International Journal Dental and Medical Sciences Research (IJDMSR)
ISSN: 2393-073X Volume 4, Issue 7 (July - 2020), PP 17-23
www.ijdmsr.com

Assessment of Diagnostic X-ray Machine Resolution Using Modulation Transfer Function

Huyam F. Deiab[1], Nedal A. AbdAllh[2], A. A. Beineen[3], M. E. M. Gar-Elnabi,[1,2]
[1]*Sudan University of Science and Technology. College of Medical Radiologic Science, P.O.Box 1908, Khartoum, Sudan*
[2]*Faculty of Radiology and Medical Imaging Sciences - National University, Sudan-Khartoum*
[3]*Radiation Safety Institute, Sudan Atomic Energy Commission, P. O. Box 3001, Khartoum, Sudan*
**Corresponding Author: Huyam Deiab*

ABSTRACT:- This study design to measure the x-ray machine resolution using MTF which gives a full description of the machine resolution. The x-ray machines were investigated the optimum resolution using wire phantom designed by the researcher which consisted of variable thicknesses used to test variable exposure factors. The prototype phantom consisted of five wires with different thickness assessed the diagnostic x-ray machine resolution by found the optimum kV relative to machine type. This study showed that the best machine resolution was Shimadzu 2011 for Khartoum emergency hospital that had high resolution 97% at 46Kv for thickness of 1.4mm compared with Toshiba 2011 for Almotkamil hospital that had 92% at 46Kvp. Also, the result showed that for the two types of x-ray machines the x-ray tubes don't produced the same exposure and the output decreased with age of x-ray unit, also the resolution reduced when decreased the thickness of the wires.
And from all measurement we notice when the spatial resolution become smaller the resolution becomes better and with increase the x ray machines tube voltage the resolution become best. For spatial resolution 0.36 the resolution is better than the other frequencies and when compares the kilo voltage 40, 44 and 46 kV the voltage 46 kV give best resolution than 40 and 44 kV.

Key word: Image Quality, Prototype Phantom, Spatial Frequency, Spatial Resolution

I. INTRODUCTION:

Digital images have vital advantages in health services. Image quality has been improved and patient radiation dose reduced by the introduction of digital imaging systems including computed radiography (CR) and digital radiography (DR). In addition, digital imaging modalities have revolutionized communication between radiographers, radiologists, and physicians [1,2]. However, CR and DR also have some limitations such as higher initial cost, particularly for DR. In addition, consistent feedback that is required to obtain optimal acquisition may not be available for technologists. Potential increase in radiation dose, due to wide dynamic range of digital systems, is also a potential drawback of CR and DR. Patients may be overexposed with more radiation than is required for a diagnostically sufficient image. Diagnostic information may be suppressed as a result of suboptimum image processing [2,3]. Therefore, it is essential to regularly investigate image quality to ensure correct and accurate image interpretation.

Image quality parameters:

There are several parameters that characterize the quality of digital images. Resolution, noise, and artefacts are the main parameters of image quality [4]. Some studies include blur factors which relate so far to the spatial resolution [5,6]. Resolution describes the ability of medical imaging process to discriminate adjacent structures in organ tissues being examined. Signal from detected photon should be recorded with sufficient resolution in space, intensity and possibly time to produce a digital image that enables a medical interpretation of tissue structure and function. Therefore, resolution is of three main categories, spatial resolution (space), contrast resolution (intensity) and temporal resolution (time) [7].

The modulation transfer function (MTF) of an imaging system is defined as the absolute value of its optical transfer function, normalized to unity at spatial frequency zero [8-10]. One established method to determine the MTF is based on the use of a sharp edge that is imaged to produce an edge spread function (ESF). The ESF is then differentiated to obtain the line spread function (LSF), from which the MTF is calculated by a Fourier transform [11-16]. An edge test device with a well-defined edge is usually realized by carefully machining a thin piece of metal, e.g., lead, tungsten, or platinum. Material thicknesses of 0.1 to 0.25 mm are often used to allow easy manufacturing and handling as well as accurate alignment of the edge in the x-ray beam. [17-19].

Depending on the actual thickness of the material and on the beam, quality used for imaging, the metal sheet may be either (almost) fully absorbing or semitransparent. When x rays hit the edge test device, scattered radiation is inevitably generated. The scattered radiation may exit from the back side of the edge device toward the detector if the material is not thick enough to absorb all radiation. The MTF, which can be expressed as the image contrast values for spatial frequencies (k) over the native object contrast, can be used to correct contrast loss resulting from non-ideal imaging performance. For example, in plasma and laboratory astrophysics, X-ray absorption contrast imaging is an established method for spatially resolving high energy density (HED) object features and measuring key properties, such as areal densities.

Image contrast reduction, originating in source and/or detector performance limitations, can cause uncertainty in quantitative measurements of object properties, and although effects of degraded contrast can be unfolded by deconvolving the line-spread function (LSF), it is often simpler to divide-out the MTF in k-space. In particular, HED experiments using X-radiography of sinusoidal objects are naturally suited to contrast correction with the MTF. This study aims to assess the diagnostic x-ray machine resolution using MTF in order to find the optimum exposure factor that preserve x-ray machine resolution

II. MATERIAL AND METHODS:

The X-ray machines resolution has been assessed using designed phantom which was consisted of five wires, embedded in a 6 x 9.5 x 1 cm wood holder, each wire is 1 cm away from the adjacent wire with thickness of 1.4mm, 0.8mm, 0.6mm, 0.5mm and 0.4mm. The radiographic measurements were performed in five conventional X-ray machines in five hospitals. The X-ray was manufactured by : Shimadzu PN503-55050–SN0266M11707 (2007), Shimadzu model 0.6/1.2P18DE-85 (2011), Toshiba model DRX-3724HD (2003), Toshiba DRX-3724HD (2003) and Toshiba model E7239X (2011) and these correspond to hospital of Ahmed Gasim, Khartoum emergency, Khartoum, Gafr and Almotkamil respectively.

Method of data collection

Determination of the spatial resolution is essential in order to find the optimum KV relative to machine type, the phantom is placed on the detector surface, and a uniform source of radiation is placed above the bar phantom that was the focus-to-film distance was 1m. An image is acquired, the units was set at 2mAs and 40kVp value. An X-ray exposure was made. This step was repeated at same constant mAs and different Kvp settings (40, 44 and 46kVp) and that was repeated for the five models of the x-ray machines. The choice of x-ray tube voltage (kV) affected the image contrast and is one of the adjustable factors of x-ray equipment and in different x-ray units the images were obtained by applying the same parameter setting. The images of the phantom were scanned to a computer, and using Interactive Data Language IDL for generate a profile throw the lines in ordered to drown a curve and obtain the resolution, modulation transfer function and frequency of the lines with different Kv and thickness, Then calculation of the Fourier transform of the LTF to obtain the MTF an alternative is to use the Modulation Transfer Function (MTF) in order to describe the ability of the system to maintain the amplitudes of spatial frequencies passing through it and MTF is a plot of resolution, measured in percent, against spatial frequency measured in lp/mm.

III. RESULTS AND DISCUSSION:

The results of this stud illustrated using tables, bar graphs, and line graphs for a phantom image consisted of wires of five thicknesses correspond to spatial frequency of 0.36, 0.63, 0.83, 1 and 1.25cycles/mm respective. Each of the wire exposed to 40, 44 and 46 Kv in five hospitals. The tables showed the resolution % for each thickness versus the Kv for the different hospital, while the bar graphs illustrated the table's data graphically for evaluation. The scatter plot depicted the linear regression of the resolution in respect to the spatial frequency. Similarly, the line graphs display the MTF % versus the spatial frequency for the different KVs and the different hospital for visual perception.

From all measurement the kV 46 give a better resolution than 44 and 40kV while in resolution decrease with increase the spatial frequency, we notice that the value 1.25 cycles/mm give a worst resolution and the reduce the spatial frequency the resolution gets better for that the value 0.36 give a best resolution than 0.63, 0.83, 1 and 1.25 cycles/mm. as shown in tables and figures below:

Table 1. show relation between the spatial resolutions with tube voltage at Khartoum emergency hospital:

Spatial frequency	40 kV	44 kV	46 Kv
0.36	56%	72%	97%
0.63	48%	56%	63%
0.83	40%	46%	58%
1	31%	38%	56%
1.25	25%	27%	51%

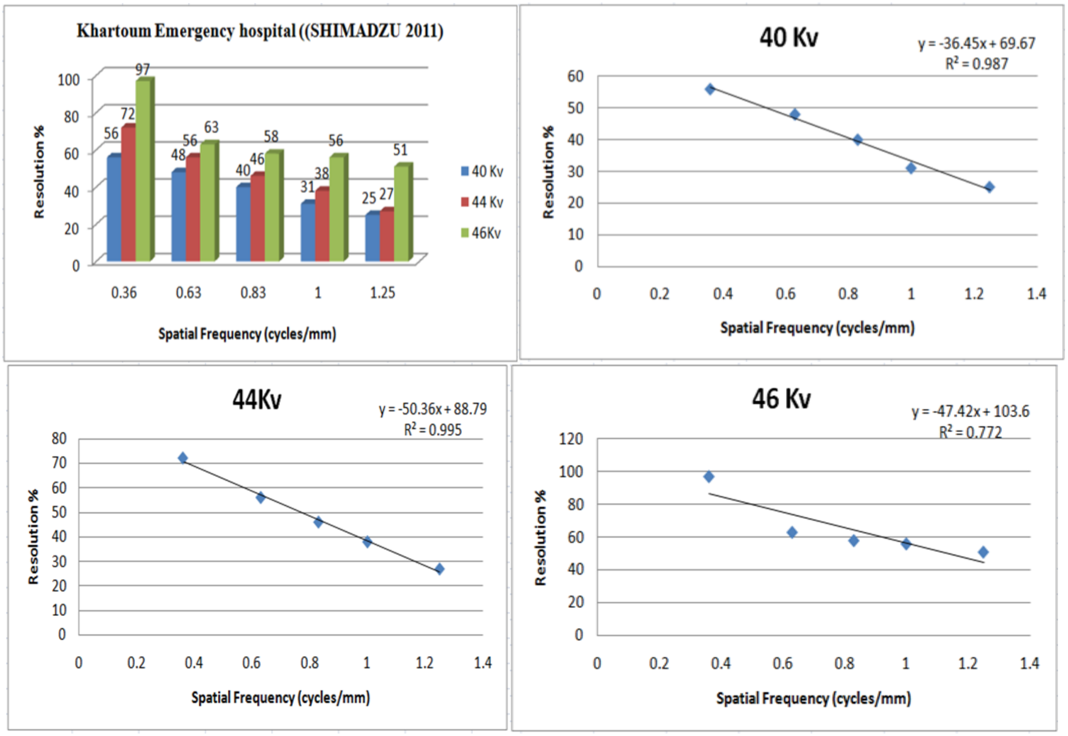
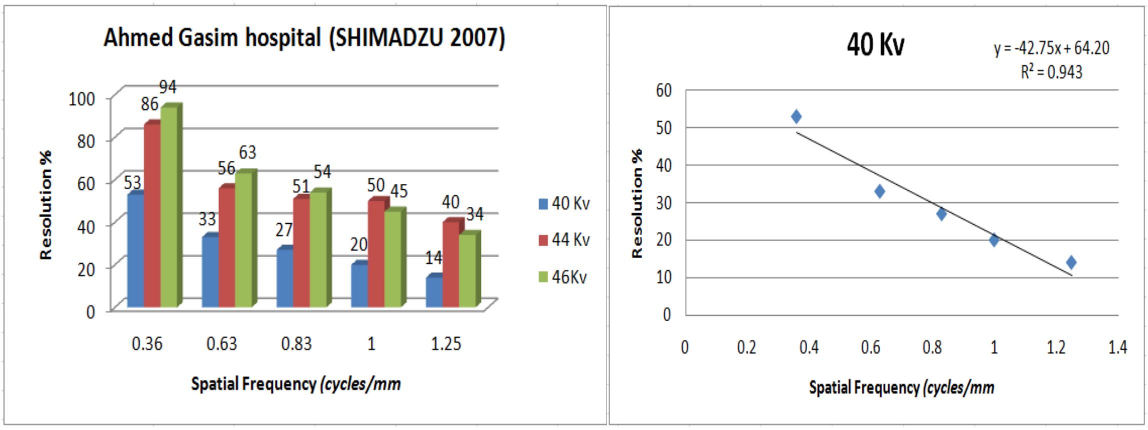


Figure 1. Show relation between the spatial resolutions with tube voltage at Khartoum emergency hospital:

Table 2. The resolution in percentage for Ahmed Gasim hospital at voltage 40, 44 and 46 Kv:

Spatial Frequency	40 kV	44 kV	46 Kv
0.36	53%	86%	94%
0.63	33%	56%	63%
0.83	27%	51%	54%
1	20%	50%	45%
1.25	14%	40%	34%



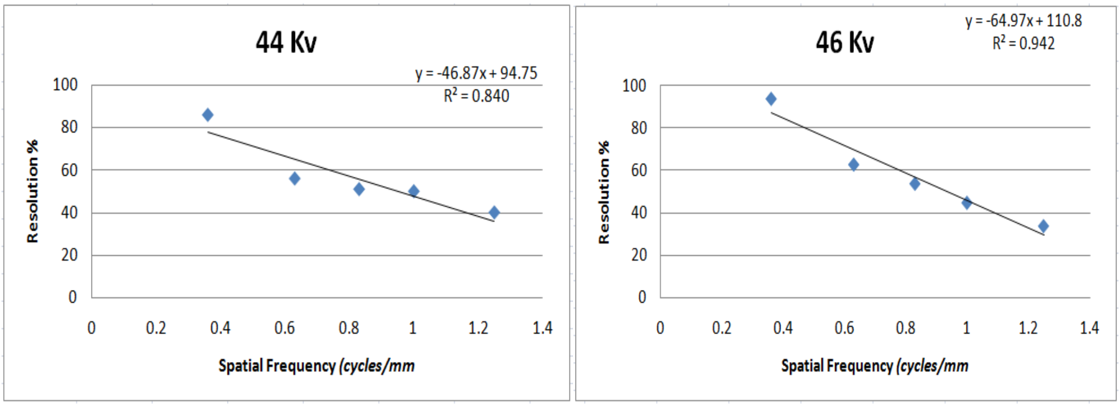


Figure 2. The resolution in percentage for Ahmed Gasim hospital at different voltage:

Table 3. Resolution in percentage for Almotkamil hospital at voltage 40, 44 and 46 Kv:

Spatial Frequency	40 kV	44 kV	46 kV
0.36	53%	89%	92%
0.63	30%	70%	75%
0.83	28%	66%	46%
1	20%	40%	30%
1.25	10%	38%	28%

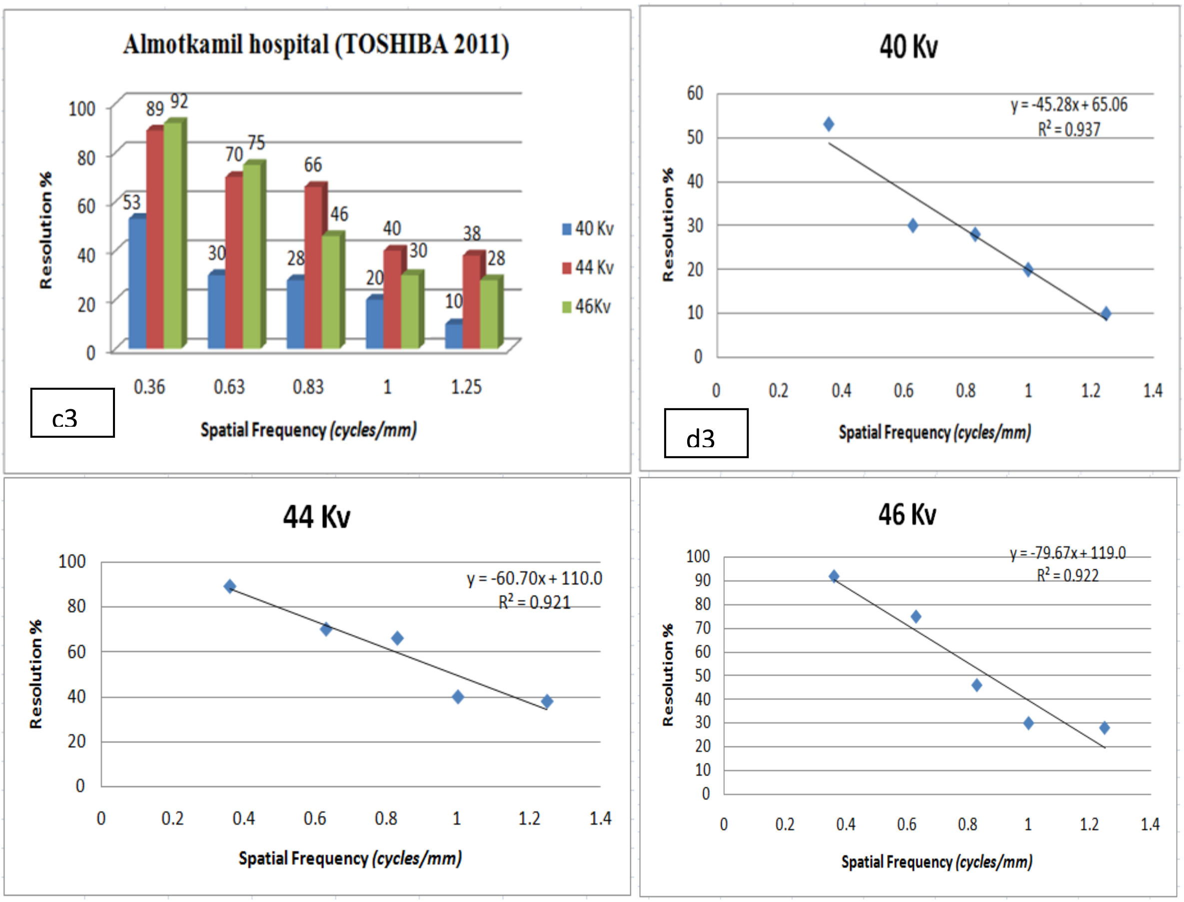


Figure 3. Resolution in percentage for Almotkamil hospital at different voltage:

Table 4. Resolution in percentage for Khartoum hospital at voltage 40, 44 and 46 Kv:

Spatial Frequency	40 Kv	44 Kv	46Kv
0.36	36%	50%	56%
0.63	22%	29%	30%
0.83	16%	25%	28%
1	14%	16%	25%
1.25	12%	14%	23%

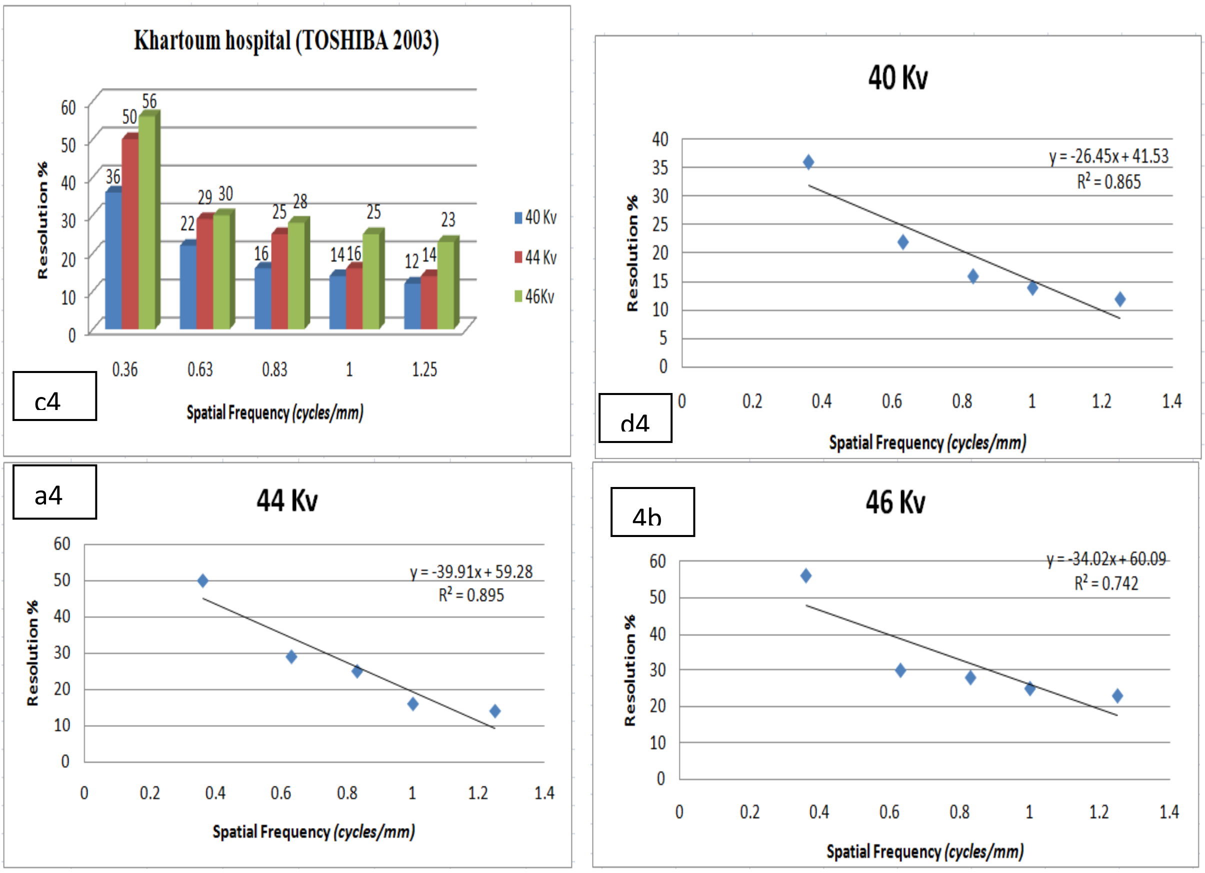


Figure 4. Resolution in percentage for Khartoum hospital at different voltage:

Table 5. Resolution in percentage for Gafr ben Owf hospital at voltage 40, 44 and 46 Kv:

Spatial Frequency	40 kV	44 kV	46 kV
0.36	33%	56%	75%
0.63	16%	27%	52%
0.83	14%	19%	35%
1	13%	15%	24%
1.25	10%	14%	18%

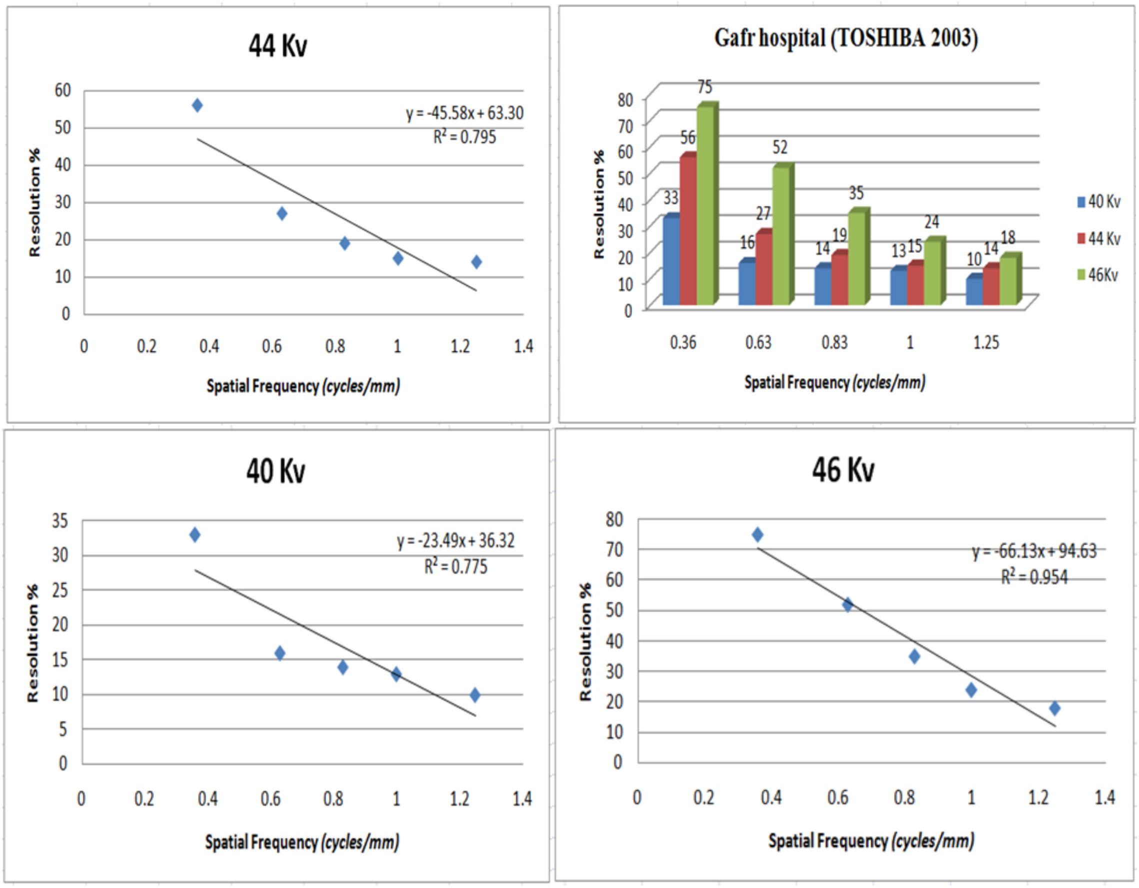


Figure 5. Resolution in percentage for Gafr ben Owf hospital at different voltage:

And from all measurement we notice when the spatial resolution become smaller the resolution becomes better and with increase the x ray machines tube voltage the resolution become best. For spatial resolution 0.36 the resolution is better than the other frequencies and when compares the kilo voltage 40, 44 and 46 kV the voltage 46 kV give best resolution than 40 and 44 kV.

IV. CONCLUSION:

The main objective of this study was to measure the x-ray machine resolution using MTF which gives a full description of the machine resolution. In this study five conventional x-ray machines were investigated using wire phantom designed by the researcher which consisted of variable thicknesses used to test variable exposure factors. this study introduced the a more reliable method of measuring the resolution which is modulation transfer function (MTF) which gives a complete description of the resolution instead of using full width at half maximum (FWHM) or the visibility method which is more qualitative where MTF is a real quantitative method, by designed a prototype phantom consisted of five wires with different thickness and Kvp for five x-ray units and assessed the diagnostic x-ray machine resolution by found the optimum Kv relative to machine type. This study showed that the best machine resolution was Shimadzu (2011) for Khartoum emergency hospital that had high resolution 97% at 46Kv for thickness of 1.4mm compared with Toshiba 2011 for Almotkamil hospital that had 92% at 46Kvp and . Also the result showed that for the two types of x-ray machines the x-ray tubes don't produced the same exposure and the output decreased with age of x-ray unit, also the resolution reduced when decreased the thickness of the wires.

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***Corresponding Author: Huyam Deiab**
[1]Sudan University of Science and Technology. College of Medical Radiologic Science,
P.O.Box 1908, Khartoum, Sudan*