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Clinical Image Quality Assessment in Panoramic Radiography

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ÖZET

Panoramik radyografide kalite değerlendirmesi

Amaç: Bu çalışmada elde edilen panoramik radyografilerin kalitesinin değerlendirilmesi ve tanı için yetersiz görüntülere neden olan hataların tespiti amaçlanmıştır.
Yöntem: Çalışmada Oral Diagnoz ve Radyoloji AD arşivlerinde yer alan 150 adet panoramik radyografi incelenmiştir (Morita Veraviewwopcs model 550 ,Kyoto-Japan, en yüksek KVP of 80, mA=12, monitör 17 inç TFT LCD, 100-240 VAC 60/50 Hz, Global Opportunities). Bütün grafiler aynı radyografik ekipman ile yapılmıştır. Görüntüler JPEG (Joint Photographic Experts Group) dosyası olarak kaydedilmiş ve kontrast, parlaklık ve büyütme ve data kompresyonu açısından herhangi bir düzeltme yapılmamıştır. Elde edilen görüntüler iki maksillofasiyal radyoloji uzmanı tarafından Klinik Görüntü Kalitesi Değerlendirme Çizelgesi kullanarak değerlendirilmiş, panoramik radyografide genel görüntü kalitesi sınıflandırılmış ve görüntüleme hatalarının nedenleri incelenmiştir. Veri tablolama ve tanımlayıcı istatistik SPSS 15.0 yazılımı (SPSS Inc., Chicago. IL., USA) kullanılarak yapılmıştır.
Bulgular: Klinik Görüntü Kalitesi Değerlendirme Çizelgesi ortalama değeri 79.69±14.87 olarak ölçülmüştür. Görüntü kalitesinin skorlamasında 28 görüntünün tanısal bilgide en iyi görüntü kalitesine sahip olduğu, 80 görüntünün tanı için yeterli olduğu, 37 görüntünün tanı koyma açısından zayıf ama teşhis edilebilir olduğu ve 5 görüntünün tanı için yetersiz olduğu belirlenmiştir. Tüm görüntülerde izlenen hataların nedenlerinin analiz sonuçları şu şekildedir: 103 görüntüde konumlandırma hatası, 15 görüntüde işlem sırasında oluşan hata, 4 görüntüde ünite kaynaklı hata görülmüş ancak hiçbir radyografide anatomik abnormaliteye bağlı hata izlenmemiştir.
Sonuç: Panoramik radyografinin görüntüleme işlemi sırasında hasta konumlandırma tarafından kaynaklanan hatalar çalışmamızda en yaygın izlenen hata tipi olarak bulunmuştur. Ancak daha fazla hasta grubu ile farklı radyografik yöntemler kullanılarak görüntü kalitesinin değerlendirildiği çalışmalara ihtiyaç duyulmaktadır.
Anahtar sözcükler: Oral radyoloji, değerlendirme, görüntü kalitesi, panoramik radyografi, dijital görüntüleme

ABSTRACT

Clinical image quality assessment in panoramic radiography

Aim: This study was performed to assess the quality of panoramic radiographs obtained and to identify those errors directly responsible for diagnostically inadequate images.
Materials and Methods: This study consisted of 150 panoramic radiographs obtained from the Department of Oral Diagnosis and Radiology. All projections were made with the same radiographic equipment (Morita Veraviewwopcs model 550 (Kyoto-Japan) with the maximum KVP of 80, mA=12, monitor 17 inch TFT LCD, 100-240 VAC 60/50 Hz, Global Opportunities). The images were exported and saved in Joint Photographic Experts Group (JPEG) file and no adjustment of contrast, brightness and magnification was performed. Two oral and maxillofacial radiology specialist evaluated the images using the Clinical Image Quality Evaluation Chart and classified the overall image quality of the panoramic radiographs and evaluated the causes of imaging errors.
Results: The mean (SD)score was 79.69±14.87. In the classification of the overall image quality, 28 images were deemed 'optimal for obtaining diagnostic information', 80 were 'adequate for diagnosis', 37 were 'poor but diagnosable', and 5 were 'unrecognizable and too poor for diagnosis'. The results of the analysis of the causes of the errors in all the images were as follows: 103 errors in positioning, 15 in processing, 4 due to radiographic unit, and none of them was due to anatomic abnormality.
Conclusion: The positioning errors found on panoramic radiographs were relatively common in our study. The quality of panoramic radiographs could be improved by careful attention to patient positioning.
Key words: Oral radiology, assesment, image quality, panoramic radiography, digital imaging

INTRODUCTION

Since its introduction into the dental practise, panoramic radiography has become a popular and valuable diagnostic tool (1,2). A high quality panoramic radiography has been used for routine screening of patients at various institutions and private clinics because it allows examination of the entire dentition, alveolar bone, temporomandibular joints,

and adjacent structures easily (3,4). All radiation exposures must be kept as low as reasonably achievable (ALARA) while having all kinds of radiographs including panoramic radiography. This could be achieved in three ways, using physical methods of minimizing dose, applying selection criteria, and consistently producing high quality radiograph to avoid repeat exposure (5).

A non-diagnostic quality image often requires a need for supplementary images and a repetition of examinations (6,7). A non-diagnostic quality image which leads to repetition is a result of errors made by the operator during patient positioning and processing of the image (8-11). Also, there are a number of factors inherent to panoramic radiology, not applicable to intraoral imaging, which reduce its diagnostic quality and which should be considered when examining its diagnostic value. These include the limitations imposed by the film/screen/cassette combination, tomographic blur, superimposed soft tissue and 'ghost' shadows, the overlap of adjacent teeth and variations in magnification (5).

Among the various types of image quality evaluation, clinical imaging evaluation is the most important inspection that enables actual and comprehensive evaluation since it reflects the entire quality assurance process, and it must be performed continuously (11,12). Choi et al. (11) investigated the image quality of panoramic radiographs taken at dental hospitals and clinics across Korea using a Clinical Image Quality Evaluation Chart. As no appropriate guideline on quality control has been prepared in Turkey, we investigated the level of clinical image quality for panoramic radiographs and to provide a basis for clinical image evaluation by using very few differences on this Clinical Image Quality Evaluation Chart. The aim of this study is to determine and evaluate the frequency of common errors that could happen in panoramic imaging and to identify the causes for these errors in order to eliminate them to reach the most diagnostic perfectibility.

MATERIALS AND METHODS

150 panoramic radiographs that were taken between December 2012 and February 2013 were obtained from the archives of the Department of Oral Diagnosis and Radiology, Marmara University Faculty of Dentistry. All the radiographs were of patients referred from various departments for clinical and diagnostic purposes. All projections were made with the same radiographic equipment (Morita Veraviewopcs model 550 (Kyoto-Japan) with the maximum KVP of 80, mA=12, monitor 17 inch TFT LCD, 100-240 VAC 60/50 Hz, Global Opportunities) and all radiography were carried out by the same technician. The images were exported and saved in Joint Photographic Experts Group (JPEG) file and no adjustment of contrast, brightness and magnification was performed; and all the images were reviewed under identical conditions on the computer screen.

Training of clinical image evaluators and clinical image evaluation using a clinical image quality evaluation chart

To ensure a professional and efficient evaluation, two oral diagnosis and radiology clinicians working in the Department of Oral Diagnosis and Radiology evaluated the clinical images. During meetings for the pilot study, these two clinicians were trained to evaluate panoramic images, by a specialist who had been working in the Department of Oral Diagnosis and Radiology for more than fifteen years. An agreement on the objective criteria for the qualitative evaluation of the images was forged among the evaluators. We investigated the level of clinical image quality for panoramic radiographs using a slightly modified version of the Clinical Image Quality Evaluation Chart (Table 1) used by Choi et al. (11) at a study investigating the image quality of panoramic radiographs taken at dental hospitals and clinics across Korea.

The chart was used to evaluate the image quality of a panoramic radiograph while viewing the images; and if there was any inconsistency between their evaluations, an agreement was made through discussion. It was worked on during multiple meetings of evaluators.

After evaluating images using the forementioned chart the two clinician calculated the total score. The perfect score in the clinical image evaluation was 100 points. The image quality grade was classified into the following 4 grades:1. Optimal for obtaining diagnostic information (100-80), 2. Adequate for diagnosis (80-60), 3. Poor but diagnosable/unrecognizable (60-40), and 4. Too poor for diagnosis (40-0) (Figure 1,2,3).

The cause of the errors observed on the image was

Table 1: Clinical image quality evaluation chart

		Score	
1. Identification	**Name of patient Sex**	**yes**	**no**
2. Artifacts	Internal artifacts or artifacts of unknown origin: not present/present but don't interfere with diagnosis/ may interfere with diagnosis	4	2/0
3. Coverage area	Top: include the inferior border of the orbit	2	0
	Left: include outside of 0.5 mm to temporomandibular joint	2	0
	Right: include outside of 0.5 mm to temporomandibular joint	2	0
	Bottom: include underside of 0.5 mm to inferior cortical border of the mandible	2	0
4. Patient positioning	a) Occlusal plane: appropriate/flat/steep downward V-shape/ inverted V-shape	6	4/2/0
	b)Antero-posterior positioning: adequate/former or rear but diagnosis is possible/ unclear anterior portion	4	2/0
	c) Right-left symmetry: symmetry/the discrepancy is less than half of the width in M-D of mandibular 1st molar/ above half of the width in M-D of mandibular 1st molar	4	2/0
	d) Hyoid bone overlapped the mandible	4	0
	e) Patient movement (right and left): none of dual images	4	0
	f) Patient movement (right and left): none of disappeared images	4	0
	g) No soft tissue movement (evaluation of the soft palate, tongue and hyoid bone)	4	0
5. Density, Sharpness, image contrast	a) Distinguishable dentinoenamel junction: distinguishable/ almost distinguishable/indistinguishable in 2 of 6 of the regions/indistinguishable in 4 of 6 of the regions.	6	4/2/0
	b) PDL space and lamina dura: distinguishable/almost distinguishable/ indistinguishable in 2 of 6 of the regions/indistinguishable in 4 of 6 of the regions	6	4/2/0
	c) Accuracy of root shape: distinguishable/almost distinguishable/ indistinguishable in 2 of 6 of the regions/indistinguishable in 4 of 6 of the regions	6	4/2/0
	d) Metal artifact: distinguishable with secondary caries/indistinguishable	4	0
	e) Extent of the proximal overlap: overlapped under the DEJ/over the DEJ	4	0
	f) Homogeneity of the background density: homogeneous/heterogeneous	4	0
	g) Distinguishable alveolar crest in alveolar bone: distinguishable/almost distinguishable/indistinguishable in 2 of 6 of the regions/indistinguishable in 4 of 6 of the regions	6	4/2/0
	h) Distinguishable trabecular pattern in alveolar bone: distinguishable/ almost distinguishable/ indistinguishable in 2 of 6 of the regions/ indistinguishable in 4 of 6 of the regions.	6	4/2/0
	i) Regional contrast-TMJ area	4	0
	j) Regional contrast-maxillary sinus	4	0
	k) Regional contrast-mandibular area	4	0
	l) Noise: not present/present	4	0
Total Score		100	
6. Cause of the error	Positioning errors during the radiograph taking (patient preparation, position of the mandible and maxilla, patient movement, and angle of the cervical spine)		
	Errors from the radiographic unit and other mechanical error accessories (irregularity of the exposure roller and error of the sensor and reader)		
	Pre- and post-processing errors (enhancement errors, noise, and abnormal density and contrast)		
	Errors due to anatomic abnormality (malformation of the mandible and maxilla, and congenital dental anomaly)		

determined and marked. The errors were classified into one of the following class: positioning errors during radiography (patient preparation, position of the mandible and maxilla, and angle of the cervical spine); errors from the radiographic unit and other mechanical errors (irregularity of the exposure roller and error of the sensor and reader); pre- and post-processing errors (enhancement errors, noise, and abnormal density and contrast); and errors due to anatomic abnormality (malformation of the mandible and maxilla, and congenital dental anomaly). Data tabulation and analysis was processed using SPSS 15.0 software (SPSS Inc., Chicago. IL., USA).

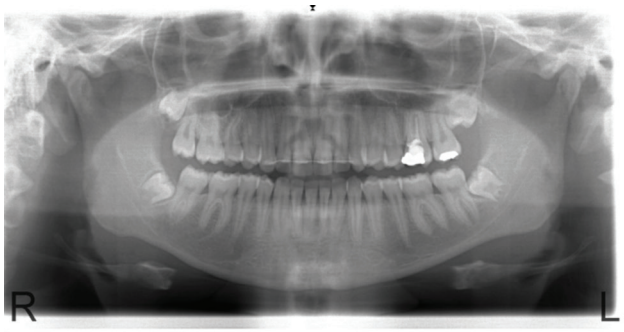

Figure 1

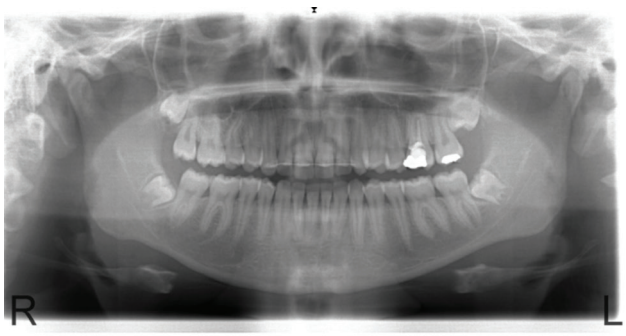

Figure 2

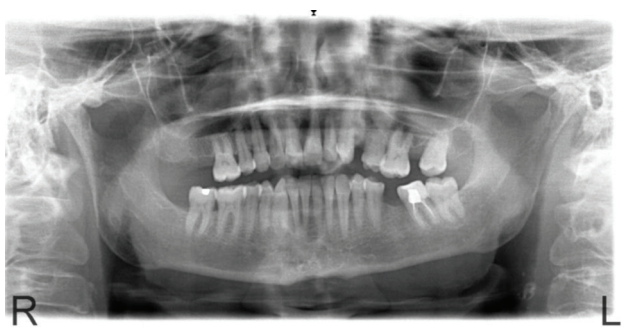

Figure 3

Table 2: Image quality grade classification

Image quality grade classification	n	%
Unrecognizable, too poor for diagnosis	5	3.3
Poor, but diagnosable	37	24.7
Adequate for diagnosis	80	53.3
Optimal for obtaining diagnosis information	28	18.7

Table 3: Causes of errors

Causes of errors	n	%
Positioning errors	103	84.4
Errors from the radiographic unit and other mechanical errors	4	3.3
Pre- and post-processing errors	15	12.3
Errors due to anatomic abnormality	0	0

RESULTS

There were 63 radiographs of male, 87 of female patients. The age range of patients was 7 - 83 years. The mean (standard deviation (SD)) age was 32.57±17.81 years.

In the classification of the overall image quality by the two evaluators, 28 images were deemed 'optimal for obtaining diagnostic information', 80 were 'adequate for diagnosis', 37 were 'poor but diagnosable', and 5 were 'unrecognizable and too poor for diagnosis'. Seventy-two percent (n=108) of the images were rated 'optimal for obtaining diagnostic information' or 'adequate for diagnosis' (Table 2). Twenty-eight percent (n=42) of the images were 'poor but diagnosable' or 'too poor for diagnosis'.

The results of the analysis of the causes of the errors in all the images were as follows (Table 3). There were 103 errors in patient positioning; 15 errors in processing such as an abnormal density, contrast, and resolution; 4 errors due to the radiographic unit and other mechanical problems; and none due to anatomic abnormality. The total number of errors was not the same as the total number of images; because some had no errors at all and some had multiple errors such as "artifacts caused by external and internal factors (3.3%), patient movement (2.7%), superposition of shadows of soft tissues and surrounding air (62.7%) or hard tissues (24.7%).

The most common errors encountered in the images which were 'optimal for obtaining diagnosis information' were minor errors in positioning but these errors did not affect the quality of the images as much as they did in the other groups. The most common errors in the images which were 'adequate for diagnosis' and 'poor but diagnosable' were errors in positioning, followed by processing errors and the mechanical errors of the radiographic unit. The most common errors in the images which were 'unrecognizable, too poor for diagnosis' were errors in positioning and nonetheless there were errors in patient movement, superposition of soft or hard tissues (Table 4).

The mean of the scores given by two clinicians according to the Clinical Image Quality Evaluation Chart was

Table 4: Causes of errors according to image quality grades in each group

Image quality grades	Causes of errors		
	Positioning errors n (%)	Errors from the radiographic unit and other mechanical errors n (%)	Pre- and post-processing errors n (%)
Unrecognizable, too poor for diagnosis	2 (%1.9)	0 (%0)	1 (%6.7)
Poor, but diagnosable	9 (%8.7)	1 (%25.0)	3 (%20)
Adequate for diagnosis	37 (%35.9)	2 (%50.0)	7 (%46.6)
Optimal for obtaining diagnosis information	55 (%53.5)	1 (%25.0)	4 (%26.7)
Total	103	4	15

Table 5: Representative values according to the overall image quality grade

	Min	Max	Mean	Std. Deviation
1	28	40	33.33	6.11
2	44	58	52.00	4.16
3	60	78	71.39	5.05
4	80	100	89.70	5.98
1+2	28	58	48.50	8.68
1+2+3	28	78	65.48	11.80
1+2+3+4	28	100	79.69	14.87

1: optimal for obtaining diagnosis information, 2: adequate for diagnosis, 3: poor, but diagnosable, 4: unrecognizable, too poor for diagnosis, min: minimum, max: maximum, std: standard

79.69±14.87 (maximum possible: 100), with the highest and lowest scores 100 and 28, respectively. The mean and representative scores of each group based on the overall image quality grade are shown in Table 5.

DISCUSSION

The value of a panoramic radiograph is reduced when it is of poor diagnostic quality. Low quality radiographs can lead to misinterpretation, resulting in incorrect diagnosis and treatment planning, and it also leads to the need for supplementary images exposing the patient to additional radiation doses (6,7,13). Given the 2007 recommendations of the International Commission on Radiological Protection (ICRP) which result in an upward reassessment of fatal cancer risk from oral and maxillofacial radiographic examinations, it is important that retakes must be kept at a minimum (14). Other consequences are increased cost and extended examination times. However, it has been shown that a considerable number of radiographs exposed in dentistry are of marginal or non-diagnostic quality (4,15).

The Guidelines on Radiology Standards for Primary Dental Care set quality standards for dental radiography, defining the terms 'excellent', 'diagnostically acceptable', and 'unacceptable'. The basic standard was that the rate of 'unacceptable' radiographs should not exceed 10% and not less than 70,0% 'excellent' (fault-free) films was also suggested (16). In our study we investigated the image quality of panoramic radiographs using the Clinical Image Quality Evaluation Chart, where the images were also classified into four grades, and 72% of the images had an acceptable or optimal quality. In contrast to our study, Choi et al. (11) who investigated the image quality of panoramic radiographs taken at at local dental clinics, found out that 59% of the images had a normal or higher-level image quality. Akesson et al. (17), reported lower image quality in panoramic radiographs obtained from various external clinics than radiographs taken in hospital environment. In each of these two studies samples were collected from external clinics and the patient positioning was not uniform during the image taking; the radiology technicians were not same; and this situation could led to differences in error frequencies. Nonetheless different machines with varying ages were used to produce the radiographs in previous studies and radiographs produced with older machines might increase error rates because of the extended usage of the focal through in

such a case recalibration could be needed (18). Similar to our study, Dhillon et al. (19) assessed the quality of panoramic radiographs in a sample of records collected from a dental college and found out that 75.1% were diagnostically acceptable and optimal.

The radiographs evaluated in the present study were gathered from patient documents that were requested from other clinics for radiographic examination in our department. During the time period when the radiographs were being taken, the department technician was permanent and unaware of this study so the samples may be regarded as representative of everyday radiograph quality. The most common error in our samples was incorrect positioning of the patient, and it was followed by pre-processing and radiographic device errors. On panoramics, the most frequent faults were in patient positioning, and in density and contrast; this finding complied with the findings of Brezden and Brooks et al. (20) and Akesson et al. (17). Likewise, in a large sample of panoramic radiographs, Rushton et al. (8) found that errors in patient positioning and faults in film density and contrast most frequently contributed to diagnostic inadequacy of films. Schiff et al. (21) evaluated a variety of films taken by dental students, faculty members and technicians in a hospital environment. They found that 80% of radiographs showed some degree of fault; the number of faults being reduced to 53% by using only one and trained technician to position all patients. In this study superposition of shadows of soft tissues and surrounding air (62.7%) during exposure was also common.

Superimposition of this shadow results in difficulty in interpretation of the periapical region of maxillarry teeth. The possible explanation for this error might be a lack of communication of the dental technicians instructing the patients to swallow and to keep the tongue on the roof of the mouth. Another explanation was that the patients sometimes could find it difficult and might misunderstand the instructions given by the technician. This result was in concordance with the results obtained in the studies performed by many other investigators (8,22). Therefore, following technical points is also fairly important when a panoramic radiograph is taken: (1) The patient should be seated or should stand fully upright, with the head immobilized, utilizing a chin rest and a radiolucent bite block. (2) Spectacles, neck chains, earrings, and dentures must be removed before the exposure. (3) The patient should place the tongue against the palate during the exposure in order to prevent a radiolucent stripe above the maxillary teeth. (4) Because of the relatively long exposure, the machine movement should be explained to the patient to ensure cooperation especially with children (23). Despite all the proper instructions, sometimes optimal positioning of the patients for imaging could not be achieved due to the facts that either patients were unable to follow the instructions or they had abnormal physical structure, swelling/growth, facial asymmetry. In such cases, panoramic scanning errors are mostly inevitable, however, in our study, there was not any error caused by an anatomic abnormality.

Our study faces some limitations: the sample size was relatively small and images with different age groups have been evaluated. Studies on a larger population, with a patient group aged >18 are needed to enhance the strength of the results. Nevertheless, our findings point out important issues of panoramic radiography procedure. Also further studies on the quality of panoramic radiographs of children would be interesting, as many panoramic films are taken for ortohodontic purposes and concerns over radiation protection are much more important in children.

In conclusion, there are numerous factors only pertinent to panoramic radiography, which can reduce the diagnostic quality of radiographs. The panoramic radiographs taken at our department generally have a normal or higher level image quality. Therefore, when images are taken, patient position should be adjusted with great care. In light of the literature, it can be suggested that operator skill, better communication with the patient, and spending time in patient positioning could decrease the number of errors and help produce high quality radiographs. Using a clinical image quality evaluation chart which helps identification of faults and what caused them, would contribute to individualising quality control measures.

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