International Journal of Allied Medical Sciences and Clinical Research (IJAMSCR)

ISSN:2347-6567

IJAMSCR |Volume 8 | Issue 1 | Jan - Mar - 2020
www.ijamscr.com

Research article *Medical research*

The role of the application of variations in voxel size on noise and spatial resolution of cbct endodontic images

Solikhatul Istijabah[1*], Lina Choridah[2], Gatot Murti Wibowo[1], Hari Santoso[1], M. Choiroel Anwar[1], Sugiyanto[1]

[1]*Postgraduate Program, Master of Applied Diagnostic Imaging, Semarang Health Polytechnic, Indonesia*
[2]*Department of Radiology of FK-KMK UGM/Dr. Sardjito Central General Hospital Yogyakarta, Indonesia*

***Corresponding Author**: **Solikhatul Istijabah**
Email id: solikhatulistijabah@gmail.com

ABSTRACT

CBCT is a diagnostic tool that is very useful for conventional endodontics to improve treatment planning. The resolution and noise of CBCT image results will greatly affect the image quality associated with diagnostic accuracy. Unclear anatomical images are likely to occur because of poor image quality. Factors affecting unclear anatomical images are related to voxel size and there is a need to improve image quality. This was an empirical study which aims to observe the role of the application of variations in voxel size on noise and spatial resolution of CBCT endodontic images. This was a quasi-experimental study with a pre-post test only group design. The study samples were ACR CT phantom images and the images of the test object (human skull). CBCT scanning was conducted with 2 (two) variations in voxel size. Each voxel size was scanned with 6 (six) parameter variations. 3 samples of ACR CT phantom images were taken for each parameter. Statistical data analysis was performed with descriptive statistics and Wilcoxon. The study results showed that voxel size of 180 μm had a lower noise value than the voxel size of 300 μm, there was a significant effect of voxel size on CBCT noise (p-value of 0.026) in the FOV variation of 10x5cm KV90. There was an effect of voxel size on the spatial value of CBCT resolution, although it was not significant. Application of FOV variation of 10x10cm KV90 after Image-J filtering on median filter and sharpening was the most optimal way to produce the best endodontic image quality and anatomical information using CBCT.

Keywords: Noise, CBCT endodontic, Spatial resolution, Voxel

INTRODUCTION

Cone Beam Computed Tomography (CBCT) imaging technology was first introduced in the 21st century. Imagine using this technology has become popular and is often used to help dentists and other health care professionals in diagnostic tasks to improve the care towards orthodontic patients. In Indonesia, Cone Beam Computed Tomography (CBCT) is a new tool with a very limited tool population. This tool is currently available in seven hospitals within the Central Java and Special Region of Yogyakarta areas. The use of CBCT endodontic can detect periapical lesions, root fractures, and anatomical exploration of the root canal system and their abnormalities. CBCT examination is justified if the required diagnostic information cannot be obtained using a conventional dental tool. The results of previous CBCT examinations significantly provided more accurate results for detecting periapical lesions than conventional and digital radiographs. [1] This study showed that 26% of periapical lesions detected on CBCT examination were not detected on periapical radiographs. Even if two consecutive periapical X-rays from the same tooth were made at different angles, the accuracy of the detection of periapical radiographs could not be similar to the results of the CBCT scan. [2]. The previous study concluded that CBCT could be used to determine endodontic WL in combination with EAL [3], while other studies stated that limited CBCT could be used for WL measurement. [4, 5] In onother study it was explained that electronic measurements were more reliable than CBCT scans for WL. [6] The difference in the results of these studies arose due to different voxel sizes because each using different CBCT parameters will affect the image quality.

CBCT is a very useful diagnostic tool for conventional endodontic treatment to improve treatment planning. Spatial resolution and noise from CBCT image results will greatly affect the image quality associated with diagnostic accuracy. Unclear anatomical images are likely to occur because of poor image quality. Factors affecting unclear anatomical images are related to voxel size and there is a need to improve image quality. Advances in CBCT technology and 3D pre-endodontic evaluation can be used to detect apical periodontitis, diagnose resorption lesions, and plan endodontic treatment of root canal anatomical complexes. [7, 8] Based on the kids of literature, CBCT examination cannot to record subtle changes in attenuation in various tissue radiodensity ranges. Contrast resolution in endodontic is important to distinguish soft tissue, periapical or sinus contents. Optimal image resolution in endodontics involves the smallest structure that is affected by voxel size. From these backgrounds, the role of the variations in voxel size will be examined whether there is an effect on the quality of CBCT endodontic images. This study aims to prove the role of voxel size on physical/photographic image quality, and prove the role of voxel size on anatomical/pathological image quality. This was an empirical study on the role of the application of variations in voxel size on noise and spatial resolution of CBCT endodontic images and was a factual study of the phenomena in the field.

MATERIALS AND METHODS

This was a quasi-experimental study with a pre-post test only group design. The selection of this study design aims to determine changes before (pre-test) and after treatment (post-test) in the treatment group. The study subjects were CBCT images.

This study was carried out sequentially, by conducting a preliminary study first. The study began with the setting of variations in voxel size on the object of ACR CT phantom, to produce noise and spatial resolution values physically. Then study on the test object (human skull) was conducted. The use of test object aimed as a substitute for a human head to avoid the risk of exposure to radiation doses. The study sample were taken using a purposive sampling technique which is a technique in determining samples with certain considerations by following the desired study objectives. [9]

The study samples were ACR CT phantom images and the images of the test object (human skull). CBCT scanning used 2 (two) voxel size variations. Each voxel size was scanned with 6 (six) parameter variations. 3 samples of ACR CT phantom images were taken for each parameter.

Instruments used in this study included CBCT Carestream Tool, Laptop, Image-J Program for filtering median filter and sharpening, test object of ACR CT Phantom with the GAMMEX brand and human skull.

Descriptive statistical analysis was used to assess the spatial resolution and noise of ACR CT Phantom. Different test analysis of with Wilcoxon was used to assess the effect of the difference in endodontic anatomical information with CBCT before and after filtering the median filter and sharpening with Image-J. Determination of the optimal value in producing CBCT endodontic image quality was obtained from the best values compilation.

RESULTS

Noise measurement was done by selecting 3 images from each parameter. Then five ROIs were chosen, namely in the middle of the phantom image, in the directions of 3, 6, 9, 12 o'clock as shown in Figure 1. Furthermore, the mean value of each ROI was measured using Image-J software in the Dicom file with the plug-in Bio Format. The noise was measured from the standard deviation of the pixel value in ROI on the Phantom ACR CT module 3 scans. The results of the measurement of the mean noise value are shown in Table 1.

Table 1: Results of noise value measurement on phantom ACR CT using CBCT

FOV (cm)	KV	VOXEL µm	MEAN NOISE (STDev)
8X8	90	VOXEL180	5.4418
		VOXEL300	6.0968
8x8	60	VOXEL180	8.3734
		VOXEL300	8.7421
10x5	90	VOXEL180	7.2494
		VOXEL300	8.4072
10x5	60	VOXEL180	12.5263
		VOXEL300	13.0280
10x10	90	VOXEL180	4.6670
		VOXEL300	5.3650
10x10	60	VOXEL180	8.0702
		VOXEL300	8.6029

Voxel size of 180µm at high energy of KV 90 obtained the lowest mean value of noise of 4.6670 at a 10 cm FOV10x setting. Voxel size of 300µm at high energy of KV 90 obtained the lowest mean value of noise of 5.3650 in the 10 x 10 cm FOV setting. Voxel size of 180µm at low energy of KV 60 obtained the lowest mean value of noise of 8.0702 at a 10 x 10 cm FOV setting. Voxel size of 300µm at low energy of KV 60 obtained the lowest mean value of noise of 8.6029 at a 10 x 10 cm FOV setting. The lowest noise values that produced good image quality based on this study was shown in table 2.

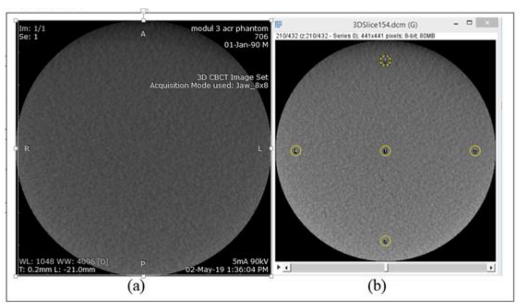

Figure 1. Image Noise of CBCT on ACR CT phantom noise with the axial slice on the phantom diameter of 200mm. a 90 KV, 180 µm b. ROI Measurement with Image-J

Table 2: Results of mean value of noise measurement that produced 6 good image quality

No	FOV(cm)	KV	mAs	VOXEL	MEAN NOISE
1	10x10	90	8	180	4.6670
2	10x10	90	8	300	5.3650
3	8X8	90	8	180	5.4418
4	8X8	90	8	300	6.0968
5	10x5	90	8	180	7.2494
6	10x5	90	8	300	8.4072

Figure 2. ACR Phantom module 4 scanning to measure high contrast (spatial) resolution as shown in Figure 2.

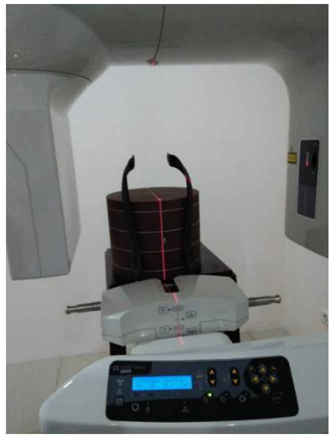

Figure 2. ACR CT Phantom

The results of high contrast (spatial) resolution measurement used the exposure factors of 60 KV, 90 KV, 40 mAs with voxel size variation of 180.300 μm and FOV size variations of 8X8 cm, 10x5cm, 10x10 cm. Spatial resolution was measured by visual analysis of bar patterns on the axial cut. Visual analysis of the bar pattern is determined only by grouping 9 and 10 lp/cm. Only two groups of images could be seen as pairs of lines that are separated on the axial due to the limited size of FOV as seen in figure 3. Example of axial cut images of voxel size variations.

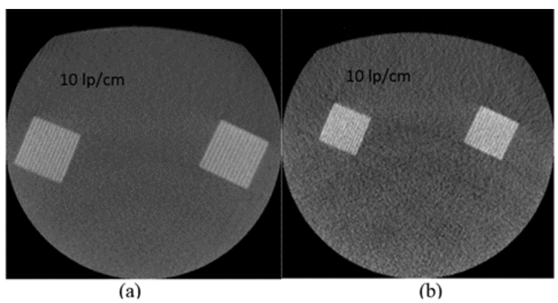

Figure 3. Pair of axial cut lines of ACR CT phantom module 4 (a) Voxel size of 180 μm, FOV 8x8, 90KV, 5 mA (b) Voxel size of 300 μm, FOV 10x5, 60KV, 5 mA

Spatial resolution was clear at high KV and not clear at low KV parameters. The results of visual measurements are shown in table 3. The mean value of spatial resolution at high energy level of KV 90 was better than at low energy level of KV 60.

Table 3: Results of Visual Spatial Resolution Measurement on ACR CT Phantom

***FOV* (cm)**	**KV**	**VOXEL**	**MEAN SPATIAL RESOLUTION**
8X8	90	Voxel of 180	3
		Voxel of 300	3
10x5	90	Voxel of 180	3
		Voxel of 300	3
10x10	90	Voxel of 180	3
		Voxel of 300	3
8x8	60	Voxel of 180	1
		Voxel of 300	1
10x5	60	Voxel of 180	1
		Voxel of 300	1
10x10	60	Voxel of 180	1
		Voxel of 300	1

The further test was a scan using a CBCT instrument on a human skull object as shown in figure 4. The exposure factor setting was the same as the test stage on ACR CT phantom. Exposure factors are 60 KV, 90 KV, 40 mAs with voxel size variations of 180 µm and 300 µm FOV 8 X 8cm, 10 x 5cm, 10 x 10 cm. The results of endodontic anatomical images were evaluated for spatial resolution and noise values and were assessed for anatomic information of lower premolar teeth by observers namely two Radiologists with more than 5 years experience. Scanning results of skull object with CBCT instrument and anatomy assessed can be seen in Figure 5.

Figure 4. Human Skull

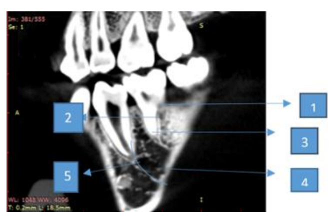

Figure 5. Anatomy of CBCT images assessed by observers 1. Enamel, 2. Dentin 3. Pulp chamber 4. Root canal, 5. Root length.

As many as 12 parameter variations of the samples of image results measurement were obtained. In Figure 6. The image of the skull that has not been filtered on the median filter and without sharpening with Image-J. And an example of image 7. Skull image that has been filtered on the median filter and uses sharpening with Image-J. In Figure 5. Filtering of the median filter was performed to reduce noise in the image, and then sharpening was arranged to add image detail.

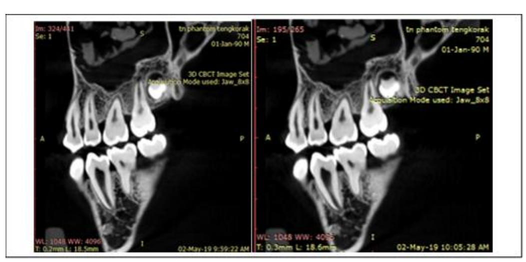

Figure 6. CBCT images of skull scan before Image-J filtering

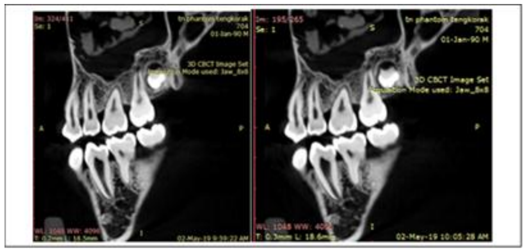

Figure 7. CBCT images of skull scan after Image-J filtering

Conformity analysis between observers was carried out on the results of the anatomic information and image quality assessments on CBCT scans. Evaluation of all images was carried out by the observers. The results of the image assessment were analyzed by the kappa test and shown in table 4. Observation of the image assessment was carried out twice to measure the consistency of the results conducted by the two observers.

Table 4: Kappa test for anatomic assessment of lower premolar teeth image using CBCT

Observer	Kappa Test	
	K	**Description**
Pre Observer 1* Pre Observer 2	0.756	Perfect
Post Observer 1 * Post Observer 2	0.866	Perfect

The results of the kappa test for the assessment of anatomical information on endodontic images of lower premolars using CBCT showed that observers 1 and 2 before processing using image-J obtained 0.756, and after processing using Image-J obtained 0.866. This indicated that the conformity of the answers of the two observers had a value of > 0.75, with a perfect conformity level.

Table 6. Different test on voxel size variations of anatomic information

VARIATION	MEAN	P VALUE
FOV8x8_vox180_kv90post- FOV8x8_vox180_kv90pre	4.214286 3.642857	0.004678
FOV8X8_vox180_kv60post FOV8X8_vox180_kv60pre	3.142857 3	0.157299
FOV8x8_vox300_kv90post FOV8x8_vox300_kv90pre	4.214286 3.642857	0.004678
FOV8x8_vox300_kv60post FOV8x8_vox300_kv60pre	3.357143 3	0.058782
FOV10x5_vox180_kv90post- FOV10x5_vox180_kv90pre	4.142857 3.642857	0.008151
FOV10X5_vox180_kv60post- FOV10X5_vox180_kv60pre	3.357143 3	0.058782
FOV10x5_vox300_kv90post- FOV10x5_vox300_kv90pre	4.142857 3.642857	0.008151
FOV10x5_vox300_kv60post- FOV10x5_vox300_kv60pre	3 3	1
FOV10x10_vox180_kv90post- FOV10x10_vox180_kv90pre	4 3.571429	0.014306
FOV10X10_vox180_kv60post- FOV10x10_vox180_kv60pre	3.285714 2.857143	0.033895

FOV10x10_vox300_kv90post-	4	0.023141
FOV10x10_vox300_kv90pre	3.428571	
FOV10x10_vox300_kv60post-	3.071429	0.157299
FOV10x10_vox300_kv60pre	2.928571	

There were differences in anatomical information on lower premolar teeth using CBCT after filtering the median filter and sharpening with Image-J. Bivariate analysis to test anatomical difference used the Wilcoxon Signed rank Test due to non-parametric scale data. Differences in anatomical information after difference test using the Wilcoxon Signed rank Test are shown in table 6. The p values of <0.05 in the pre and post difference test meant that there was a difference in anatomical information after processing with image-J. Based on table 6, in the variation of high energy paired samples at voxel sizes of 180 and 300 µm, it was obtained p values of <0.05. In the variation of low energy paired samples at 180 and 300 µm voxel sizes obtained p values of > 0.05. In the voxel size of 180µm at high energy of KV 90, the best anatomical information was obtained after filtering with image-J with a mean value of 4.214 in the 8x8 cm FOV setting. An inter-voxel difference test on 300 µm at high energy of KV 90 obtained the best anatomical information after processing with image-J with a mean value of 4.214 in an 8 x 8 cm FOV setting. Anatomical information difference test between the voxel size of 180µm and a voxel size of 300µm at KV 90 obtained a mean value of 4.214 in the 8x8 cm FOV setting.

The inter voxel difference test of 180µm at low energy of KV 60 obtained the best anatomical information after being processed with image-J with a mean value of 3.357 in the 10 x 5 cm FOV setting.

The mean ranks of anatomical information are shown in table 7.

Table 7. Application of filtering median filter and sharpening with Image-J towards the optimal anatomical information on CBCT endodontic images

PARAMETER	MEAN RANK
Voxel of 180µm *FOV* 8x8cm KV 90	59
voxel of300µm *FOV* 8x8cm KV 90	59
voxel of 180µm *FOV* 10x5cm KV 90	58
voxel of 300µm *FOV* 10x5cm KV 90	58
voxel of 180µm *FOV* 10x10cm KV 90	56
voxel of 300µm *FOV* 10x10cm KV 90	56

The best anatomical information values were in the parameter settings of voxel sizes of 180 µm and 300 µm 8x8cm, KV 90 after filtering the median filter and sharpening with Image-J. Wilcoxon test to observe differences in anatomical information based on voxel size variations can be seen in table 8.

Table 8. Wilcoxon test to observe differences in anatomical information based on voxel size variations

VARIATION	N	MEAN	STANDARD DEVIATION	P value
Voxel of 180 pre	6	50.33	1.211	.026
Voxel of 180 post	6	57.67	1.366	
Voxel of 300 pre	6	41.50	0.837	.041
Voxel of 300 post	6	44.83	2.137	

Information N : Number of Test Parameter Variations (FOV 8x8cm KV90, FOV 8x8cm KV60, FOV 10x5cm KV90, FOV 10x5cm KV60, FOV 10x10cm KV90, FOV 10x10cm KV90

The way to determine the best voxel size values can be seen in table 9 as the compilation of the results of spatial resolution visual analysis, the best noise and the best anatomy. Six parameters were obtained which resulted in optimization of endodontic anatomical image information with low noise value and spatial resolution value using visual analysis which had a good mean.

Based on table 9, it can be seen the best physical test results and selection of voxel size was at the voxel size of 180µm KV 90 FOV 10x10cm. Whereas regarding the best anatomical information on the KV 90 FOV 8x8cm setting to assess the CBCT endodontic, the 180µm and 300 µm voxel settings did not show a difference.

Table 9: Compilation of Study Results

CBCT PARAMETER	SPATIAL RESOLUTION	BEST NOISE	BEST ANATOMICAL INFORMATION
	VISUAL ANALYSIS		
VOXEL of 180µm KV 90 *FOV* 8X8	3	5.4418	59
VOXEL of 300µm KV 90 FOV 8X8	3	6.0968	58
VOXEL of 180µm KV 90 *FO*V 10X5	3	7.2494	59
VOXEL of 300µm KV 90 *FOV* 10X5	3	8.4072	56
VOXEL of 180µm KV 90 FOV 10X10	3	4.6670	58
VOXEL of 300µm KV 90 FOV 10X10	3	5.3650	56

Optimal endodontic images were those that have the good spatial resolution, anatomic values, the lowest noise in the 180µm KV 90 FOV 10x10cm voxel parameter setting as shown in Figure 8.

Figure 8. Endodontic image of lower premolar teeth in a 180µm KV 90 FOV 10x10cm voxel parameter setting

DISCUSSION

The noise was measured from the standard deviation of the pixel value in ROI on the ACR CT Phantom scan. Image noise is categorized into two types namely quantum noise and noise detector. [10] Quantum noise is produced by stochastic fluctuations related to absorption and scattering processes when radiation passes through an object. The number of quanta that reaches the detector varies. Quantum noise is proportional to X-ray intensity. Detector noise is caused by thermal noise generated by electrons in the detector and is not dependent on X-ray exposure. The parameters for all variations of the mAs value test in this study were set equal so that the noise factor caused by radiation intensity could be minimized. Image noise which is visually in the form of dots differing in colour from the surrounding colour and grainy not only depends on the intensity of the radiation but also depends on the reconstruction algorithm and the thickness of the incision. [10] This difference can also be due to the number of quanta produced by the X-ray generator which is then detected by the detector. The amount of this quanta is a function of thickness, density of the object being scanned, and the quality of the X-ray beam. To find out whether the X-ray generator is functioning properly or not, an X-ray tube potential accuracy test and mAs setting has been carried out and have been declared to have passed the conformity test by the BPFK testing institute. This conformity test is important because the potential miscalibration of X-ray tubes can cause quantitative analysis errors. [11]

Based on the descriptive output, the highest mean value of noise was obtained at a voxel size of 300µm KV 60, and the lowest noise value at a vape cell size of 180 µm KV 90. In this study, an increase in the voxel size would affect the noise value, and an increase in the exposure factor ,in this case, the KV would decrease noise value in the image. The use of high KV produces homogeneous energy so that X-ray scattering will decrease and the noise value will be better. The best noise value can be seen in the lowest mean value of noise, while the high mean value of noise will produce a bad image. From the results of the measurement table on noise value, it was obtained a p-value of> 0.05 then H0 was accepted and Ha was rejected. It indicated that there was no difference in the mean value of noise between voxel sizes of 180 and 300µm. If the p-value was <0.05, then H0 was rejected and Ha was accepted, which meant there was a significant difference in the mean value of noise between voxel sizes of 180 µm and 300µm. At the size of 10x5cm FOV, KV 90, there was a significant difference between the mean value of noise between voxel sizes of 180 µm and 300µm. In another study [12] it was found that using smaller voxels detected fewer X-ray photons than using larger voxels. A decrease in the number of photons that small voxels received resulted in a decreased in the signal, which led to an increase in image noise. A scan was performed using the CBCT instrument on ACR CT Phantom module 4. In this study the spatial resolution value based on visual analysis of the bar pattern only appeared in 9 and 10 lp/cm groups, it was due to the FOV limitations on the CBCT instrument. Spatial resolution is one of the most important parameters that objectively determines the quality of dental endodontic images. In this study visual analysis was assessed at 10 lp/cm. Based on the descriptive output, there was no difference in the mean value of resolution between voxel size of 180µm and a voxel size of 300µm. It can also be seen In this study that the spatial resolution changed significantly when the KV value increased. The best resolution value was at KV 90 with voxel sizes of 180 or 300 µm, while the lowest resolution spatial value was at KV 60 with voxel size of 180 or 300 µm.

It is stated in the literature that spatial resolution of visual pair lines (lp) measurement ranges from 0.6 to 2.8 lp/mm. [13] Previous study carried out spatial resolution measurement based on visual analysis on a grouping of 10 lp/cm. [14] According to the study, at 0.4mm, 0.3mm, 0.25mm and 0.2mm voxel sizes, there were no differences in spatial resolution based on visual analysis. Meanwhile, measurement using MTF with the voxel sizes of 0.2mm and 0.25mm produced better resolution than 0.3mm and 0.4mm voxel sizes. The result another study found that voxel size affected spatial resolution. [15,16] The greater the voxel size, the less the spatial resolution. This was du to the measurement of the mean value of spatial resolution used visual so that the validity would be reduced compared to physical measurement using the MTF value. Anatomical information on CBCT endodontic images after Image-J filtering on median filter and sharpening based on dental anatomical criteria included images of enamel, dentin, pulp chamber, root canal, root length, resolution and noise. The results which obtained p-value of <0.05 showed in the pre and post different test on voxel sizes of 180 and 300µm meant that there was a difference in anatomical information after processing with image-J. Meanwhile, results which obtained p-value of > 0.05 showed in the pre and post different test on voxel sizes of 180 and 300µm meant that there was no difference in anatomical information after processing with image-J. The results of different test table on information obtained a p-value of <0.05 in the variations of KV 90 parameter of all FOVs and there was a difference in anatomical information before and after processing with Image-J in KV 60 FOV 10x10 voxel size of 180µm, whereas in KV 60, other than FOV 10x10 voxel size of 180 µm had a p value of >

0.05 which meant that there was no difference before processing with Image-J.

In this study, the highest image anatomy information was on the FOV 8x8 KV 90 post-Image-J processing with voxel sizes of 180 and 300 µm post the application of the median filter and sharpening using Image-J with a mean rank value of 4.21486. The voxel sizes of 180 and 300 µm did not significantly influence the image information. This is inconsistent with the previous study that images obtained with a voxel size of 0.2mm were significantly more accurate than those obtained using a voxel size of 0.4mm. [17] In the physical measurement of noise and spatial resolution, the best image resolution was on the parameter setting of voxel 180µm KV 90 FOV 10x10cm. The application of a combination of median filter and sharpening using image-J resulted in a better endodontic image of lower premolar teeth, as shown in Figure 9. For anatomical information, the voxel size of 180 µm had a p-value of 0.026 and voxel size of 300 µm had a p-value of 0.041, meaning that there were differences in anatomical information with voxel size variations. Filtering the median filter and sharpening using Image-J were able to minimize noise, improve image quality and anatomical information on CBCT endodontics.

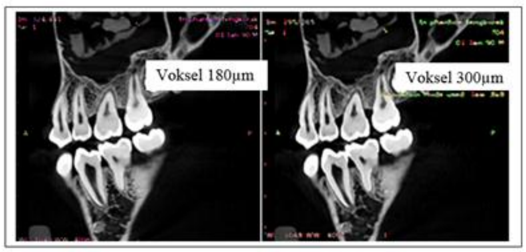

Figure 9. Endodontic image post image-J FOV 8x8cm KV 90 processing

CONCLUSIONS AND RECOMMENDATIONS

Based on the results it can be concluded that the filtering of the median filter and sharpening with Image-J were able to minimize noise, improve endodontic anatomical image quality and information using CBCT. The voxel size of 180 µm had a lower noise value than the voxel size of 300 µm, there was a significant effect of voxel size on CBCT noise (p-value of 0.026) on the FOV variation of 10x5cm KV90, it was not significant on other variations. The lowest noise value was 4.667 in the 180µm FOV 10x10cm KV 90 voxel parameter setting. There was an effect of voxel size on the CBCT spatial resolution value although it was not significant with p-value of > 0.05. In the KV 90 exposure factor setting, the mean value of spatial resolution was better than the KV 60 exposure factor in all FOV variations. The application of the FOV variation of 10x10cm KV90 after filtering the median filter and sharpening using Image-J was the most optimal way to produce the best endodontic image quality and anatomical information using CBCT, the highest mean rank value was 4.2142 both at voxel sizes of 180 and 300µm. Similar further studies in the future can be conducted using a phantom object, a preferably dental phantom with endodontic abnormalities. Assessments on resolution and noise should use the CBCT on QCT phantom. Studies on CBCT endodontic image quality should not only examine spatial resolution, but contrast resolution is also important to study.

ACKNOWLEDGEMENTS

On this opportunity, I would like to deliver sincere gratitude to all those who have encouraged me both morally and materially, especially to my husband, children and parents for their continuous support throughout the study at Semarang Health Polytechnic of the Ministry of Health. The author expects that this Journal can be useful for the educational environment of Semarang Health Polytechnic of the Ministry of Health, particularly Postgraduate Program of Master of Applied Diagnostic Imaging, and for all parties who read it in general.

REFERENCES

[1]. Bornstein MM, Lauber R, Joint P, Arx T von. Comparison of periapical radiographs and cone-beam computed tomography was limited to mandibular molar for analysis of landmark anatomy before apical surgery. Endod J 37, 2011, 151-157.

[2]. Sogur E, Grondahl HG, Baksı BG, Mert A. Does the combination of two radiographs improve accuracy in detecting acid-induced periapical lesions and does it approach the accuracy of beam-beam tomography scanning? Endod J 38, 2012, 131-136

[3]. Janner, S.F., Jeger, F.B., Lussi, A., Bornstein, M.M., Precision of endodontic working length measurements: a pilot investigation comparing cone-beam computed tomography scanning with standard measurement techniques. J.Endod. 37(8), 2011, 1046–1051.

[4]. Jeger, F.B., Janner, S.F., Bornstein, M.M., Lussi, A., Endodontic working length measurement with preexisting cone-beam computed tomography scanning: a prospective, controlled clinical study. J. Endod. 38(7), 2012, 884–888.

[5]. Liang, Y.H., Jiang, L., Chen, C., Gao, X.J., Wesselink, P.R., Wu, M.K., Shemesh, H., The validity of cone-beam computed tomography in measuring root canal length using a gold standard. J. Endod. 39(12), 2013, 1607–1610.

[6]. Lucena, C., Lopez, J.M., Martin, J.A., Robles, V., Gonzalez-Rodriguez, M.P., Accuracy of working length measurement: electronic apex locator versus cone-beam computed tomography. Int. Endod. J. 47(3), 2014, 246–256.

[7]. Patel S, The use of cone beam computed tomography in the conservative management of dens invaginatus: a case report. Int. Endod. J. 43(8), 2010, 707–713

[8]. Patel, S., Dawood, A., Ford, T.P., Whaites, E., The potential applications of cone beam computed tomography in the management of endodontic problems. Int. Endod. J. 40(10), 2007, 818–830.

[9]. Weber EC, Vilensky JA, Carmichael SW, Lee KS. Netter's Concise Radiologic Anatomy. Elsevier 2, 2014.

[10]. Buzug TM, Computed Tomography From Photon Statistics to Modern Cone Beam CT, Springer-Verlag Berlin, 2008.

[11]. Lin PP, Beck TJ, AAPM Report No. 39, Spesification and Acceptance Testing of Computed Tomography Scanners. The American Institute of Physics New York

[12]. Bechara B, McMahan CA, Moore WS, Noujeim M, Geha H, Teixeira FB. Contrast-to-noise ratio difference in small field of view cone beam computed tomography machines. J Oral Sci. 54(3), 2012, 227-32

[13]. Brullmann D, Schulze RK. Spatial resolution in CBCT machines for dental/maxillofacial applications-what do we know today? Dentomaxillofac Radiol 44, 2015, 20140204

[14]. Sonya DA, Davies J, Ford NL. A comparison of cone-beam computed tomography image quality obtained in phantoms with different fields of view, voxel size, and angular rotation for iCAT NG. J Oral Maxillofac Radiol 4, 2016, 31-9

[15]. Spin-Neto R, Gotfredsen E, Wenzel A.Impact of Voxel Size Variation on CBCT-Based Diagnostic Outcome in Dentistry: a Systematic Review.J Digit Imaging 26, 2013, 813-820

[16]. Al-Rawi B, Hassan B, Vandenberge B, Jacobs R: Accuracy assessment of three-dimensional surface reconstructions of teeth from cone beam computed tomography scans. J Oral Rehabil 37, 2010, 352–358.

[17]. Librizzi ZT, Tadinada AS, Valiyaparambil JV, Lurie AG, Mallya SM: Cone-beam computed tomography to detect erosions of the temporomandibular joint: effect of field of view and voxel size on diagnostic efficacy and effective dose. Am J Orthod Dentofacial Orthop 140, 2011, 25–30.

How to cite this article: Solikhatul Istijabah, Lina Choridah, Gatot Murti Wibowo, Hari Santoso, M. Choiroel Anwar, Sugiyanto. The role of the application of variations in voxel size on noise and spatial resolution of cbct endodontic images. Int J of Allied Med Sci and Clin Res 2020; 8(1): 32-42.
Source of Support: Nil. **Conflict of Interest:** None declared.