Optimum Image Compression Rate Maintaining Diagnostic Image Quality of Digital Intraoral Radiographs

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ABSTRACT

Purpose : The aims of the present study are to determine the optimum compression rate in terms of file size reduction and diagnostic quality of the images after compression and evaluate the transmission speed of original or each compressed image.

Materials and Methods : The material consisted of 24 extracted human premolars and molars. The occlusal surfaces and proximal surfaces of the teeth had a clinical disease spectrum that ranged from sound to varying degrees of fissure discoloration and cavitation. The images from Digora system were exported in TIFF and the images from conventional intraoral film were scanned and digitalized in TIFF by Nikon SF-200 scanner (Nikon, Japan). And six compression factors were chosen and applied on the basis of the results from a pilot study. The total number of images to be assessed were 336. Three radiologists assessed the occlusal and proximal surfaces of the teeth with 5-rank scale. Finally diagnosed as either sound or carious lesion by one expert oral pathologist. And sensitivity, specificity and κ value for diagnostic agreement was calculated. Also the area (Az) values under the ROC curve were calculated and paired t-test and oneway ANOVA test was performed. Thereafter, transmission time of the image files of the each compression level was compared with that of the original image files.

Results : No significant difference was found between original and the corresponding images up to 7% (1 : 14) compression ratio for both the occlusal and proximal caries ($p<0.05$). JPEG3 (1 : 14) image files are transmitted fast more than 10 times, maintained diagnostic information in image, compared with original image files.

Conclusion : *1 : 14 compressed image file may be used instead of the original image and reduce storage needs and transmission time.* ***(Korean J Oral Maxillofac Radiol 2000 ; 30 : 265-274)***

KEY WORDS : digital image compression, diagnostic quality, transmission

Introduction

Original image of the digital intraoral radiograph, at its full resolution, occupies 100 to 250 kB. It could rapidly fill the hard disk space available and also takes longer time when transmitting the image to a distant site. To accommodate adequate size of image files, the use of file compression techniques can be considered. Image compression may reduce storage needs and reduce transmission time when transmitting image file to a distant site.

Compression techniques can be performed either as a lossless or lossy compression.[1-6] Lossless or reversible compression (for example, GIF, TIFF) may compress the image to approximately maximum 1 : 3 for its original file size with preserving all the information in each pixel of the original image. That is, reconstructed image exactly perfectly match the original data file. Lossy or irreversible compression (for example, JPEG) offers higher compressibility of the image at the price of losing a certain amount of information from the original image. The overall effectiveness of lossy compression on a given image is dependent on both the amount of real data discarded and the mathematical algorithm used to compress the data.

JPEG (Joint Photographic Expert Group) compression protocol has been introduced as an ISO standard for the compression of still-frame, continuous-tone, color images and is a lossy compression algorithm that use a DCT (discrete cosine transform) in transforming a set of data from the spatial domain to the frequency domain.

Usually, a small amount of loss of information probably will not corrupt the diagnostic process. Van der Stelt et al. found that sensitivity of common diagnostic tasks was not

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affected even with a very high compression rate by JPEG image compression and specificity of the same tasks was very high for all compression rates.[7] Wenzel et al. showed that for caries diagnosis, compression rates of 1 : 12 can be justified before accuracy and image quality is significantly affected.[8] Some authors insisted that compression rates of 1 : 20 can be acceptable on occlusal caries diagnosis.[9,10]

Thus, till now, the dilemma is to determine the balance between the possible loss of information due to the lossy compression procedure, and nevertheless maintaining a satisfactory level of diagnostic quality.

The aims of the present study are to determine the optimum compression rate in terms of file size reduction and diagnostic quality of the images after compression and evaluate the transmission speed of original or each compressed image.

Materials and Methods

The material consisted of 24 extracted human premolars and molars. The occlusal surfaces and proximal surfaces of the teeth had a clinical disease spectrum that ranged from sound to varying degrees of fissure discoloration and cavitation.

The teeth embedded three in a row with approximal contact in an anatomical position from the apex to the cemento-enamel junction, in plaster of Paris contained in wax moulds.

XCP were adapted to hold both the conventional film and the storage phosphor plate during the exposure. The X-ray unit (Heliodent, Siemens, Germany) operated at 60 kVp, 8 mA, 0.04sec for storage phosphor plate and at 60 kVp, 8 mA, 0.25sec for Ektaspeed plus film. SSD (source-skin distance) was 30 cm. The images from Digora system were exported in TIFF (tagged image file format) and the images from conventional intraoral film were scanned and digitalized in TIFF by Nikon SF-200 scanner (Nikon, Japan).

To prevent identification of the image, the images were cut, one full tooth and one half neighboring tooth included in one image, by Adobe Photoshop (version5.0, Adobe system , CA), so that they could not be recognized by their size.[9] Thereafter the images were compressed using the JPEG irreversible compression standard available in the JPEG Optimizer (version4.0, xat.com internet technology, UK). Six compression factors were chosen on the basis of the results from a pilot study : JPEG1, JPEG2, JPEG3, JPEG4, JPEG5, JPEG6 (respectively 10%, 8%, 7%, 5%, 4%, 3% of the original image). The original image and the six compressed images are

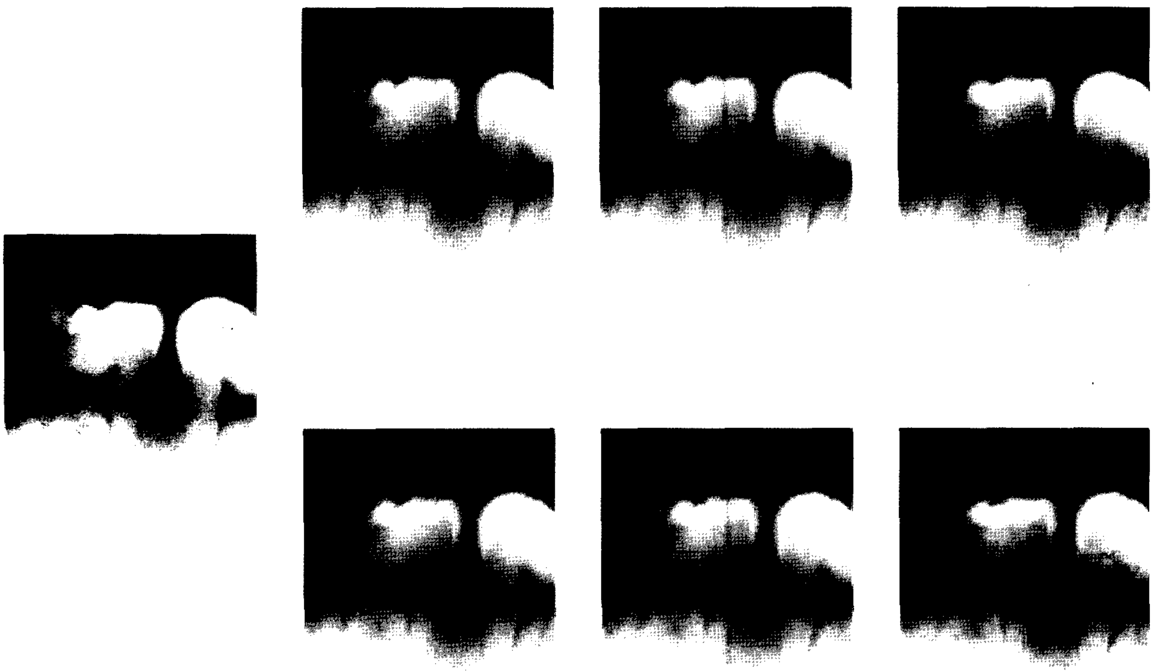

Fig. 1. Occlusal caries on the mandibular second molar : left center = original image. Upper line = 10%, 8% and 7% compressed image of the original image. Lower line = 5%, 4% and 3% compressed image of the original image.

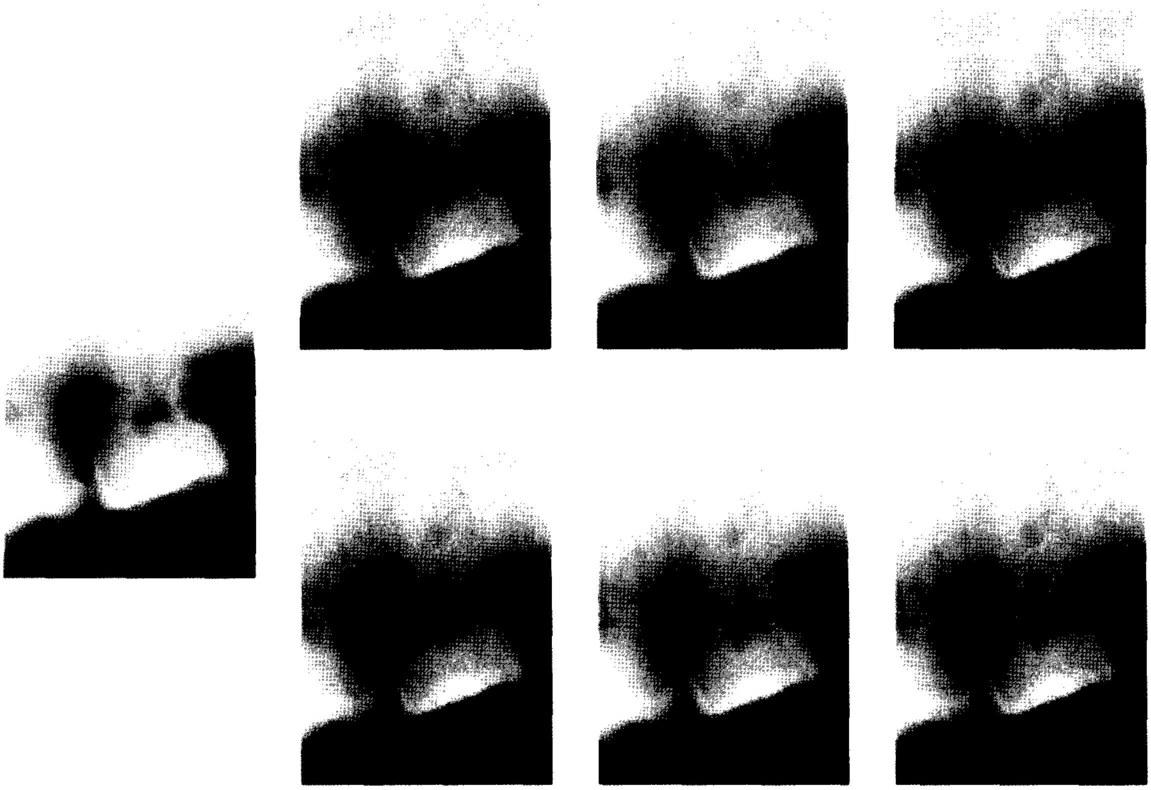

Fig. 2. Proximal caries on the maxillary second molar : left center = original image. Upper line = 10%, 8% and 7% compressed image of the original image. Lower line = 5%, 4% and 3% compressed image of the original image.

shown in Fig. 1 and Fig. 2. The total number of original images were 24 for Digora images and 24 for conventional intraoral images. Thus the total number of images to be assessed were 168, respectively Digora images and digitalized conventional intraoral images.

Each of the workstations used for the assessments consisted of an IBM-compatible PC (Pentium Celeron 433MHz) and 17 SVGA monitor (Green monitor, Samsung Electronics, Korea) with 256 color display. Images were, in ACDSee32 (version 2.3, ACD system, USA), displayed to the observers in a random order generated by the computer.

Three radiologists (Observer1-Observer3), all familiar with assessing digital radiographs, assessed the occlusal and proximal surfaces of the teeth. A 5-rank confidence scale was used to score caries as 1 = definitely absent, 2 = probably absent, 3 = unsure, 4 = probably present, 5 = definitely present.

After assessments were completed, the teeth were removed from the plaster of Paris and individually embedded in acrylic. And the teeth were fixed to the sectioning position of a low speed diamond saw (ISOMET, Buehler, Germany). The acrylic models were serially cut into sections with approximate 800 μm thickness in a plane oriented mesiodistally and parallel to the long axis of the tooth crown (Fig. 3 and Fig. 4). The sections were grounded and fixed to microscope slides and viewed under a stereomicroscope (Nikon SMZ-U, Japan) at a 25 magnification and finally diagnosed as either sound or carious lesion by one expert oral pathologist. Furthermore carious lesions were divided into three categories; Enamel lesion, Lesion extending to DEJ, Dentinal lesion.

Observer's scores 4 and 5 were interpreted as positive caries diagnosis and scores 1, 2 and 3 were interpreted as negative caries diagnosis. The diagnostic performance of each observer, for both the Digora digital images and digitalized image from conventional films, was evaluated with the true diagnosis (gold standard, by histologic validation) by calculating true positive (TP) and false positive (FP) and true negative and false negative values. And sensitivity and specificity was calculated and Kappa for diagnostic agreement was calculated. And κ statistic was also used that a finding was either present or absent. As described by Lardis and Koch,[11] $\kappa = 0$ to 0.20 suggests slight agreement, $\kappa = 0.21$ to 0.40 suggests fair agreement, $\kappa = 0.41$ to 0.60 suggests moderate agreement, $\kappa = 0.61$ to 0.80 suggests substantial agreement, and $\kappa = 0.81$ to 1.0 suggests almost perfect agreement.

Fig. 3. Microstereoscopic image of the sectioned tooth with occlusal caries extending into the dentin (× 25 magnification).

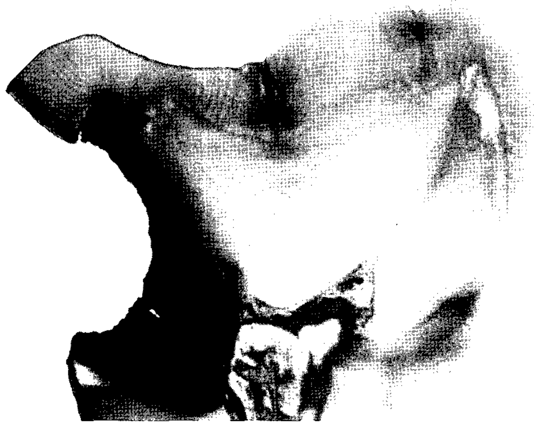

Fig. 4. Microstereoscopic image of the sectioned tooth with proximal caries extending into the dentin (× 25 magnification).

Table 1. Sensitivitie, specificitie, and κ value for occlusal and proximal caries detection

	Occlusal caries detection						Proximal caries detection					
	Digora			Digitalized film			Digora			Digitalized film		
	Sen	Spe	κ	Sen	Spe	κ	Sen	Spe	κ	Sen	Spe	κ
Observer 1	0.81	0.88	0.63	0.69	0.94	0.44	0.86	0.97	0.90	0.78	0.97	0.83
Observer 2	0.80	1.00	0.57	0.66	0.75	0.45	0.91	0.95	0.97	0.82	0.95	0.88
Observer 3	0.71	1.00	0.45	0.65	0.75	0.44	0.80	0.91	0.92	0.69	0.88	0.85

Digora : digital image from Digora system
Digitalized film : digitalized image from conventional film scan
Sen : sensitivity, Spe : specificity, k : Kappa value

The area (Az) under the ROC curve expressed the diagnostic accuracy of each observer, and paired t-test was to analyze differences between the Az scores. Interobserver variations in Digora digital images and digitalized images from conventional films were evaluated by kappa values and oneway ANOVA test.

Thereafter, file size of the original images and images of each compression level were recorded and transmitted by Outlook Express (version5.0, Microsoft, USA) via (1) 56kbps modem (modulation-demodulation), 2) ADSL (Asymmetric Digital Subscriber Line, max. upload 640kbps). Transmission time of each original image files and that of corresponding compressed images were recorded. And transmission time of the image files of the each compression level was compared with that of the original image files.

Results

Prevalence of occlusal caries was 83% (enamel lesion 40%, lesion extending to DEJ 10%, dentinal lesion 50%) whereas of proximal surfaces, it was 45.8% (dentinal lesion 100%). Sensitivitie, specificitie, and κ value for each observer are shown (Table 1).

For Digora image, interobserver sensitivities ranged between 0.71 and 0.81 and specificities between 0.88 and 1.00 for the detection of occlusal caries, and sensitivities ranged between 0.80 and 0.91 and specificities between 0.91 and 0.97 for the detection of proximal caries.

For digitalized image from conventional film, interobserver sensitivities ranged between 0.65 and 0.69 and specificities between 0.75 and 0.94 for the detection of occlusal caries, and sensitivities ranged between 0.69 and 0.82 and specificities between 0.88 and 0.97 for the detection of proximal caries.

Sensitivities and specificities seems to be relatively high for the detection of proximal caries than those of occlusal caries, and those for Digora images are higher than those for digitalized images. An analysis of paired t-test was performed and the results were as follows : for both the Digora and digitalized images, sensitivities for the detection of proximal caries were statistically significantly higher than those of for the detection of occlusal caries, but specificities are not significant ($p < 0.05$); For the detection of occlusal caries, specificities when examined with Digora image is statistically significantly higher than those when examined with digitalized image. But sensitivities are not statistically significant ($p < 0.05$); For the detection of proximal caries, when used either Digora images or digitalized conventional images, sensitivities and specificities are not statistically significant ($p < 0.05$).

When looking at the values for Kappa, these can be assumed to represent 'fair' (0.45) to 'substantial' (0.63) diagnostic agreement for occlusal caries diagnosis and 'perfect' (0.90-0.97) agreement for proximal caries diagnosis when used the Digora images, and represent 'fair' (0.44-0.45) diagnostic agreement for occlusal caries and 'perfect' (0.83-0.88) agreement for proximal caries diagnosis when used digitalized images.

An analysis of oneway ANOVA test was performed and no significant differences were seen between observers, image type (Digora or digitalized image), and examined tooth surfaces (occlusal or proximal surface) ($p < 0.05$).

An analysis of receiver operating characteristic curve (ROC) area was performed and the all original images had a higher Az value than the corresponding compressed images. However, no significant difference was found between original and the corresponding images up to 7% compression ratio for both the occlusal (Table 2) and proximal caries (Table 3) ($p < 0.05$). The mean Az value of Digora images is slightly higher than that of digitalized images, but no significant differences found between Digora and digitalized images ($p < 0.05$).

Using 56kbps modem, images were transferred via electronic mail (E-mail) system in average 57sec, 72sec, respectively in original image (222.5kb) of Digora, digitalized image (255 kb) from conventional radiograph. While each compressed forms of Digora images was transferred in average 6 sec, 5 sec, 4.5 sec, 4 sec, 3 sec, 2 sec and digitalized images from conventional radiographs were transferred in average 8sec, 6 sec, 5 sec, 4 sec, 3 sec, 2 sec, respectively JPEG1 (10%), JPEG 2 (8%), JPEG3 (7%), JPEG4 (5%), JPEG5 (4%), JPEG6 (3%).

Using ADSL, original images were transferred, via the same e-mail system as modem, in less than 10sec for both the Digora original images and digitalized original images. And all compressed files of Digora and digitalized image were transferred in less than 2 sec. In occasion, transmission speeds vary with the traffic in the system. Thus transmission time of this results were calculated as average.

Discussion

Digital radiography provides conventional radiography with the advantages of digital images : lower cost, less radiation, examinations are easier to perform, image acquisition and display processes are separated, and images can be processed, image file stored and transferred through a computer network.[12,13]

The digital intraoral radiograph occupies approximately 200kB depending on pixel matrix when stored in its full resolution in hard disk. And the implementation of digital radiography in the dental office will therefore require large electronic storage media and long transmission time. Therefore, image compression methods were developed to reduce storage need and transmission time.

Table 2. The area under ROC curve (Az) for original image and each compressed image for occlusal caries detection

	Digora					Digitalized film				
	Original	10%	8%	7%	5%	Original	10%	8%	7%	5%
Observer 1	0.58	0.57	0.55	0.52	0.50	0.53	0.52	0.50	0.50	0.50
Observer 2	0.63	0.58	0.57	0.52	0.50	0.57	0.55	0.54	0.52	0.50
Observer 3	0.57	0.57	0.52	0.52	0.50	0.55	0.53	0.53	0.52	0.48
Mean	0.59	0.57	0.55	0.52	0.50	0.55	0.53	0.52	0.51	0.51

Original: Original image, 10%: 1 : 10 compressed image, 8%: 1 : 12 compressed image, 7%: 1 : 14 compressed image, 5%: 1 : 20 compressed image

Table 3. The area under ROC curve (Az) for original image and each compressed image for proximal caries detection

	Digora				Digitalized film			
	Original	10%	8%	7%	Original	10%	8%	7%
Observer 1	0.70	0.62	0.62	0.54	0.62	0.60	0.57	0.56
Observer 2	0.69	0.67	0.66	0.65	0.60	0.59	0.58	0.57
Observer 3	0.64	0.60	0.57	0.53	0.62	0.58	0.57	0.53
Mean	0.68	0.63	0.62	0.57	0.61	0.59	0.57	0.55

Data compression is the process of reproducing information in a more compact form. And people compress data to save space in a hard disk and to decrease data transmission time over a network or phone line.

Usually data compression algorithms remove repeated and/or irrelevant information from the original data whether in the lossless or lossy method.

In the equation X $X_{compressed}$ Y, X is the original data and $X_{compressed}$ is the data after compression, and Y is the data decompressed. After lossless compression, Y is identical to X. But, after lossy compression, Y is not exactly X, because some bits have been lost.[14] Lossy compression has one big advantage over lossless compression; lossy generally allows for higher compression ratios.

Lossless compression (for example, LZW) scheme is operated with dictionary technique. This algorithm identifies strings of repeated symbols and stores a code instead of the string. For example, the LZW is a patented lossless packing routine that may be considered a standard for GIF (Graphics Interchange Format) and TIFF (Tagged Image File Format) images.

Otherwise lossy compression scheme is operated with transform coding technique ; this technique divide the source data into parts or blocks and the individual blocks are compressed using whatever method is most applicable. The lossy version of the public domain is JPEG image standard. And JPEG lossy images are transformed, quantitized and Huffman coded in order to achieve a high rate of compression.

When a image file compressed by lossy compression method, the major artifacts are a result of the mismatching of the low-frequency components of the image at the edges of the blocks. Except in areas of very large dynamic changes, when the low frequencies are removed from consideration by subtracting the low-frequency components, the artifact disappear. And the eye is less sensitive to noise at the high frequency, permitting coarser quantitization at the higher frequencies, accomplished by frequency weighting the transform coefficients. This process was included in the JPEG lossy compression. Hence JPEG lossy compression format takes advantage of the way the human mind perceives visual image, and loses data that humans wont miss. This process of losing the bits that humans don't need to see is called 'perceptual coding'.[1,15]

Wavelet lossy compression has better compression quality at constant compressed file size compared with JPEG.[16] And Aware wavelet compression has better image quality than Pegasus wavelet or JPEG at similar compression level. But, DICOM(Digital Imaging and Communication in Medicine) standard not yet include wavelet as recognized because of expensive software licenses and introduction of proprietary elements in the standard. JPEG standard is not. Therefore we used the JPEG standard compression method on our present study.

In the field of medial radiology, Sneiderman[17] found that dermatologist's performance in diagnosing skin lesions on digitalized color images not to be affected by the level of 1 : 40 compression. Good[18] showed that mammograms could be compressed to 1 : 15 before experts were able to notice a difference in a image. McMahon[4] evaluated a form of adaptive block cosine transform coding, this new compression technique allows considerable compression of digital radiographs with minimal degradation of image quality and suggested that a compression ratio as high as 1 : 25 has been found acceptable for primary diagnosis in digitalized chest radiographs. Also they suggested that, with this compression scheme, compression ratios as high as 20 : 1 may be acceptable for primary diagnosis in digitalized chest radiographs. Jonathan[24] suggested that digital angiography at 1 : 15 compression level, with optimized compression algorithm, could be acceptable.

Also, in dental field, many studies for digital image compression have been performed. Wenzel et al.[8] evaluated storage needs, subjective image quality, and accuracy of caries detection in digital radiographs being compressed to various levels (approximately 20%, 8%, 5%, and 3%, respectively of the original storage space) by a lossy compression methods. They suggested that for caries diagnosis, compression rates of 1 : 12 can be justified before accuracy and image quality is significantly affected. And one study suggested that the subsequent loss of information in 1 : 25 lossy compression does not restrain the diagnostic quality of the images for the diagnostic task of assessment of endodontic file length in intraoral digital radiographs.[10] And van der Stelt et al.[7] showed that sensitivity was constant for all diagnostic tasks irrespective of the compression rate and specificity was very high for all compression factors, but slightly reduced for some lesion types at 1 : 10 compression rates and higher. And they showed that a considerable file size reduction can be obtained using the JPEG compression algorithm and a reduction of file size by more than 90% seems not to hamper the diagnostic quality of the images.

On the other hand, Wenzel et al.[9] evaluated the diagnostic accuracy of caries detection with four intraoral digital radiographic system (Digora, RVG, Sens-A-Ray, and Visualix) *in vitro* and investigated the impact of image compression. The four digital imaging systems evaluated almost equally well for the detection of occlusal and proximal carious lesions. Image compressed to 8% of their original storage requirements were no less accurate than their originals.

Generally, there is always some noise in radiographs. The sources of noise in a digital system include quantum noise, electronic noise, sensor noise, and quantitization noise (from converting analog-to-digital to indirect digital). Commonly, Spatial resolution as well as both the total number of densities and their dynamic range of densities are reduced during digitization. It is also possible that noise is generated when the radiograph is transferred electronically to a remote site.

Ohki et al.[19] pointed out that the digitization process may make the distinction of subtle changes in the tooth structure more difficult, being a potential source of image degradation.

On our study, the applied exposure time for this experiment was selected individually for each system, to provide adequate image density, because of these noises within the images may reduce the diagnostic accuracy. This results in images with little quantum noise.[20,21] But we did not exclude electronic noise and sensor noise, and quantization noise. With result from our study, sensitivity and specificity, and Az value of the digitalized images from conventional film are lower than those of the Digora digital images. We think that this result is due to containing more noise components within digitalized images from conventional films.

On the other hand, Janhom et al.[22] attempted to determine the effect of noise on the compressibility and the diagnostic accuracy for caries detection of digital bitewing radiographs. The compressibility of the images decreased as the noise level increased. And no significant difference between the original and compressed images within the same noise level. JPEG compression at 1 : 14 level can be used without significant deterioration in diagnostic accuracy. Compression at this level seemed to reduce the effect of noise to some extent. This is due to one of the effects of the JPEG algorithm on the image quality, namely noise reduction. The JPEG algorithm at a low level of compression will typically discard some of the high frequencies that contain noise. This results in less noise in the decompressed image without any crucial loss of diagnostic information. Therefore we think that this effects affected compression of digitalized images in our study and some positive compensation make in the compressed images from digitalized original image (from conventional films).

Noise also influenced the reported depth ; however, as it predicted this had little effect for the large lesions. The tooth samples used in our study almost dentinal caries and we think that noise had little effect in this aspect.

Diagnostic quality of digora image and conventional film (include digitalized image) radiography is of no value for detection of initial (enamel) occlusal lesions. One report found the digital systems to perform less accurately than film for initial caries. Whereas a radiolucency in dentin is recognized as good predictor for demineralized dentin.[23]

And no difference was found between the digital imaging technique and conventional imaging techniques from Medline database between 1988-1995.[24]

Wenzel[15] suggested that, for the detection of proximal dentinal lesions, sensitivities and specificities and the predictive values of radiographic methods are fair (0.6-0.8), but they are poor, however, for the detection of lesions validated to be confined to the enamel as occlusal lesions.

In general, digital intraoral radiography seems to be as accurate as current dental films for the detection of caries. And usually digital intraoral radiography seems to be as accurate as current dental films for the detection of caries. Sensitivities are fairly high (0.6-0.8) for detection of occlusal lesions extending into dentin with false positive fraction of 5-10 %.

Film radiography provided the best predictive value of a positive test and likelihood ratios and a high specificity for the overall detection of dentinal caries. However, it provided a poor sensitivity for the detection of deep caries in dentin. Digital radiography, on the other hand, detected over 70% of the deep lesions, without giving rise to more false-positive diagnosis in truly caries free teeth.[25] And it is now accepted that caries diagnosis is more dependent on intra-tissue contrast in the image than on resolution.[15,26]

Some authors suggested that assessment of conventional radiographs increased the true-positive detection rate for all observers to approximately 40%. Examination of digitalized radiographs resulted in a true-positive detection rate of approximately 60%.

Wenzel[9] and Hintze[27] suggest that original images taken by the Digora phosphor plate provided diagnostic accuracy as good as or better than other digital systems and film. Direct digital imaging continues to gain acceptance in dentistry. However, all the commercial systems currently available have as a limitation inferior spatial resolution compared with radiographic film. Spatial resolution has been reported to vary from 6 to 10 line pairs per millimeter (l p/mm) depending on the digital system. Whereas film is up to 20 lp/mm. But the effect of resolution on observer performance is equivocal. And in a recent study that used simulated enamel lesions, it was reported that film out performed a photostimulable phosphor (PSP) digital system.[17] In one study, there was no significant difference in performance between the digitalized images, which had a resolution of 8 lp/mm and the original film images, which have a resolution greater than 14 lp/mm.[28]

Espelid et al.[29] showed that on average, all the big proximal dentinal lesions and approximately 54% of the small proximal dentinal lesions were correctly diagnosed in dentin by the radiographic examination. And they examined the quality of radiographic diagnosis of occlusal dentinal lesion. There was wide variation in the ability to identify dentinal caries correctly between the observers; the sensitivity values ranged from 0.77 to 1.0 (mean 0.90) and the specificity values from 0.45 to 0.93 (mean 0.76). The tendency to make false-positive diagnosis in the dentin adjacent to enamel seems to be a major problem in radiographic diagnosis of occlusal caries.

Mileman and Weele[30] described that the accuracy of Dutch general dental practitioners using bitewing radiographs for the diagnosis and treatment of proximal caries in dentin. On their result, sensitivity was 54% and specificity was 97%.

The result from our study is that on occlusal caries diagnosis, mean sensitivity is 77% and 67%, and mean specificity is 96% and 81%, respectively Digora image and digitalized image. And on proximal caries diagnosis, mean sensitivity is 86% and 76%, and mean specificity is 94% and 93%, respectively Digora image and digitalized image. No significant differences between many previous reports and our results. On the basis of this, evaluation for the diagnostic accuracy and further compression level was performed.

Diagnostic accuracy for proximal caries detection was not significantly different for conventional film or desktop monitor and laptop displays for the detection of enamel caries or dentinal caries.[17,30]

Lederberg et al.[17] showed that significant differences between observers, lesion size, examiner/monitor interaction and examiner block interaction. However, no significance was found between monitors. Therefore they suggest that observer performance is independent of the visual characteristics of the display monitors.

A recent study has shown that the odds for detecting mechanically created lesions are 1.4 times greater than those for natural lesions.[31] Therefore, in order not to overestimate the accuracy of radiography, human teeth with natural lesions are preferable in experimental studies. Hence we used natural carious teeth of human in our study.

The radiographic scores were histologically validated as described in detail in several study.[15,21,32-34] Eventually a validation existed for 24 occlusal and proximal surfaces. For the occlusal surfaces, the disease prevalence was 83% (enamel lesion 40%, lesion extending to DEJ 10%, dentinal lesion 50%) whereas for proximal surfaces, it was 45.8% (dentinal lesion 100%).

In order to test for accuracy, the outcome of the diagnostic method must be evaluated against the true diagnosis. The true diagnosis should be obtained by a separate method which fulfils three criteria : (1) It should be established by a method that is precise; (2) It should reflect the patho-anatomical appearance of the disease; (3) It should be established independently of the diagnostic method under evaluation.

Stereomicroscopy was the most reliable method of validation as none of the unerupted sound teeth were scored as falsely positive, while at the same time more positive scores were made in the erupted teeth.[35] Stereomicroscopy of sectioned teeth is therefore recommended for validation in studying the accuracy of caries diagnosis.

Many authors compared the effect of the choice of gold standard on the diagnostic outcome of approximal caries detection in original and compressed digital radiographs.[32-34] They use the observer score in the original and compressed images as gold standard and diagnostic accuracy either increased or unchanged in compressed images than in original images. It is illogical that accuracy should increase in degraded images. Therefore, they suggested that the use of terms like silver standard to justify using observers to validate calculations of diagnostic accuracy should be abandoned as they only confuse the findings.

Classically, histology has been used to validate caries diagnosis, because it is more accurate than visual examination. However this validating method is not an absolute true diagnosis or gold standard, and this technique identify demineralization only.

The radiographic diagnoses have been analyzed according to the ROC technique.[36,37] ROC curves described the relationship between true-positive scores which are the positive caries diagnosis corresponding to the actual carious lesions and false -positive scores which are sound surfaces diagnosed on the radiographs as having caries. And ROC curves compare the performance of diagnostic technology and diagnostic algorithms. Therefore, ROC analysis is widely used to evaluate diagnostic performance. Sensitivity is highly dependent on specificity, therefore the use of Receiver Operating Characteristic (ROC) analysis, which evaluates sensitivity and specificity simultaneously, has been advocated for use in diagnostic studies in dentistry.[38] As it is independent of observers decision strategies, an ROC curve provides a more complete and easily assessible picture of the accuracy of a diagnostic method. An ROC curve provides a concise description of trade-off available between sensitivity and specificity. The area under an ROC curve, denoted Az when the ROC curve is fitted with the conventional binormal model. The value of the Az index can be interpreted as the average value of sensitivity over all possible values of specificity (between 0 and 1) or alternatively, as the average value of specificity over all possible values of sensitivity (between 0 and 1). And the quality of the diagnosis was measured by the area under the ROC curve (Az).

When dichotomized caries scores were used, scores 4 and 5 were interpreted as positive caries diagnosis and scores 1, 2 and 3 as negative caries diagnosis.

The area under ROC curves (Az) can be obtained in three ways : (1) by the trapezoidal rule; (2) as output from the Dorfman and Alf maximum likelihood estimation program ; (3) from the slope and intercept of the original data when plotted on binormal graph paper. We calculated the areas under ROC curve using this trapezoidal rule.

On our study, the occlusal caries prevelance was 83% (enamel lesion 40%, lesion extending to DEJ 10%, and dentinal lesion 50%), whereas the proximal caries prevalence was 45.8% (dentinal lesion 100%). And on our result, Az values have relatively low values, it is thought that the evaluated tooth surfaces, including no carious lesions and enamel lesions, were rated 'definitely absent (scale 1)' or 'probably absent (scale 2)' and these data were effected to calculate Az values and, as a result, Az values have low values.

Considerations such as costs and discomfort and risk to the patient are frequently ignored in the evaluation of the value of a diagnostic test.

Diagnostic accuracy with digital radiography was equivalent to that of conventional radiography (but there were variations depending on the type of examination). And no significant tendency to reduced procedure times for all examinations. Working conditions improved, including greater availability for the patient, improved safety, and increased job interest. And showed reduction in the cost of film for examinations analyzed when digital radiography used instead of conventional radiography. For all the examinations, digital radiography reduced film consumption, waiting times and procedure times, although additional annual cost was generated by the purchase of a digital radiography.

Teleradiology system could provide advantages to the dentist as well as dental radiologist.[14,18] First, immediate availability of radiographs could be markedly improved by transmitting and storing permanent radiographs in the office. These electronic images take less space and thus are more easily stored. Second, electronic transfer of images may markedly facilitate consultation with other radiologists and specialists.

Timothy et al.[14] appraised that the accuracy of interpretation of the radiographic findings from the transmitted image compared with the actual plain film. There is no statistical difference between the interpretation of the plain film and the digital image was revealed.

In the medical field, the JPEG routine has been shown suitable for introduction into PACS (picture archiving and communication systems) and ISDN (integrated services digital network) with very fast response time as a result.

And digital transmission of dental radiographs has previously been used in telediagnostics and remote education.[39] With true digital imaging in the dental office, compression may be part of image communication.

The larger file size is, the longer transfer time of images, and may result in unacceptable transfer times over available telephone lines when information is needed immediately. Hence image compression methods have been applied to image transmission procedures.

On the basis of our results, ADSL is more convenient to use than 56 kbps modem, and e-mail systems provide the convenience to the recipient of being able to open the transmitted files at leisure.

In addition, confidentiality of information can only be achieved between sites. When the image is received it would theoretically be possible for the recipient to send as many copies out to as many sites as they wished, but this is not different for conventional films that can be copied using duplicate film. And also encrypting on digital images are possible. Therefore, digital image is more confidential than conventional film.

Particular attention should be paid to the relation between *in vitro* and *in vivo* test results from one and the same diagnostic test. Unless a perfect simulation of a patient is achieved in the *in vitro* model, translation of the results into the clinical situation will not be straightforward. And should remember that the acceptance level of compression is task-dependent selecting only one compression level is probably not suitable for all diagnostic tasks.

Further study must be directed to improve the resolution when needed, image compression rate maintaining diagnostic quality, decrease image transfer time, ensure patient confidentiality, and train dentists to become comfortable with this new frontier of medicine.

In Conclusion, the optimum compression rate for both the occlusal and proximal caries was 1 : 14. And it is thought that 1 : 14 compressed image files can be substitute for original image files for the detection of dental caries in dental fields.

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