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# Upgrading Of The Existing Analog Radiography System To Digital And Comparison Of Both Systems

Omer Karal[*1], Nazime Tokgoz[2]
*[*1]Department of Electronics Engineering, Ankara YildirimBeyazit University, Ankara, Turkiye*
*[2]Department of Electronics Engineering, Ankara YildirimBeyazit University, Ankara, Turkiye*
*Corresponding Author:Omer Karal*

***ABSTRACT:****One of the most important areas where the developments in technology are most visible is medical. Medical radiographic images previously only obtained in analog while currently they can be obtained by digital systems. The aim of this study is to first upgrade the existing analogue radiography system to digital by using wireless AED (automatic exposure detection) and then compare both systems in terms of image quality, time, dose and cost. For this purpose, IBA primus-L test phantom is used. These phantom images are compared and evaluated in terms of image quality using image J software, doses are calculated with Caldose software. The results of this study show that the use of digital up-graded system is easy and fast to use. Moreover, in contrast to the analogue system, images obtained from the digital up-graded system have shown better results in terms of sharpness and dynamic range even at lower doses.*

***KEYWORDS:****Analog radiography, Digital Radiography, Dose, IBA Primus-L Phantom, X-ray.*

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## I. INTRODUCTION

Medical imaging systems have been developing rapidly in recent years. While radiographic images can only be acquired in analog form, they are now digitally acquired. Therefore, existing X-ray systems are usually classified as analog (conventional) and digital. The working principles of these systems are the same, but the methods of image acquisition are different. That is, in analog systems, the image is acquired by the film inside the cassette, whereas in digital systems, the image is acquired by the receiver detector.

Various studies have been performed in the literature to compare analogue and digital radiography systems. Most of them have been performed on dental films. Ajmal and Elshinawy [1] compared both analog and digital radiographic images of 25 teeth in terms of image quality and showed that analogue radiographic imaging yielded better results. Sumer et al. [2] evaluated the visibility of anatomic structures such as mandibular canal, mental foramen, anterior looping of the mental nerve, incisive canal and lingual foramen on conventional and digital panoramic radiographs. It has been seen that conventional and digital panoramic systems give similar results in the visualization of anatomical structures. Longo et al. [3] evaluated the correlation between analogue and digital radiographic methods in the measurement of periapical lesions in primary molars and compared the time used to obtain the radiographic images between both methods. It has been found that there was a strong positive correlation between digital and analogue methods in lesion measurements, but the digital method required shorter time to obtain radiographic images. Wei et al. [4] compared the clarity of images obtained with conventional and digital radiography systems for maxillary incisors. It has been observed that the image of digital radiography was superior to conventional radiographic. Tavakoli et al. [5] compared digital and analogue radiography images in the diagnosis of bronchial pattern in dogs. It has been concluded that digital radiography system is superior to analogue radiography in determining the details of thoracic radiography of normal dogs.

Unlike the above studies, in this study, the existing analogue radiography system is first upgrade to digital and then the two systems are compared in terms of image quality, time, dose and cost under IBA primus-L contrast detail phantom.

## II. UPGRADING CONVENTIONAL RADIOGRAPHY SYSTEM TO DIGITAL

Conventional systems are time consuming since chemical solvents are used for film processing (see Figure1a). In addition, hospitals should allocate a small dark room for film processing. On the other hand, it is impossible to modify the analog image. It is very difficult to send to a different location from the environment in which the images are acquired. To overcome these difficulties, hospitals digitally upgrade their existing systems or buy a digital radiography (DR) system [4].


**Figure 1: (a)Cassetteused in conventionalsystem, (b) Flat Panel Detector in DigitalSystems**

In DR systems, X-rays fall into flat panel detectors instead of film and are converted into electrical signals (see Figure 1b). Radiographic images generated by these signals are displayed directly on the computer screen. For this reason, DR systems are widely used today [6].

Instead of having a completely new digital system, using a flat panel detector instead of a cassette in the receiver part of the existing analog system is a simpler and cheaper method. Because of this, most of the hospitals upgrade conventional (analog) radiography systems to digital. Systems that are converted from analog to digital have some advantages and disadvantages over fully digital systems [7]. Flat panel detectors are used in digital radiography systems and in up-grading existing analog radiography systems to digital systems. There are two types of flat panel detectors: direct and indirect [8].

In direct conversion flat panel detectors, an amorphous selenium-coated thin-film-transistor (TFT) array is used to convert X-rays into digital signals [9]. Indirect flat panel detectors use thin silicon films integrated with photodiode arrays. Unlike the selenium-based system, this type of indirect-conversion detector technology requires a two-step process for X-ray detection, the scintillator converts the X-ray beams into visible light, and light is then converted into an electric charge by photo-detectors, such as amorphous silicon photodiodes [10].

In this study, an indirect flat panel detector, which is the latest technology [11] was used to upgrade the conventional IMD Basic-100 mobile radiography to the digital system. The flat panel detector with automatic exposure detection (AED) is wirelessly integrated into the analogue system. The system consists of a computer, a software, a wireless AP, a Li-polymer battery, a charger and a detector as seen in Figure 2.


**Figure 2: DigitalFlat panel connection**

## III. COMPARISON OF DIGITAL AND CONVENTIONAL RADIOGRAPHY SYSTEMS

In this study, a IMD Basic-100 mobile radiography machine has been used for the analogue and digital radiography system. Mobile X-ray systems are specially used in emergency units of the hospitals. The technical specifications of the IMD mobile X-ray system can be seen at the Table 1. X-ray tube of the system has a rotating anode with 3000 rpm and the focal spot sizes are 1.3/0.6.

**Table 1: Flat panel detector specifications**

| Item | Description |
|---|---|
| Image matrix size | 2304*2816 pixels |
| Pixel pitch | 154µm |
| Grayscale | 16 bit 65536 grayscale |
| Scintillator | Csi(cesium Iodide) |
| Fill Factor | 0.65 |
| Special Resolution | Min 3.3 line pair/mm |
| Dynamic range | ~82 db |
| Modulation Transfer Function | ~70 % @ 1lp/mm~40 %.@ 2lp/mm~22 %.@ 3lp/mm |
| Detector Quantum Efficiency | (@RQA5, 30µGy)~65%.@ 0lp/mm~20 %.@ 3lp/m |
| Rated power supplyWireless | DC 24V, Max 1.5 APowered by battery pack |
| Power consumption | 36W |

Quality measurement in real body parts for conventional radiography system is very difficult. Only experienced radiologist can determine the quality of image subjectively. So; the phantoms are designed to measure the quality of the image. It is possible to find phantoms in different shapes belonging to many brands in order to measure the quality in the radiographic image. We used the IBA primus L test phantom to evaluate the contrast, dynamic range and resolution values in both digital and conventional systems.The picture of the phantom and the meaning of the regions are shown in Figure 3.
IBA Primus-L Test phantom is used in 75±7 kV values according to user guide. PMMA plexiglassesare used to increase the thickness of the phantom. The thickness of the PMMA is 10 mm.

X-ray source was set at the constant setting of 75 kVp and 5 mAs. The IBA primus-L phantom was placed over the film and the phantom distance with the X-ray source was set at 110 cm. Then film was processed using automatic processing machine (Huq). These steps were repeated for the same phantom using three plexiglass. Developer and Fixer processing solutions were used at 3 min and then test radiographs were obtained. These analog images were placed on an x-ray negatoscope in the dark room and photographed with a 1080x1920 resolution camera and transferred to a PC computer with Pentium processor,Windows system and imported to the Image J software.

1. Direction of the tube axis
2. Dynamic step wedge (Step 1 : 0.00 mm Cu;Step17 : 3.48 mm Cu)
3. 16 detail contrast objects with a diameter of 4mm, depth 2.5 mm in PMMA (for the evaluationof the contrast resolution in each step of thecopper step wedge)
4. kV-test area made of Ytterbium, 0.78 mm thick
5. Line cross as center mark
6. 8 detail contrast objects with a diameter of 10 mm, depth 0.4 - 4 mm; for the determination of the contrast resolution at the current work settings.
7. Unstructured inner area
8. High resolution test 0.6 - 5.0 lp/mm (Dimension of the deposited plate of copper:1.1 mm)
9. Radiographically visible numbers for indication of the dynamic steps.

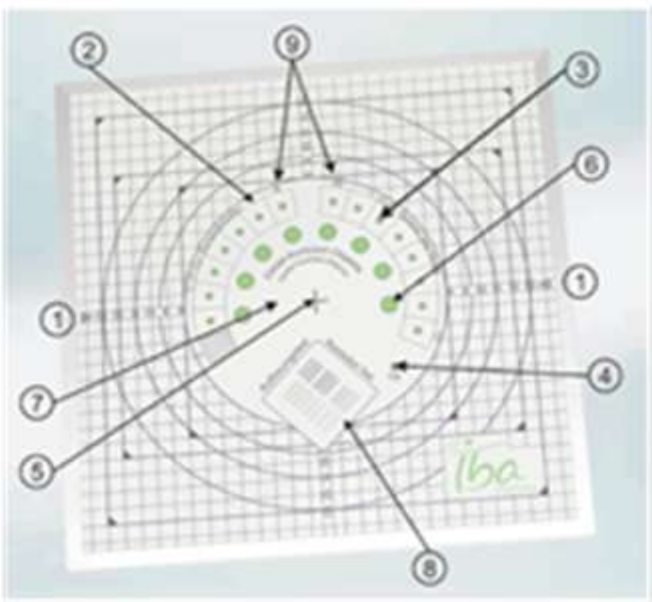
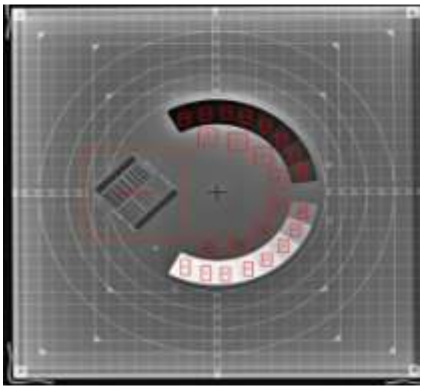



**Figure 3: IBA primus-L test phantom and the meaning of the regions**

Similar operations were performed to obtain digital radiography images, but the indirect panel detector was used instead of film in the receiver section.The obtained analogue and digital radiographic images are shown in Figure 4, while the exposure values can be seen in Table 2.



(a)Test phantom Primus L reference image

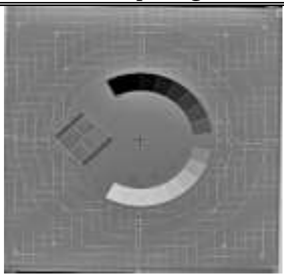
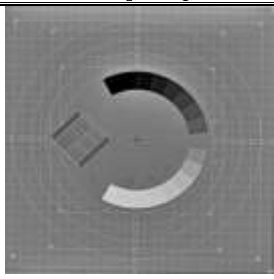
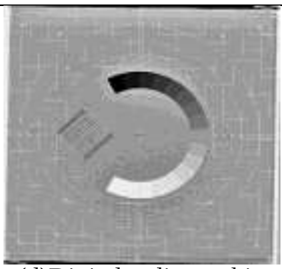
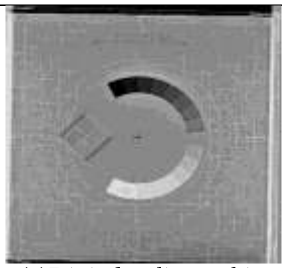
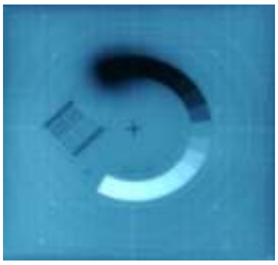
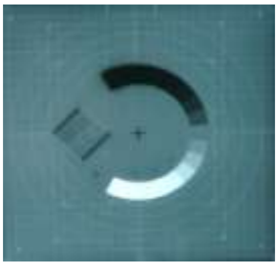
| Without plexiglass | With 3 plexiglass |
|---|---|
| <br>(b)Digital radiographic<br>Exposure values:75kV and 3.3mAs | <br>(c)Digital radiographic<br>Exposure values:75kV and 3.3mAs |
| <br>(d)Digital radiographic<br>Exposure values:75kV and 2.6mAs | <br>(e)Digital radiographic<br>Exposure values:75kV and 2.6mAs |
| <br>(f)Analog radiographic<br>Exposure values:75kV and 5 mAs | <br>(g)Analog radiographic<br>Exposure values:75kV and 5 mAs |

**Figure 4: Reference image (a), digital images with and without plexiglass (b-e), analog images with and without plexiglass (f-g).**

**Table 2: Exposure values for the test Phantom IBA Primus L.**

| Type of Phantom | Exposure values for Analog radiography | | Exposure values for Digital up-graded radiography | |
|---|---|---|---|---|
| IBA Test Phantom | 75kV | 5mAs | 75kV | 3.3 mAs |
| | | | 75kV | 2.6 mAs |
| IBA Test Phantom (3 plexiglass) | 75kV | 5mAs | 75kV | 3.3 mAs |
| | | | 75kV | 2.6 mAs |

The images are compared by using the primus-L phantom quality factors. Contrast, detail, resolution and dynamic steps detected and evaluated. The reference image that is taken under 80 kVp 320 mA and 20ms in Figure 4(a) shows the specific regions such as the visible contrast and dynamic wedge steps. There are 8 circles

(Figure 3- section 6) on the test phantom to determine the contrast and 16 dynamic wedge steps (Figure3-section 2) around these circles. These circles are labeled with Ci and dynamic step wedges are labeled with Di (Figure4(a)).

To see that the image quality changes depending on the exposure values and conditions, the test image values are first determined and then the other values are determined by decreasing the exposure values and adding PMMA to the test phantom.

All images were separately evaluated by experienced the 15 radiologists and the 5 radiology technicians. It was asked to score the points to the observers according to the rate of appearance of the circles and the visibility of the circles. These scores were evaluated by using the 5-point scale provided. The scale graded criteria as invisible (0), hardly visible (1), slightly visible (2), visible (3), totally visible (4) as seen in Table 3.

**Table 3: Detail contrast visibility for the Reference Image**

| Ci | Visibility | Rate |
|---|---|---|
| C1 | 4 | %100 |
| C2 | 4 | %100 |
| C3 | 4 | %100 |
| C4 | 4 | %100 |
| C5 | 3 | %75 |
| C6 | 3 | %75 |
| C7 | 2 | %50 |
| C8 | 1 | %25 |

Finally, observers' results for analog and digital systems are statistically listed in Table 4 in terms of circles that can be seen in phantoms. Table 4 shows the rating scores of the visibility regions. As can be seen from the Figure 4 and the Table 4, total countable circle in digital images were statistically more than analog system.

**Table 4: Exposure values for the test Phantom IBA Primus L.**

| Figure 4 | C1 | C2 | C3 | C4 | C5 | C6 | C7 | C8 | % visibility | Rate |
|---|---|---|---|---|---|---|---|---|---|---|
| a | 4 | 4 | 4 | 4 | 3 | 3 | 2 | 1 | 78.125 | %100 |
| b | 4 | 4 | 4 | 3 | 2 | 1 | 1 | 0 | 59.375 | %76 |
| c | 4 | 4 | 4 | 3 | 2 | 1 | 0 | 0 | 56.25 | %72 |
| d | 4 | 4 | 4 | 3 | 2 | 1 | 0 | 0 | 56.25 | %72 |
| e | 4 | 4 | 3 | 2 | 1 | 0 | 0 | 0 | 43.75 | %56 |
| f | 4 | 4 | 3 | 2 | 1 | 0 | 0 | 0 | 43.75 | %56 |
| g | 4 | 4 | 3 | 1 | 0 | 0 | 0 | 0 | 37.5 | %48 |

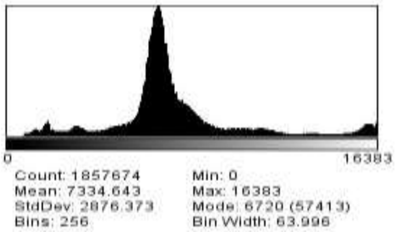
The density values between black and white of the pixels used in digital image systems have a large dynamic range. Digital and analog X-ray image histograms can be measured by using image J software as can be seen in Figure 5.

As it can be seen from the histograms, dynamic ranges are long in digital image which means there are many color tones between black and white.

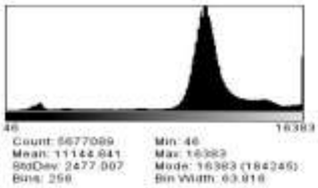
These systems are also compared according to the time spent. Preparation time is the time required for the system to be ready for examination. Positioning the patient and placing the film in the cassette or detector and adjusting the exposure factors (kV, mA, mAs). In digital systems, acquisition profile can be selected according the region like shoulder, chest, pelvis. etc. Examination steps starts with pushing the exposure button (two steps in analog system: prepare and ready, one push for digital system), ends with a signal corresponding that the image is acquired in the image receptor. After the acquired images are processed in digitally or chemically. The required times for acquiring images are listed in Table 5.

To compare absorbed doses in digital and analogue radiographic images, Caldose software was used in this study [12]. Caldose software is used to estimate incident air kerma(INAK) and entrance surface air kerma(ESAK)[13]. The primus-L phantom is exposed to the same values of X-rays (75 kV, 5mAs, and FDD) for the analog and digital images. The measured dose values are tabulated in Table 6.

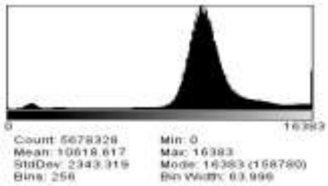
It is clear from Table 6 that the digital images give more details (see Figure 4) with less x-ray exposure than analogue images.



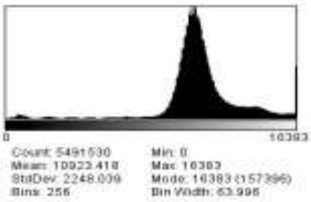

(a)



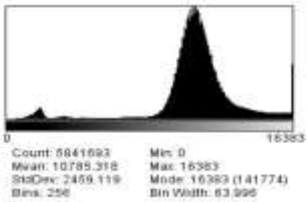
(b)



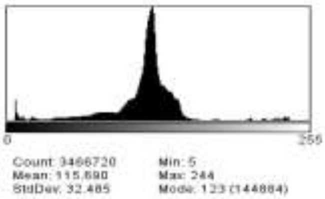
(c)



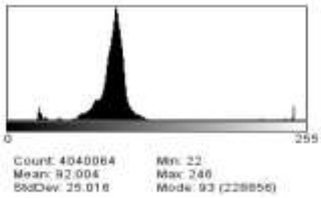
(d)



(e)



(f)



(g)

**Figure 5:Histograms of the images in Figure 7.**

**Table 5: The time required to obtain digital and analog radiograph images**

| Time (seconds) | Analog System | Digital up-grade system |
|---|---|---|
| Preparation | 40 | 20 |
| Examination | 30 | 10 |
| Processing | 160 | 5 |
| Acquiring the image and quality control | 10 | 10 |
| Re-take the film | 240 | - |
| Total time | 240 | 45 |

**Table 6: Comparison of conventional and digital (up-graded from analog) radiography systems in terms of X-ray exposure.**

| System | Conventional X-ray system-IMD BASİC-100 | After up-grade with Careray wireless AED detector | |
|---|---|---|---|
| kv | 75 kV | 75 kV | 75kV |
| mAs | 5mAs | 3.3mAs | 2.6mAs |
| FDD(cm) | 110 | 110 | 110 |
| ESAK(mGy) | 0.91 | 0.6 | 0.47 |
| INAK(mGy) | 0.66 | 0.43 | 0.34 |
| KAP(dGy*cm²) | - | 1.09 | 0.82 |

The cost of each system can be calculated as follows. The price of a full digital portable X-ray machine is $ 75,000 in American dollars. The price of a conventional mobile X-ray machine is is $ 5,000-10,000. The flat panel detector used to upgrade the conventional X-ray device to the digital costs $ 20,000-25,000. As a result, instead of buying a new digital x-ray device for $ 75,000, buying a flat panel detector for $ 20,000-25,000 for the existing analog x-ray device is more beneficial both in terms of cost and efficient use of resources.

## IV. CONCLUSION

Digital X-ray systems are widely used today. Especially hospitals digitally upgrade their existing systems or buy a digital radiography (DR) system. In this study, instead of buying a new digital X-ray machine for $ 75,000, the existing analogue radiography system was upgraded to digital by purchasing wireless AED (automatic exposure detection) for $ 20,000.Then, both systems were compared in terms of image quality, time and dose. Comparisons of radiographic films obtained from conventional and digital radiography systems have previously been generally performed on dental images.Differently, in this study, both systems were adjusted to view the abdominal region and compared using the IBA primus-L test phantom.According to the results obtained, the use of the digital system is better than the analogue system in that both the patient is less exposed to ionizing radiation and the time loss of processing analogue images is avoided.

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