente menores ( $p=0,005$ ) em comparação com os arquivos salvos em BMP. Pode-se concluir que as radiografias digitais tanto com extensão JPEG quanto BMP são acuradas, independente do sistema digital utilizado e as imagens salvas em JPEG são mais indicadas em telerradiologia.

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## References

1. De Almeida SM, de Oliveira AE, Ferreira RI, Bóscolo FN. Image quality in digital radiographic systems. *Braz Dent J* 2003;14:136-141.
2. Al-Rawi W, Teich S. Evaluation of physical properties of different digital intraoral sensors. *Compend Contin Educ Dent* 2013;34:e76-e83.
3. Abdelkarim A, Nummikoski P, Gakunga P, Hatch JP, Dove SB. Effect of JPEG2000 compression on landmark identification of lateral cephalometric digital radiographs. *Am J Orthod Dentofacial Orthop* 2010;138:518-524.
4. Noujeim M, Geha H, Shintaku W, Bechara B, Kashi KA. Effect of JPEG compression on the diagnostic accuracy of periapical images in the detection of root fracture. *Dent Traumatol* 2012;28:233-237.
5. Gegler A, Mahl CEW, Fontanella V. Reproducibility of and file format effect on digital subtraction radiography of simulated external root resorptions. *Dentomaxillofac Radiol* 2006;35:10-13.
6. Wenger NA, Tewson DHTK, McDonald F. Direct digital lateral cephalometry: the effects of JPEG compression on image quality. *Med Eng Phys* 2006;28:560-567.
7. Xavier CRG, Araujo-Pires AC, Poleti ML, Rubira-Bullen IRF, Ferreira Junior O, Capelozza ALA. Evaluation of proximal caries in images resulting from different modes of radiographic digitalization. *Dentomaxillofac Radiol* 2011;40:338-343.
8. Yasar F, Apaydin B, Yilmaz HH. The effects of image compression on quantitative measurements of digital panoramic radiographs. *Med Oral Patol Oral Cir Bucal* 2012;17:e1074-e1081.
9. Yasar F, Yesilova E, Apaydin B. The effects of compression on the image quality of digital panoramic radiographs. *Clin Oral Invest* 2012;16:719-726.
10. Siragusa M, McDonnell DJ. Indirect digital images: limit of image compression for diagnosis in endodontics. *Int Endod J* 2002;35:991-995.
11. Seidenari S, Pellacani G, Righi E, Nardo AD. Is JPEG compression of videomicroscopic images compatible with teleradiology? Comparison between diagnostic performance and pattern recognition on uncompressed TIFF images and JPEG compressed ones. *Telemed J E Health* 2004;10:294-303.
12. Pittayapat P, Thevissen P, Fieuws S, Jacobs R, Willems G. Forensic oral imaging quality of hand-held dental X-ray device: comparison of two image receptors and two devices. *Forensic Sci Int* 2010;194:20-27.
13. Hintze H. Diagnostic accuracy of two software modalities for detection of caries lesions in digital radiographs from four dental systems. *Dentomaxillofac Radiol* 2006;35:78-82.

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