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ORIGINAL ARTICLE

The effects of compression on the image quality of digital panoramic radiographs

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Abstract Size reduction through compression is an important issue that needs to be investigated for possible effects on image quality. The aim of the present study was to evaluate the subjective image quality of digital panoramic radiographs which were lossless and lossy compressed for the visualization of various anatomical structures. Fifty-five digital panoramic radiographs in Tagged Image File Format (Tiff) were used in the study. Two types of lossy (Joint Photographic Experts Group (Jpeg)) and one type of lossless (Lempel–Ziv–Welch) compression were applied to the original radiographs. These radiographs were evaluated by two observers separately for the visibility of some anatomical structures with visual grading. Mean quality number for each radiograph was obtained. The differences between the mean quality numbers in each compression and original image mode were evaluated with Friedman test. Pair-wise comparisons revealed that there were statistically significant differences between all groups (p=0.000) for all comparisons except for Jpeg_1 and Jpeg_2 groups. Kappa statistics was used to evaluate inter- and intra-observer agreements. Intra-observer agreements were ranging from 0.229 to 1.000 and inter-observer agreements were ranging from 0.154 to 1.000. The observers had better inter- and intra-observer agreements in highly compressed Jpeg_1 images. The anatomical structures evaluated in this study had better visibility in Tiff images than Jpeg images except for mandibular canal and mental foramen. While Jpeg compressed images offer high inter- and intra-observer agreements, the visibility of anatomical structures are better in Tiff images except for mandibular canal and mental foramen.

Keywords Digital panoramic radiography · Image compression · Image quality · Anatomical structures

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Introduction

The first digital X-ray sensors for use in dentistry were introduced in the mid-1980s by Francis Mouyen, and the most important advantage of digital radiography is its ability to process the image data so that the information content of the image is more accessible for the human visual system [1]. The move to panoramic digital radiography in dentistry has been slower than the move toward intraoral digital radiography but is now accelerating [2].

Dental panoramic radiography is a specialized tomographic technique which produces a flat representation of the curved surfaces of the jaws [3]. It is an excellent and widely performed technique for providing an overview of the dentition, generalized pathology such as periodontitis, and odontogenic and non-odontogenic lesions of the jaws

[4]. Recognizing normal anatomic structures on panoramic radiographs is challenging because of the complex anatomy of the mid-face, the superimposition of various anatomic structures, and the changing projection orientation. The most important finding of the radiograph might be the absence of a normal anatomical structure. Thus, identifying the presence and integrity of the major anatomical structures during interpretation of panoramic radiographs is essential [5]. Farman reports that 50 distinct soft tissues and bony and dental landmarks can be labeled on a panoramic radiograph [2]. In this study, some of the most commonly seen and evaluated anatomical landmarks during interpretation were chosen.

Because of the bigger file size of digital panoramic radiographs, size reduction through compression is an important issue that needs to be investigated for possible effects on image quality [6]. The reduced image size will contribute not only to electronic space but also to a faster data transmission [7, 8]. The aim of the present study was to evaluate the subjective image quality of digital panoramic radiographs which were lossless and lossy compressed for the visualization of various anatomical structures because nowadays, it is not a rare event to have patients seeking for treatment with their digital intraoral and/or panoramic radiographs, exposed in other clinics and recorded to compact discs in Joint Photographic Experts Group (Jpeg) formats.

Materials and methods

The archive of the Oral Diagnosis and Radiology Department was analyzed retrospectively covering 15-day period. Among approximately 1,000 radiographs, 55 high-quality digital panoramic radiographs fulfilling the below mentioned criteria were selected for the study. None of the patients had known systemic disease that would affect bone metabolism (hyperparathyroidism, hypoparathyroidism, Paget's disease, osteomalacia, renal osteodystrophy or osteogenesis imperfect, osteoporosis), cancers with bone metastasis, or significant renal impairment. They were not using specific drugs or hormones (corticosteroids, excess thyroid hormone) which are known to have adverse effects on bone metabolism. The radiographs were exposed for other purposes during patients' clinical examinations. The radiographs had high image quality. The standardization of the projection geometry in panoramic radiographs was obtained by the aid of bite plate and light guides. As the patients are always requested to remove metal objects and appliances in the area about the oral cavity, and in the oral cavity, prior to the exposure of the panoramic radiographs, there were no radiopaque artifacts on the panoramic images. All of the radiographs were exposed with a digital panoramic system (Kodak 8000 with a CCD sensor) under standard exposure factors, as recommended by the manufacturer. Thus, there were no over- or under-exposed radiographs because Kodak 8000 offers different settings for patients according to their ages or body sizes, such as adult patients were exposed with 67 kV–5.0 mA–13.9 s, large patients (according to body size) 71 kV–12 mA–13.2 s, medium patients 71 kV–10 mA–13.2 s, and small patients 71 kV–6.3 mA–13.2 s.

The digital panoramic radiographs were exported as Tagged Image File Format (Tiff) files and by using Adobe Photoshop CS2 program two types of Jpeg (lossy) and Lempel–Ziv–Welch (LZW—lossless) compressions were applied to the original Tiff files. Original Tiff files (Tiff_2 group), LZW compressed images (Tiff_1 group), and two types of Jpeg (Jpeg_1 group and Jpeg_2 group) compressed images were evaluated by two observers separately for the visibility of some anatomical structures mentioned below. Before the observations began, one of the authors, who was not an observer in the study, numbered all of the radiographs so the radiographs contained no information about the identity of the patient. Each radiograph was labeled with different numbers in different compression mode groups. It took at least 10 days for the observers to evaluate one group of radiographs. There was an interval of 1 week between the observations of the other group of images with different compression modes and numbers. Two weeks after the observations of all groups finished, the observers reevaluated 10 radiographs from each group. Those 10 radiographs from each group were selected randomly by the same person who was not an observer, and these radiographs were renumbered again. When a radiograph was selected to be reevaluated in one compression group, it was not taking place in the other groups. Both of the observers were oral radiologists, and they worked in the same clinic for 10 years together and both of them evaluated digital panoramic radiographs every day. So interpreting panoramic radiographs was not a hard task for them, and at the beginning of the study, the two observers evaluated 10 panoramic radiographs together which were not included to the study. Digital images were viewed in a silent and dim room with a 19-in. high-resolution (1,280 × 1,024 pixels and 256 gray levels of super video graphics array) color liquid crystal monitor. The observers were not allowed to make any brightness/contrast adjustments, and both of them evaluated the radiographs under the same conditions.

For Jpeg_1 group, high compression was applied to the original images and they were compressed in low quality with baseline optimized format. For Jpeg_2 group, the images were less compressed than Jpeg_1 group and they were in high quality with baseline optimized format. For Tiff_1 group, LZW compression with interleaved pixel order was used. Tiff_2 group was the original Tiff files exported from Kodak software. The anatomical structures that are present on right and left sides of the panoramic radiographs were evaluated together; however, the structures that are also present on the midline, such as alveolar crestal bone level, inferior cortex, and maxillary and mandibular anterior trabecular bone, were evaluated separately. The anatomical structures that were evaluated in the study are given in Table 1. The total number of the anatomical structures evaluated was 19.

Visual grading of the anatomical structures was evaluated with a five-grade scoring system such as below [9].

1. *Excellent image quality*: no limitations for clinical use
2. *Good image quality*: minimal limitations for clinical use
3. *Sufficient image quality*: moderate limitations for clinical use but no substantial loss of information
4. *Restricted image quality*: relevant limitations for clinical use, clear loss of information
5. *Poor image quality*: image not usable, loss of information, image must be repeated

Each anatomical landmark in a radiograph was evaluated with a score of 1 to 5, and all the scores for a radiograph were summed and divided to the number of anatomical structures evaluated, which is 19 in this study, and a quality number for each radiograph in all imaging modes for each observer (Jpeg_1, Jpeg_2 and Tiff_1 and Tiff_2) was obtained. Then, these quality numbers were divided to the number of observers (which was two in this study), and a mean quality number for each radiograph was found. These mean quality numbers were used when comparing the image quality of the groups with each other. SPSS 16.0 was used for the statistical analysis. The differences between the mean quality numbers in each compression and original image mode were evaluated with Friedman test. As there was statistically significant difference between the groups, pair-wise comparisons were made with Wilcoxon Signed Ranks Test. Since multiple comparisons were made, Bonferroni correction was applied, and for statistically significance, α was used as 0.0083 [10]. That is 0.05 is divided to the number of comparisons, which is 6 in this study, and α value was obtained as 0.0083. Kappa statistics was used to evaluate inter- and intra-observer agreements.

Results

The minimum and maximum numbers of teeth that were present were 18 and 32, respectively (mean number of teeth, 28.55; standard deviation, 3.023). The minimum and maximum ages of the patients were 13 and 60, respectively (mean of age is 29.56, with a standard deviation of 9.603). Descriptive statistics for the quality numbers of the anatomical structures are given in Table 2. Friedman test, which is a non-parametric test for related samples, was applied to evaluate whether there were statistically significant differences in the quality numbers of the panoramic radiographs between the four groups of images. As there was statistically significant difference (p=0.000) between the groups, pair-wise comparisons were made with Wilcoxon Signed Ranks Test (Table 3). There were statistically significant differences between all groups (p=0.000 for all comparisons) except for Jpeg_1 and Jpeg _2 groups (p: 0.056). The total quality numbers for the anatomical structures for each group are given in Figs. 1 and 2. Because of the design of the study, the smaller mean quality number means better image quality for the anatomical structure. Descriptive statistics of kappa values for anatomical structures of the first observer's intra-observer agreement results and descriptive statistics of kappa values for anatomical structures of the second observer's intra-observer agreement results are given in Tables 4 and 5, respectively. Descriptive statistics of kappa values for anatomical structures for the inter-observer agreement results of the two observers are given in Table 6. The kappa results were interpreted according to Landis and Koch [11]. According to Landis and Koch, less than 0.00 indicates poor agreement, 0.00–0.20 slight agreement,

Table 1 The anatomical structures evaluated in the study

The anatomical structures evaluated	
Condylar process on both sides	Floor of maxillary sinus on both sides
Coronoid process on both sides	Zygomatic arch on both sides
Mandibular inferior cortex on both sides	Articular eminence on both sides
Mandibular inferior cortex in the middle	Alveolar crestal bone level on both sides
Mandibular canal on both sides	Alveolar crestal bone level on the middle
Mental foramen on both sides	Maxillary anterior trabeculation
External oblique ridge on both sides	Maxillary posterior trabeculation on both sides
Anterior nasal spine	Mandibular anterior trabeculation
Nasal septum	Mandibular posterior trabeculation on both sides
Medial wall of maxillary sinus on both sides	

Table 2 Descriptive statistics for the quality numbers of the digital panoramic radiographs

	Number	Minimum	Maximum	Mean	Standard deviation
Jpeg_1	55	1.947	3.421	2.629	0.399
Jpeg _2	55	1.579	3.368	2.544	0.369
Tiff _1	55	1.579	2.737	2.153	0.246
Tiff _2	55	1.632	3.474	2.087	0.300

0.21–0.40 fair agreement, 0.41–0.60 moderate agreement, 0.61–0.80 substantial agreement, and 0.81–1.00 is described as almost perfect agreement. A kappa index higher than or equal to 0.41 was considered sufficient intra-observer agreement [12].

Discussion

Increasing use of digital radiography and increasing resolution of newly developed systems result in higher storage and transmission requirements for digital images. These requirements can be considerably reduced by image compression [7], and this compression would lead to faster data transmission [8].

The use of irreversible compression is receiving more attention as a means of reducing the file size of diagnostic digital images to reduce storage and decrease image transmission times. Essentially, there are two types of image compression: "lossless" (reversible) and "lossy" (irreversible) compression. There is no loss of information in the compressed image data in lossless compression. Lossy compression involves at least three steps: image transformation, quantization, and encoding. No loss of information occurs in the transformation step. Quantization is the step in which the data integrity is lost. It attempts to minimize information loss by preferentially preserving the most important coefficients where less important coefficients are roughly approximated, often as zero. Finally, these quantized coefficients are compactly represented for efficient storage or transmission of the image [13]. Jpeg and wavelet-based compression schemes have been the widely used lossy compression methods for medical images [14].

The effects of compression on image quality depend on the image content, spatial and spectral distribution, and the compression level (or quality factor) which determines the degree of the quantization. These effects might be removal of noise at low level compressions, blurring at moderate to high levels of compression, and artifacts at high levels of compression. Subtle pathologies that may be difficult for the human eye to discern because of low contrast, but which have a significant spatial extent, are typically characterized by low frequencies in the spectral domain, and they are quite tolerant to compression. High-frequency features are usually more vulnerable to compression. Fine, irregular texture patterns such as the trabecular pattern of bone would contain many small, high-frequency coefficients, so it would be expected for them to degrade easily long before a subtle fracture which has lower frequency [13].

The application of lossless compression algorithms, like the Lempel–Ziv–Welch (LZW), results in a compression ratio of 2:1, which will reduce the size of an image in half. This kind of compression is used in graphic formats such as "Tagged Image File Format" (Tiff) and "Graphic Interchange Format." It is preferred to apply lossless compression to images [8]. However; the image size will not reduce considerably in this type of compression.

Typical intraoral radiographic images require 100 to 300 kb of storage space [15]. Currently used panoramic digital image sizes are reported to exceed 4 MB [8]. The effects of compression in intraoral digital radiography have been studied in various studies till today [16–19]. In this study, it was aimed to evaluate the subjective image quality of digital panoramic radiographs which were lossless and lossy compressed for the visualization of various anatomical structures.

Wenzel et al. reported that compression rates of 1:12 can be justified for caries diagnosis without any significant effect on accuracy and image quality in images taken with storage phosphor plates in intraoral radiography [16]. The effect of lossy image compression on caries detection was evaluated in another study with storage phosphor plates, and the authors reported that compression rates of 1:16 can be used for proximal caries detection with no significant deterioration in diagnostic efficacy [17].

Table 3 The results of the pair-wise comparisons with Wilcoxon Signed Ranks Test statistics

Pair-wise comparisons	z	Asymptotic significance (2-tailed)
Jpeg1_Jpeg2	-1.910^{a}	0.056
Jpeg1_Tiff1	-6.055^{a}	0.000
Jpeg1_Tiff2	-5.905^{a}	0.000
Jpeg2_Tiff1	-5.922^{a}	0.000
Jpeg2_Tiff2	-5.758^{a}	0.000
Tiff1_Tiff2	-3.639^{a}	0.000

[a] Based on positive ranks

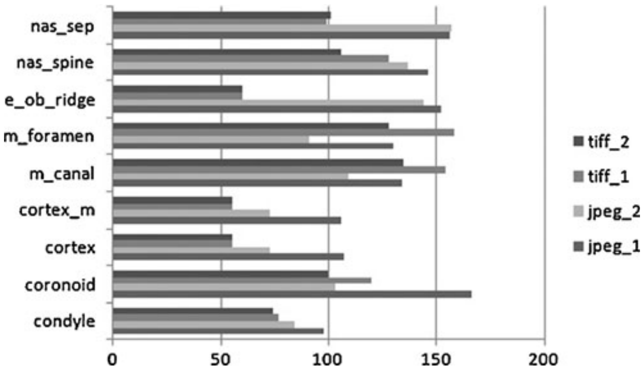

Fig. 1 The total quality numbers for the anatomical structures such as nasal septum, nasal spine, external oblique ridge, mental foramen, mandibular canal, mandibular cortex in the middle, mandibular cortex on both sides, coronoid process of the mandible, and conyle of the mandible

Koenig et al. found that Jpeg compression does not impact detectability of artificial periapical lesions at low and moderate compression ratios up to and including 28:1 [18]. However, in another study, high lossy compression ratios are found to have a severe impact on the diagnostic quality of digital intraoral radiographs for the detection of periapical lesions [19].

The first observer had higher intra-observer agreement than the second observer in all compression modes and original Tiff files. The first observer's mean kappa values were ranging from 0.797 (in Tiff_1 LZW compression mode) to 0.862 (in Jpeg_1 compression mode). The second observer's mean kappa values were ranging from 0.595 (original Tiff files) to 0.706 (Jpeg_1 files). The mean kappa results for inter-observer agreement were ranging from 0.560 (Tiff_1 LZW compressed images) to 0.677 (Jpeg_1 images). The observers had better inter- and intra-observer agreement in Jpeg_1 group. That is, higher compression led to better agreement. It might be expected that the observers would have better agreement in original Tiff images; conversely, this was not the case, and the observers had better agreement in the most compressed images (Jpeg_1). However, the quality numbers of the anatomical structures evaluated in the study were generally better in original Tiff images (Tiff_2) except for mental foramen, mandibular canal, and mandibular anterior and posterior trabeculation, maxillary anterior trabeculation. These findings are in accordance with the literature because it is reported that compression causes removal of noise and the trabecular pattern of bone which contains many small, high-frequency coefficients would be expected to degrade easily than structures having lower frequency such as a subtle fracture [13].

The most common isolated facial bone fracture site was found to be nasal bone (37.7%), followed by the mandible (30%), orbital bones (7.6%), zygoma (5.7%), maxilla (1.3%), and the frontal bone (0.3%) [20]. Because of their protected position under the zygomatic arch or zygomaticomalar complex, coronoid fractures due to direct trauma are very uncommon [21]. In this study, nasal septum and anterior nasal spine were best seen in Tiff images, and the visibility of nasal spine gradually decreases with the increase in compression. Condyle and coronoid process had also good visibility in Tiff_2 images, and the visibility decreased with the increase in the compression.

There are studies reporting that mandibular cortical width and the porosity correlate with bone mineral density and they can be used for detecting osteoporosis [22]. Fractures also affect the inferior cortical bone of the mandible. The visibility of mandibular cortex both on contra-lateral sides and on the middle was evidently better in Tiff_1 and Tiff_2 images than Jpeg compressed images. The cortex was worst visualized in Jpeg_1 group.

The knowledge of the morphology and topography of the mandibular canal is important for performing dental interventions in the jaw as it carries both the dental division of the trigeminal nerve and the nerve supply for the lower lip [23]. The mental foramen is also an important landmark when considering placing implants in the foraminal region of the mandibular arch [24]. The mandibular canal and mental foramen were best visualized in Jpeg_2 images and worst in Tiff_1 images. The visibility of mandibular canal and mental foramen was nearly same in Tiff_2 and Jpeg_1 images.

External oblique ridge is a continuation of the anterior border of the mandibular ramus, and the ideal line of osteosynthesis for angle fractures is located along the external oblique ridge [25]. External oblique ridge was clearly and equally best visualized in both kinds of Tiff images.

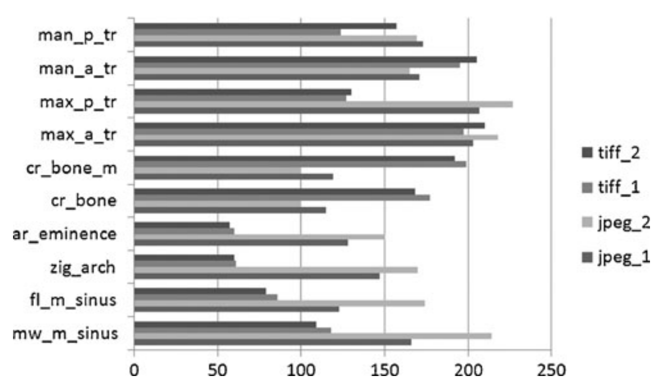

Fig. 2 The total quality numbers for the anatomical structures such as mandibular posterior trabeculation, mandibular anterior trabeculation, maxillary posterior trabeculation, maxillary anterior trabeculation, crestal bone in the middle, crestal bone on both sides, articular eminence of temporal bone, zigomatic arch, floor of maxillary sinus, and medial wall of maxillary sinus

Table 4 Descriptive statistics of kappa values for anatomical structures of the first observer's intra-observer agreement results

	Number	Minimum	Maximum	Mean	Standard deviation
Jpeg_1	19	0.750	0.927	0.862	0.044
Jpeg_2	19	0.734	0.923	0.833	0.048
Tiff_1 (LZW)	19	0.229	0.951	0.797	0.170
Tiff_2	19	0.508	1.000	0.809	0.108

Mucous retention phenomenon, antral mucoceles, opacified sinuses or fluid levels, benign cysts and neoplasms, and malignant tumors can affect maxillary sinuses, and these conditions can cause changes in the visibility of the borders of maxillary sinus on panoramic radiographs. The floor of maxillary sinus is very thin. The medial wall of the sinus, which is also the lateral wall of the nose, is also very thin, and due to angle of radiograph, it may not be seen [26]. The visibility of the floor of maxillary sinus was better than the visibility of medial wall of maxillary sinus in all compression modes and both of them were better visualized in original and LZW compressed Tiff files, and compression decreased their visibility.

Pneumatic bone cavities of the articular eminence are anatomical variations, and panoramic radiography appears to be an efficacious method to display their presence [27]. Degenerative joint diseases also affect articular eminence, and concavity replaces the normally convex eminence in severe cases [28]. In this study, the articular eminence was better visualized in both kinds of Tiff images than Jpeg compressed images.

Substantial correlation was found between the visual analysis of periapical radiographs and panoramic radiographs (rho=0.737) for the visibility of trabecular structures [29]. In this study, maxillary posterior trabeculation had the best quality numbers in original Tiff and LZW compressed files. Maxillary anterior trabeculation had the worst visibility in all compression modes. Mandibular posterior trabeculation was better visualized in LZW compressed Tiff images. Mandibular anterior trabeculation was better visualized in Jpeg_2 group. The visibility of trabecular structures on the midline either in the mandible or maxilla was inferior to posterior parts. Posterior parts of the mandible and maxilla have trabecular pattern which is larger than the anterior parts of that bone, and generally, mandible has a trabecular pattern which is coarser than maxilla. The quality numbers of trabecular pattern were not good, and the reason of this might be the architectural differences in trabecular pattern along with the inferior resolution of panoramic radiographs.

Bitewing and periapical radiography are useful tools for evaluating alveolar crestal bone. Panoramic radiography has also been used as an adjunct to the examination of marginal bone tissue, and it compares favorably with intraoral radiography in the assessment of marginal bone level [30]. In this study, the visibility of the crestal bone on the midline was worst than both sides of the mandible. The midline region is more radiopaque because of the mental protuberance, increased trabecular numbers, and attenuation of the beam as it passes through the cervical spine [5], and also, the close proximity of the roots of anterior teeth might decrease the visibility of alveolar crestal bone on the midline. Crestal bone had better visibility in both kinds of Jpeg compressed images. Removal of noise during compression might increase the visibility of alveolar crestal bone.

There are few studies evaluating the image quality of digital panoramic radiography. Digital radiography has a significantly lower potency in the assessment of periapical status of the teeth [31]. Contrast enhancement improves the diagnostic image quality significantly in digital panoramic radiographs [32]. Caries and periapical and periodontal status have the lowest subjective image quality in the premolar region of the upper jaw, and monitor images and direct thermal prints are better than inkjet prints [33]. Larger anatomical structures have more equal subjective image quality in either digital panoramic radiographs or film-based images when compared with smaller structures [34].

In this study, the visibility of trabecular bone structure of the maxilla and the mandible was showing great variability in compressed and original images. Especially the visibility

Table 5 Descriptive statistics of kappa values for anatomical structures of the second observer's intra-observer agreement results

	Number	Minimum	Maximum	Mean	Standard error	Standard deviation
Jpeg_1	19	0.524	1.000	0.706	0.025	0.110
Jpeg_2	19	0.412	1.000	0.642	0.034	0.150
Tiff_1 (LZW)	19	0.400	1.000	0.657	0.046	0.199
Tiff_2	19	0.348	1.000	0.595	0.042	0.183

Table 6 Descriptive statistics of kappa values for anatomical structures for the inter-observer agreement results of the two observers

	Number	Minimum	Maximum	Mean	Standard error	Standard deviation
Jpeg_1	19	0.400	1.000	0.677	0.043	0.186
Jpeg_2	19	0.400	1.000	0.623	0.0403	0.176
Tiff_1 (LZW)	19	0.154	1.000	0.560	0.047	0.205
Tiff_2	19	0.348	1.000	0.586	0.039	0.171

of maxillary posterior trabeculation and medial wall of maxillary sinus was poor in Jpeg compressed images. Nasal septum and external oblique ridge, articular eminence, zygomatic arch, floor of maxillary sinus, and mandibular cortex on both sides of the mandible and on the middle had better visibility in Tiff images than Jpeg compressed images.

This study has three limitations. One of them is the relatively small sample size and the other is limited number of observers. Visual assessment of image quality depends on the observer's ability, which has large individual difference [35]. Patients manifest diversity in anatomic and imaging characteristics. Observers have disparate visual and cognitive abilities that lead to differences in interpretation. Results from studies involving expert readers from a single institution are only applicable to expert readers from that institution [36]. The third limitation of this study is the two observers from the same institution having nearly same experience in interpreting panoramic radiographs, and as a result of this, observer variation among different levels of experience could not be evaluated. However, in a multi-observer radiographic caries detection study, the influence of number of surfaces and observers on statistical power was evaluated. It was found that the study designs for comparing the accuracy of several systems can be composed freely in relation to the number of surfaces and observers as long as the total numbers of evaluations per system are identical [37]. In this study, the number of the radiographs, anatomical structures, and the number of observations were identical for both of the observers. The precision and accuracy of digital measurements in digital panoramic radiography were evaluated in another study, and the measurements were carried out by one experienced observer to eliminate inter-observer variation because the performance of a single observer with any method is relatively reproducible [38]. In another study, the effect of experience on the diagnostic accuracy of dental students using bitewing radiographs for the diagnosis of dentinal caries with that of general dental practitioners was evaluated. Although the students were less experienced than the dentists, they had better sensitivity but worse specificity when compared with dentists [39]. The students had a too liberal certainty threshold for diagnosing proximal dentine caries from bitewing radiographs, but for a clinically relevant population, the dental practitioners are thought to out-perform the students in diagnostic performance.

In this study, different anatomical structures were chosen for evaluation of image quality to detect differences between the original Tiff files and images which had different levels of compressions. While some of the anatomical structures were great in size or easily detected such as mandibular condyle, mandibular cortical bone, some of them were hardly discernible such as trabecular bone or alveolar crestal bone and some of them were radiolucent such as mental foramen and mandibular canal, whose boundaries may sometimes be not clearly depicted among tiny trabecular bone structure. The visibility of nasal septum, nasal spine and external oblique ridge, mandibular cortex, articular eminence, zygomatic arch, floor of maxillary sinus, and medial wall of maxillary sinus were better in Tiff images, and the visibility decreased in compressed Jpeg images. The visibility of condyle was also better in Tiff images, and it gradually decreased in Jpeg compressed images. Medial wall of maxillary sinus, floor of maxillary sinus, zygomatic arch, articular eminence, and maxillary posterior trabeculation had a better visibility in Jpeg_1 group than Jpeg_2 group in which the image is more compressed. Mental foramen, mandibular canal, mandibular posterior trabeculation, mandibular anterior trabeculation, and maxillary anterior trabeculation had varying degrees of visibilities in different compression modes which seemed to be irrespective of the compression amount. The anatomical structures which were evaluated in this study generally had better visibility in Tiff images than Jpeg images except for mandibular canal and mental foramen. Mental foramen and mandibular canal which are radiolucent structures were better visualized in Jpeg_2 compressed images than Tiff images, and the removal of noise during compression might increase their visibility.

As a conclusion, the observers had better inter- and intra-observer agreements in highly compressed Jpeg images than Tiff images. However, it should be kept in mind that the level of disagreement in the interpretation of radiographs is dependent on the difficulty of the task, the experience of the observers, and also on other factors, such as fatigue and variations in image perception [35]. The anatomical structures evaluated in this study had better visibility in Tiff images than Jpeg images except for mandibular canal and mental foramen.

Conflict of interest The authors declare that they have no conflict of interest.

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