The Effect of Filters to Subjective Image Quality in Different Dental Regions in Digital Panoramic Images

Dijital Panoramik Görüntülerde Filtrelerin Farklı Dental Bölgelerdeki Subjektif Görüntü Kalitesine Olan Etkisi

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ABSTRACT Objective: The aim of this study was to compare the effect of different filters on subjective image quality of the alveolar crest and periapical region of maxillary and mandibular teeth on direct digital panoramic images. **Material and Methods:** Direct digital panoramic images taken from 56 patients with the Orthoralix 9200 DDE (Gendex Dental Systems, Milan, Italy) panoramic unit who required panoramic radiographic investigation. The original images were filtered with the emboss, structure enhance, sharpen and smooth filters. The subjective image quality of the alveolar crest and periapical regions of the anterior, premolar and molar teeth were assessed on the original and filtered images according to a scale. The intra-and inter-observer agreement levels were analyzed with the weighted kappa test. Any difference in the subjective image quality of the original and filtered images was analyzed with one-way ANOVA and Dunnett's t-test. **Results:** For all assessments the intra-observer reliability was found to be almost perfect. The subjective image quality of digital panoramic images differed according to filter type and examined dental region. In general, the application of the emboss and structure enhance filters led to a significant increase in subjective image quality in the most of the examined dental areas while the smooth and sharpen filters did not show a similar effect. **Conclusion:** The effect of filtering on the subjective image quality of direct digital panoramic images differed according to filter type and dental region.

Key Words: Radiography, panoramic; radiography, dental, digital; image processing, computer-assisted

ÖZET Amaç: Bu çalışmanın amacı direkt dijital panoramik görüntülere farklı filtreler uygulanmasının maksiller ve mandibular bölgedeki dişlerin alveolar kret ve periapikal bölgelerindeki subjektif görüntü kalitesi üzerine olan etkisinin incelenmesidir. **Gereç ve Yöntemler:** Çalışmada panoramik radyografik değerlendirme gerektiren 56 hastadan Orthoralix 9200 DDE (Gendex Dental Systems, Milan, İtalya) panoramik cihazı ile direkt dijital panoramik görüntüler çekildi. Daha sonra orijinal görüntüler kabartma, yapıyı artır, keskinleştir ve yumuşat filtreleri ile filtre edildi. Bu görüntüler üzerinde de maksiller ve mandibular anterior, premolar ve molar dişlerin alveolar kret ve periapikal bölgelerinin subjektif görüntü kalitesi bir skalaya göre değerlendirildi. Gözlemci içi ve gözlemci arası uyum düzeyleri ağırlıklı kappa testi ile analiz edildi. Orijinal ve filtre edilmiş görüntülerdeki subjektif görüntü kalitesi arasında herhangi bir fark olup olmadığı da tek yönlü ANOVA ve Dunnett's t-testi ile analiz edildi. **Bulgular:** Tüm değerlendirmeler için gözlemci içi uyum hemen hemen mükemmel olarak bulundu. Dijital panoramik görüntülerde subjektif görüntü kalitesi farklı dental bölgelerde uygulanan filtre tipine göre değişkenlik gösterdi. Genel olarak, hemen hemen tüm dental bölgelerde kabartma ve yapıyı artıran filtrelerin uygulanmasının subjektif görüntü kalitesini orijinal panoramik görüntülere göre anlamlı olarak artırdığı, buna karşın keskinleştir ve yumuşat filtrelerin aynı şekilde bir etkisinin olmadığı bulundu. **Sonuç:** Filtre uygulanmış dijital panoramik görüntülerde subjektif görüntü kalitesinin incelenen dental bölge ve kullanılan filtre tipine göre değişkenlik gösterdiği saptandı.

Anahtar Kelimeler: Radyografi, panoramik; radyografi, dental, dijital; görüntü işleme, bilgisayar destekli

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Panoramic radiography is a widely used radiographic technique for radiographic imaging of pathologies.[1] Besides its advantages, such as providing radiographic data of the maxillary and mandibular teeth on a single image and giving radiodiagnostic data at patients who could not tolerate intraoral radiographic examination,[2] it presents some diagnostic limitations due to insufficient image quality in specific dental areas resulting from artifacts and ghost images.[3] These limitations could be caused by the redundant shadows of the mandibular ramus (on the opposite site of the molar teeth and ramus regions), cervical vertebrae (on the anterior teeth region) [4,5] and overlying bone on the maxillary molar region (leading to low contrast in the periodontal ligament space region in molar teeth region).[3]

Digital imaging systems have some advantages compared to conventional techniques as they are obtained as numeric data. One of these advantages is image processing which helps the practitioner to make modifications on the images.[6-9]

Diagnostic image quality of digital panoramic images could be changed in areas having insufficient image quality due to superimposition of surrounding structures with the aid of various filters present on specifically written software's.[3]

The Orthoralix DDE 9200 (Gendex Dental Systems, Milan, Italy) is a direct digital panoramic machine working with a digital imaging software named VixWin pro (Gendex Dental Systems) allowing the practitioner different filters for image enhancement. As redundant shadows and ghost images could decrease the image quality in some of the dental regions and the system (Orthoralix DDE 9200,Gendex Dental Systems, Milan, Italy) offer various filters giving the opportunity of making modifications on the image, the aim of the study was to assess the effect of different filters (VixWin pro software, Gendex Dental Systems) on the subjective image quality of the alveolar crest and periapical regions of the maxillary and mandibular anterior, premolar and molar teeth.

MATERIAL AND METHODS

PATIENT SELECTION CRITERIA

Fifty six patients attending to the Oral Diagnosis and Radiology department of a dental school (30 females, 26 males, age range 18-55 years) requiring digital panoramic radiographic investigation who had no missing posterior and canine teeth in all quadrants (except third molars) were included in the study.

IMAGE INTERPRETATION

Direct digital panoramic images were taken with the Orthoralix 9200 DDE (Gendex Dental Systems, Milan, Italy) machine by one trained radiologist to prove radiographic consistency. The exposure parameters were set as 74-78 kVp, 4-10 mA, 12 sec according to the manufacturer's recommendations for patient size in order to maintain consistent radiographic density during image interpretation. The images were taken at 16-bit gray scale levels and saved as TIFF files.

Four different filters, consisted of emboss, structure enhance, sharpen and smooth, present in the VixWin pro digital imaging software (Gendex Dental Systems version 1.5) were applied to the original images separately. The emboss filter is a filter providing a simulated three dimensional (3D) image, the structure enhance filter evidences morphological structures by enhancing the edges, the sharpen filter (a high pass spatial filter) enhances the edges with an increased grainy appearance and the smooth filter (a low pass spatial filter) provides a smooth blurring on the image. The filtered images were exported in TIFF through MS paint (Microsoft®Paint version 5.1 Microsoft Corporation, Redmond WA, USA) and saved in numbered files.

IMAGE EVALUATION SESSIONS

The images were displayed on a 17 inch Super VGA monitor, having 1024x768 pixels screen resolution at the fit screen size of the program. The contrast and brightness of the images were set to 100 and 0 respectively. The computer had an intel (R) Pentium (R) with 256 MB RAM. The operative system of the computer was Windows XP (Microsoft, version 2002).

A panel which consisted of three trained maxillofacial radiologists were asked to score the subjective image quality of the alveolar crest and periapical region of the maxillary and mandibular anterior, premolar and molar teeth according to a 4-point rating scale following as: 1-significant structures are not visible, 2-only board details could be seen, 3-small details could be visualized, 4-fine details could be visualized.[10] Cases in which score 1 was rated the reason for this score was noted. Before the viewing sessions, all observers were instructed on the definition of the rating scale and the structures which they were going to examine. The images were numbered and viewed separately in a randomized order during evaluation sessions. Each time one image was evaluated under subdued lighting at a viewing distance approximately 70 cm. One month after all of the evaluations were completed, 20 of the images were re-evaluated by all observers according the same criteria used in the initial sessions to assess intra-observer reliability.

STATISTICAL ANALYSIS

The intra-and inter-observer agreement levels were analyzed with the weighted kappa test. The scores rated for each images according to the rating scale were converted into numeric data as following: score 1: 1, score 2: 2, score 3:3 and score 4: 4. This allowed the analysis of the data with comparisons of the mean of the scores between the original and each filtered image. Any difference in the subjective image quality of the original and filtered images was analyzed with one-way ANOVA and Dunett's pairwise multiple comparisons t-test using the SPSS statistical package program (version 10.0 SPSS Inc.).

RESULTS

A total of 280 digital panoramic images consisted of 56 original and 224 filtered were evaluated.

INTRA-AND INTER-OBSERVER RELIABILITY

The weighted kappa values for intra-observer reliability were calculated as 0.89, 0.83, 0.95 for the first, second and third observer, respectively.

The weighted kappa values for inter-observer reliability between the 1-2, 2-3 and 1-3 observers were calculated as 0.86, 0.84 and 0.89, respectively.

INSUFFICIENT IMAGE QUALITY

The reasons given for insufficient subjective image quality were overlapping (92.3%), blurring (5.1%) and the combination of overlapping and blurring (2.8%) in the maxillary, and blurring (80%), overlapping (15.4%) and the combination of blurring and overlapping (4.6%) for the mandibular region.

SUBJECTIVE IMAGE QUALITY

In general, the highest subjective image quality scores of the original images were calculated for the periapical region of mandibular molar and lowest for the crest region of maxillary premolar teeth.

All of the filters did not lead to a significant increase in subjective image quality of the crest region of anterior teeth for the maxillary arch. Only the emboss and structure enhance filters led to a significant increase in the periapical region of anterior teeth. None of the filters led to an increase in the quality of the crest region, while the emboss and structure enhance filters enhanced subjective image quality in the periapical region of the premolar teeth. The emboss and the structure enhance filters significantly enhanced the subjective image quality of both the alveolar crest and periapical region of the molar teeth. Details of data are shown in Table 1.

Similar to the results obtained for the maxillary arch all filters did not lead to an increase in subjective image quality of the crest and periapical region of the mandibular teeth. The emboss and structure enhance filters enhanced the quality in the crest region of anterior teeth, while a similar effect was not achieved with any of the filters for the periapical region. Only the emboss and structure enhance filters significantly increased the subjective image quality of the crest and periapical region of premolar teeth. Similarly the emboss and structure enhance filters lead to a significant increase in the alveolar crest region, but none of the filters significantly aided subjective image quality of both alveolar crest and periapical region of mandibular molar teeth. Details of data are shown in Table 2.

TABLE 1: Mean, one way ANOVA analysis and Dunnett's pairwise multiple comparisons t-test of the scores obtained for the maxillary alveolar crest and periapical region according to the ratings of three observers for the original and filtered digital panoramic images

		Original		Emboss		Enhance		Sharpen		Smooth		
		Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	One-way ANOVA
Maxillary Anterior	crest periapical	2.70	0.63	3.11*	0.76	3.16*	0.72	2.80	0.54	2.82	0.54	F=5.534, p=0.001
		2.45	0.54	2.97*	0.76	2.88*	0.73	2.59	0.56	2.59	0.58	F=9.740, p<0.001
Maxillary Premolar	crest periapical	1.94	0.90	2.26	1.17	2.27	1.20	2.15	1.09	2.19	1.12	F=1.243, p=0.292
		2.69	0.49	3.04*	0.69	2.98*	0.66	2.82	0.54	2.80	0.54	F=4.997, p=0.001
Maxillary Molar	crest periapical	2.67	0.46	3.09*	0.68	3.09*	0.68	2.76	0.50	2.78	0.51	F=9.699, p<0.001
		2.67	0.51	2.98*	0.66	2.90*	0.63	2.70	0.55	2.71	0.55	F=4.742, p=0.001

Note: * represents significant difference between means of the scores of the original and filtered images.
SD: Standart deviation.

Generally, the highest means of the rated scores for subjective image quality were obtained from images treated with the emboss and structure enhance filters. The sharpen and smooth filters did not lead to a significant increase in subjective image quality in any of the examined dental areas compared to the original image. Although all of the filters were different algorithms, the subjective image quality scored for the emboss-structure enhance and the sharpen-smooth filters were found to be similar.

DISCUSSION

The subjective image quality was found to be poor for the alveolar crest in maxillary premolar and periapical region of mandibular anterior teeth due to overlapping of teeth in the premolar and blurring in the anterior region. Other errors such as underexposure, overexposure, low or high contrast were not present because images having sufficient contrast and density were evaluated.

The subjective image quality of the original digital panoramic images was found to be high for the alveolar crest and periapical region of the mandibular molar teeth. We think the main reason for the high quality resulted from the difference in the curvature of the upper and lower jaw as the panoramic unit is programmed for the shape of the lower jaw, resulting in an adequate appearance of alveolar crest and periapical regions. Gijbels et al.[10] assessed the subjective image quality of digital panoramic images and reported the need of addi-

TABLE 2: Mean, one way ANOVA analysis and Dunnett's pairwise multiple comparisons t-test of the scores obtained for the mandibular alveolar crest and periapical region form the ratings of three observers for the original and filtered digital panoramic images

		Original		Emboss		Enhance		Sharpen		Smooth		
		Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	One-way ANOVA
Mandibular Anterior	crest periapical	2.54	0.86	3.11*	1.06	3.05*	1.02	2.77	1.01	2.79	1.02	F=4.515, p=0.001
		2.00	0.79	2.25	0.94	2.23	0.97	2.09	0.85	2.09	0.87	F=1.197, p=0.312
Mandibular Premolar	crest periapical	3.15	0.68	3.64*	0.67	3.61*	0.69	3.22	0.73	3.26	0.73	F=5.482, p=0.001
		3.32	0.51	3.57*	0.52	3.59*	0.54	3.40	0.51	3.41	0.51	F=4.199, p=0.002
Mandibular Molar	crest periapical	3.50	0.50	3.69*	0.46	3.67*	0.46	3.57	0.49	3.60	0.49	F=2.206, p=0.068
		3.54	0.52	3.66	0.47	3.70	0.45	3.59	0.49	3.64	0.48	F=1.303, p=0.268

Note: * represents significant difference between means of the scores of the original and filtered images.
SD: Standart deviation.

tional intra-oral radiographs to be very low for the examination of the mandibular molar teeth region, indicating a high number of the digital images were adequate for radiographic assessment of the region.

The aim of filtering is to improve the visualization of small details on radiographs such as periodontal ligament, alveolar crest and periapical region.[8] Therefore, we evaluated the effect of different filters on the subjective image quality of the alveolar crest and periapical region of maxillary and mandibular anterior, premolar and molar teeth.

Subjective image quality differed in different dental regions and according to filter type. The emboss and structure enhance filters were found to be useful for the evaluation of the alveolar crest and periapical region of the maxillary anterior, periapical region of premolar and both alveolar crest and periapical regions of molar teeth. The sharpen and smooth filters did not enhance the subjective image quality in none of the evaluated regions. The emboss and structure enhance filters led to a significant increase only in the alveolar crest region of mandibular anterior and molar teeth but both alveolar crest and periapical regions in premolar teeth.

Image quality in panoramic images is negatively affected due to the superimposition of the ramus, overlying bone on the maxillary molar region and cervical vertebrae. When we look at the effect of filters at these regions it was found that the emboss and structure enhance filters increased subjective diagnostic image quality in the radiographic investigation of the crest and periapical regions of the maxillary molar teeth by decreasing the unfavorable effect of overlapping bone. A similar effect was observed for the application of the emboss and structure enhance filters in the mandibular anterior crest region, but no such effect was observed at the periapical region with any of the filters.

In general, the highest increase in subjective image quality in most of the dental areas was achieved with the application of the emboss and structure enhance filters. The visual appearances of the images treated with these filters are very different from the original image. On the other hand, the appearance of the images treated with the smooth and sharpen filters are similar to each other and to the original. In fact, all filters are different algorithms acting on the pixels with different mechanisms. We think the increase in the subjective image quality achieved with emboss and structure enhance filters could be due to the difference in the appearance of the images.

Several studies have evaluated the outcome of image processing on dental radiographs.[11-15] In previous research, controversial results have been reported about the effect of filters on direct digital panoramic images. Yalçınkaya et al.[3] reported the usefulness of the periodontal I, periodontal II, periodontal III, bone enhancement, standard and noise reduction filters for digital panoramic images obtained with the Dürr Vistascan system and suggested the images should be filtered according to the diagnostic task. On the other hand, Gijbels et al.[10] reported the use of smooth down and sharpen filters present in the Orthophos digital panoramic unit did not have a significant effect on subjective image quality, but contrast enhancement resulted in a significantly better diagnostic outcome. As there is no such similar study made with the Orthoralix DDE 9200 direct digital panoramic machine and there is no standardized terminology in the digital software programs, we could not compare our results with other studies. Standardized terminology of image processing should be provided in dentistry for a more accurate comparison between the results of different research.[16]

The aim of the present study was to assess the effect of filters on subjective image quality and not to detect any pathologies hence, we made our assessments according to a rating system which gave information about subjective image quality. This method has been used in similar studies also.[3,10]

The original and filtered direct digital panoramic images were assessed by three maxillofacial radiologists with 16, 9 and 6 years of experience, respectively. Further studies could be conducted among general dentists and experienced observes in the other fields of dentistry.

The image quality of radiographs could be decreased when the image enhancement algorithms are not used properly.[17] To avoid this adverse effect and to make the assessments under standard experimental conditions the observers were not allowed to manipulate brightens and contrast of the images themselves.

Also, the aim of this study was to assess subjective image quality, not diagnostic accuracy. Therefore, one could not assume that an increase in subjective image quality also leads to an increase in diagnostic accuracy. These are two different affaires. Further research could be conducted on this aspect with different research design methods allowing the comparison of the diagnostic accuracy between original and filtered direct digital images in different dental areas.

CONCLUSION

In conclusion, the effect of filtering on subjective image quality varied in the anterior, premolar and molar teeth regions and according to the filter type on the digital panoramic images. The application of the emboss and structure enhance filters led to a significant increase in subjective image quality in the most of the examined dental areas while the smooth and sharpen filters did not. Therefore, the knowledge of the effect of filters on subjective image quality in dental regions could be helpful for the dentists when filters are going to be applied to digital panoramic images.

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