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Effect of image compression of direct digital lateral cephalograms on the identification of cephalometric points

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ABSTRACT

Background: With increase of digital imaging, the need for storage space and transmission speed also increases. Compressed images need less storage space and decrease the transmission time. However, compression could compromise image quality. The aim of this study was to evaluate the influence of image compression on the identification of cephalometric points on direct digital lateral cephalogram images, compared with the digital imaging and communications in medicine (DICOM) format.

Materials and Methods: In this analytical-descriptive study, 19 direct digital lateral cephalograms saved in DICOM format were used. They were converted to joint photographic experts group (JPEG) 2000 format with quality factors 85, 75, and 60 adding up to 76 images (DICOM, JPEG 85, 75, and 60). The images were randomized and eight cephalometric points were identified on each image by a professional, using the x-y coordinate system. Analysis of variance (ANOVA) was applied to investigate if there was a statistically significant difference in the location of cephalometric points between each group of images. All tests were applied at a significance level of 5%.

Results: The results did not demonstrate any statistically significant difference in the identification of the eight cephalometric points between the DICOM images and the JPEG2000 quality factors 85, 75, and 60.

Conclusion: JPEG2000 images of lateral cephalograms with quality factors 85, 75, and 60 did not demonstrate any alterations in the identification of cephalometric points compared with the DICOM format. JPEG2000 is a reliable file format for the compression of digital lateral cephalograms.

Key Words: Cephalometry, data compression, dental, digital, radiographs

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INTRODUCTION

The development of cost-effective extraoral digital technology, coupled with increased use of computers in orthodontic practice, has made direct digital cephalometric imaging a valid opportunity.[1] With increase of digital imaging, the need for storage space and transmission speed also increases. One method to overcome this transmission overload is to compress the image files. Compressed images need less storage space and decrease the transmission time, since the compressed file is smaller because of the reduced amount of binary data used to represent the image.[2]

There are two methods of image compression: Lossless and lossy. Lossless compression eliminates nonessential information in the image while conserving essential data so that the digital image can be reconstructed exactly.[3] Lossless image compression methods preserve all image information and their use is not questioned. However, the approximate compression ratio is 1:2-1:4, depending on image characteristics.[4] Lossy compression, on the other hand, although offering considerably higher compression ratios and smaller file sizes, involves irreversible loss of data that could be essential.[5]

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The most common file format that offers lossy compression is the joint photographic experts group (JPEG) format. The JPEG2000 file format was developed to address some deficiencies in the original JPEG standard. This file format has been adopted by the digital imaging and communication in medicine (DICOM) standard.[6] Compared with JPEG, JPEG2000 allows higher compression without compromising quality. It also offers progressive image reconstruction, provides more options and greater flexibility than the standard JPEG format.[7]

Orthodontists, radiologists, and maxillofacial surgeons frequently use cephalometric measurements obtained on JPEG cephalogram images. Many investigations have been conducted to evaluate the compression ratio that may be used without loss of accuracy for different diagnostic purposes in dentistry,[8-13] for example Noujeim *et al*.,[14] evaluated the effect of JPEG compressions on the diagnostic capability of periapical images in the detection of root fractures, the compression reduced the file size considerably [from 1.77 megabytes (MB) to 453 and 95 kilobytes (Kb)], but it did not affect the accuracy of root fracture detection. The studies on cephalometrics have emphasized that more research in this field with adequate methodology is necessary.[11,12]

Thus, this study evaluated whether JPEG2000 quality factors 85, 75, and 60 altered the image quality compared with the DICOM image enough to influence the identification of cephalometric points on direct digital lateral cephalogram images.

MATERIALS AND METHODS

In this analytical-descriptive study, 19 direct digital lateral cephalograms that had been acquired for routine orthodontic treatment were used. All radiographic images were acquired with a Soredex (Cranex D, Finland) radiographic machine with an exposure time of 9.1-14.6 s, set at 73-81 kVp and 10 mA, on a charge-coupled device (CCD) sensor (Cranex D, Finland). The patients were placed in a natural head position, looking at their eyes reflected on a mirror positioned in front of the patient. To standardize the radiographic technique, the lateral cephalograms were obtained by a single technician. The images were saved in DICOM format, each with a file size of 9.649 MB.

In the second stage of the study, digital images were compressed using an Adobe Photoshop CS5 version 12 software (Adobe Systems, San Jose, Calif). Photoshop uses a quality-factor scale that ranges from one (lowest quality) to 100 (highest quality) for JPEG2000 compression. Three JPEG2000 compressed image groups were created by using this software at quality factors of 85, 75, and 60. This resulted in compression ratios of 11:3-15:7, 17:1-26:7, 39:5-73:1, respectively [Figure 1]. The compression ratio expresses the difference between the file size of the original image and the file size of the same image when compressed. The result was four images for each patient consisting of the original uncompressed images and three compression ratios, adding up to 76 images.

To avoid bias, an independent investigator copied the images to another folder for sample blinding, numbering the image files from one to 76 and keeping the original folder. Therefore, when the examiner identified the cephalometric landmarks on the images, he was not aware of their quality factors. The cephalometric points were identified by a professional on an HP ProBook 4520s computer with an Intel Core i3 CPU M 370 @ 2.4 GHZ, 3.00 gigabyte (GB) RAM and a 14-inch screen with resolution 1366 × 768 (China). The examiner was not allowed to change the brightness and contrast of images or to use the zoom tool. The cephalometric landmarks were identified using a location tool based on the x-y coordinate

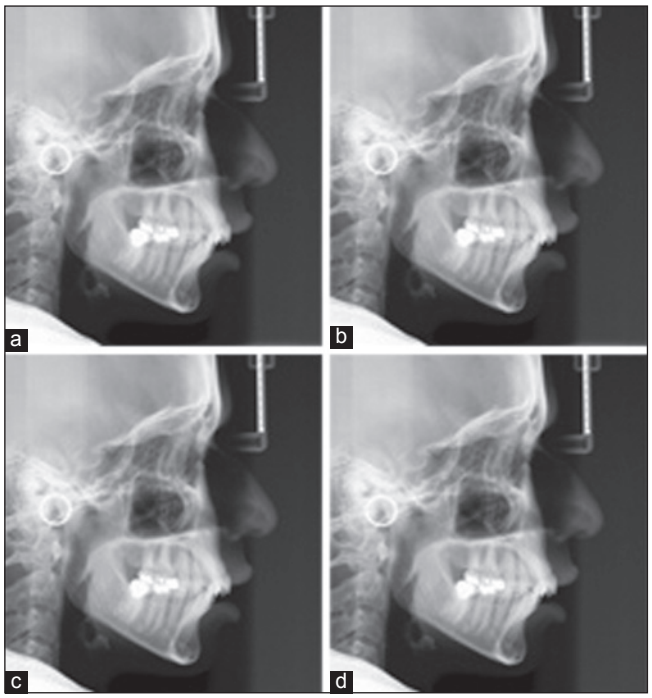

Figure 1: Example of images of a patient in (a) DICOM, (b) JPEG2000 85, (c) JPEG2000 75, (d) JPEG2000 60 formats

system (horizontal and vertical axes, respectively). The horizontal and vertical locations of each point were measured in pixels (120 pixel = 1 cm).

The following cephalometric points were identified:[15,16]

ANS anterior nasal spine (the tip of anterior nasal spine)

B B-point (The deepest point in the concavity of anterior border of the mandible)

A A-point (The deepest point of the anterior border of maxillary alveolar ridge concavity)

Or orbitale (The most inferior point of the infra orbital rim)

S sella (centre of hypophyseal fossa)

Pog pogonion (The most anterior point of the symphysis)

UI incisal (incisal edge of maxillary central incisor)

N nasion (The anterior point of the intersection between the nasal and frontal bones)

To evaluate the method error, the cephalometric points were once again identified by the examiner after 1 month interval. For evaluation of intra-examiner error, the Pearson correlation test was done for each coordinate.

The reproducibility in the identification of points, i.e. to determine if the point was identified on the same coordinate or close to it, was evaluated by analysis of variance (ANOVA). All tests were applied at a significance level of 5%. Comparison was performed between data collected from images with quality factors 85, 75, and 60 and the DICOM images. ANOVA was applied to investigate if there was a statistically significant difference in the location of cephalometric points between each group of images.

RESULTS

The correlation coefficient between the cephalometric points identified at repeated sessions was 0.99, revealing that the identification of cephalometric points is highly reproducible.

The mean and standard deviation (in pixels) of the location of the points in the original DICOM image and that of each compressed images are presented for each landmark on the x and y axes in Tables 1 and 2.

Table 3 demonstrates that the different file formats, on average, were statistically similar for each point and axis ($P > 0.05$). The results did not demonstrate any statistically significant difference in the identification of the eight cephalometric points between the DICOM images and the JPEG 2000 quality factors 85, 75, and 60.

Table 1: Mean±SD (in pixels) of the original DICOM and each quality factor (QF) for the x coordinate

Landmark	DICOM (Mean±SD)	85 (QF) (Mean±SD)	75 (QF) (Mean±SD)	60 (QF) (Mean±SD)
ANS	667.26±63.208	668.63±64.736	668.74±64.046	668.84±63.057
B	854.11±71.584	854.53±70.707	854.53±71.619	853.11±71.234
A	761.05±68.959	760.63±71.446	760.63±71.134	760.21±70.773
Or	932.21±68.980	930.32±67.965	930.53±68.212	930.95±68.363
S	1566.53±37.976	1565.16±38.972	1565.05±37.944	1565.89±38.329
Pog	846.95±80.364	848.84±79.281	847.68±80.173	848.00±79.263
N	765.05±63.761	765.47±65.159	765.47±64.294	766.32±65.092
UI	717.26±77.299	712.53±73.466	718.11±83.462	712.00±73.054

Table 2: Mean±SD (in pixels) of the original DICOM and each quality factor (QF) for the y coordinate

Landmark	DICOM (Mean±SD)	85 (QF) (Mean±SD)	75 (QF) (Mean±SD)	60 (QF) (Mean±SD)
ANS	1186.95±64.447	1188.32±64.918	1188.11±65.978	1188.21±65.814
B	1744.84±94.333	1745.05±94.440	1744.00±95.536	1745.05±93.448
A	1272.84±64.327	1270.00±66.040	1272.53±65.244	1272.95±65.096
Or	922.42±49.927	921.16±49.904	922.00±49.193	921.79±48.684
S	733.89±45.164	732.84±44.971	733.89±46.310	732.63±44.984
Pog	1867.58±87.472	1867.47±85.730	1865.58±88.163	1865.89±86.606
N	593.47±72.678	591.89±74.388	592.63±71.941	592.42±71.615
UI	1536.63±64.350	1536.84±64.410	1536.63±64.460	1537.26±64.457

Table 3: Results of analysis of variance (ANOVA), comparing each image group (DICOM, JPEG2000 85, JPEG2000 75, and JPEG2000 60) for identification of each point on the x- and y-axes

Point	Axis	Significance level of the test
ANS	x	0.664
	y	0.462
B	x	0.718
	y	0.739
A	x	0.885
	y	0.107
Or	x	0.286
	y	0.250
S	x	0.405
	y	0.157
Pog	x	0.075
	y	0.134
N	x	0.573
	y	0.469
UI	x	0.572
	y	0.625

DISCUSSION

In the present study, the quality factor (QF) was used to indicate the degree of loss in image quality, rather than the compression ratio (CR). The loss of data may be controlled in two ways. The first possibility is the selection of a QF in the compression scale of the software. The second possibility is the selection of the CR.[12] However, it has to be emphasized that CR depends not only on the degree of image loss, but also on the image content of the original image. For example, a simple image would achieve higher CR than a more complex one at the same degree of image loss. Therefore, CR might not be the most suitable parameter to be used for compression. Expressing the information loss by the QF seems ideal as it is image content independent.[17]

The Adobe Photoshop software was used in this study for the JPEG2000 compression because it is well-known and easy to access. Different versions of Adobe Photoshop (Adobe Systems Inc., San Jose, CA) were also used by some of the previous authors.[11,18-21]

The QFs were not randomly selected; rather, they were based on the study of Abdelkarim *et al*.,[11] and Duarte *et al*.,[12] who studied the effect of compression on landmark identification. They strongly recommended that further studies are necessary.

We chose the landmarks based on previous researches including the points which did not show good reproducibility.[11,12]The location of cephalometric points by the x-y coordinate system was used because this is an adequate methodology, previously tested and employed by different authors.[11,12,22,23]

Cziraki *et al*.,[22] reported loss of diagnostic accuracy on digital lateral cephalograms with a CR of 25:1, whereas 12:1 was similar to the image without compression. Duarte *et al*.,[12] reported that JPEG images of lateral cephalograms with QFs 100, 80, and 60, resulting in CRs of 3.4:1-4.2:1,17:1-26:1, and 30-62:1, respectively, did not present alterations in the reproducibility of identification of cephalometric points compared with the DICOM format. Good reproducibility was achieved for the 12 points, except for point Or on the x-axis.

In a study by Abdelkarim *et al*.,[11] the effect of JPEG2000 compression on landmark identification of lateral cephalometric digital radiographs was evaluated. The images included the original uncompressed *Tagged Image File Format* (TIFF) image and the JPEG2000 format at 3:1, 12:1, 50:1, and 110:1 CRs. All landmark identifications were precise with the exception of the maxillary incisal apex and edge at the 12:1 and 50:1 CRs, respectively. They concluded that JPEG2000 is a reliable file format that can be implemented in orthodontic practice.

Wenger *et al*.,[24] used an aluminum test object to assess the effect of the JPEG CRs 60%, 70%, 80%, 90%, and 98% on direct digital cephalometric image quality. The results showed that JPEG compression does not have any effect on the perceptibility of landmarks.

As previously mentioned in the present study, JPEG2000 images with the QFs 85, 75, and 60, resulting in CRs 11:3-15:7, 17:1-26:7, and 39:5-73:1, respectively, did not present a statistically significant difference compared with DICOM images [Table 3], which seems to be in agreement with most of the results of the previous studies mentioned above. But it should be emphasized that comparing different studies is difficult because of the different softwares used for image compression and the difference in image acquisition techniques (storage phosphor systems and charge coupled device based systems). Even though JPEG has an International Organization for Standardization (ISO) standard, its compression scale is not standardized. Consequently, different programs, or even different versions of

the same program, have different or even opposing compression scales.[17]

CONCLUSION

JPEG2000 images of lateral cephalograms with QFs 85, 75, and 60 did not demonstrate any alterations in the identification of cephalometric points compared with the DICOM format. JPEG2000 is a reliable file format for the compression of digital lateral cephalograms.

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