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ORIGINAL RESEARCH ARTICLE

# Evaluation of the Effect of Spatial Resolution on Image Quality in Phosphor Plate Systems

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## Abstract

**Purpose:** This study aims to investigate the effect of 4 different scanning protocols offered by the VistaScan Mini Easy scanner on image quality at different exposure times.
**Materials and Methods:** Four number size-2 photostimulable phosphor plates were exposed with 5 different exposure times while keeping the other parameters constant. The exposed plates were scanned without delay using 4 different scanning protocols. 10 lp/mm, 20 lp/mm, 25 lp/mm, and 40 lp/mm are offered by the VistaScan Mini Easy scanner. The mean gray value was calculated using the ImageJ program by identifying three non-overlapping regions of interest from the background and each step in the obtained images. The mean of all mean gray values determined for the background and steps on a plate was also considered the mean gray value of that plate.
**Results:** When plate mean gray values at 0.20 s and 0.40 s were examined, a statistically significant difference was observed between the scanning protocols ($p<0.001$, $p=0.001$ respectively). It was determined that the plate mean gray value at 40 lp/mm in 0.20 s was lower than that of other scanning protocols. The plate mean gray value at 20 lp/mm in 0.20 s was higher than that at 25 lp/mm. It was determined that the plate mean gray value at 10 lp/mm in 0.40 s was lower than that of the other groups.
**Conclusions:** The effect of spatial resolution on diagnostics in digital imaging per se is a subject under investigation and still not agreed upon.

**Key words**: digital imaging; photostimulable phosphor plate; spatial resolution

## Introduction

Recently, with the help of developing technology, different digital imaging methods have been developed.[1,2] Although conventional imaging methods continue to be used in dentistry, the advantages of digital imaging methods have attracted the attention of dentists and these systems are gradually replacing conventional methods.[3] The most important reasons for the rapid spread of digital imaging methods are that a quality image can be obtained quickly, and images can be easily stored and transmitted.[4–6] Image formation in digital systems is based on the digital recording of the radiographic image after the exposure of solid-state detectors or photostimulable phosphor plate (PSP).[7] PSPs are similar in size to conventional films and are wireless. Additionally, since it is thin and flexible like conventional films, it is easier to manipulate in the mouth than other digital systems.[4,6,8] It is widely used in clinical practice because of the convenience provided by the PSP system and the ability to obtain images with a lower radiation dose compared to conventional radiographs.[9,10] In the PSP system, photo-stimulated phosphor luminescent plates are used. To digitize the analog image formed on the PSP, additional scanning equipment is required. Therefore, these systems are also termed semi-direct digital imaging techniques.[11] With the widespread use of digital systems, there are PSP systems of different manufacturers in the market.[12] The features of the PSP system and the scanner used vary according to the manufacturers. Some commercially available PSP systems offer the possibility to choose between high and low-resolution settings during scanning, allowing images of different resolutions to be obtained. This allows the evaluation of the relationship between spatial resolution and diagnostic image quality. The spatial resolution of the PSP receptor is a parameter that determines the quality of the final image.[13] The spatial resolution of the receptor indicates its ability to distinguish details in radiographic images and varies with pixel size. The spatial resolution is usually expressed



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in pairs of lines per millimeter (lp/mm).[13,14] Since there is a direct relationship between the resolution selected before scanning and the scanning time, slow scan motion affects resolution by increasing plate advancement. This method is used in some PSP systems to increase or decrease the resolution.[15] The effect of spatial resolution per se on diagnosis in digital imaging is a subject that has been researched and is still not agreed upon.[13,16] Additionally, the number of radiographs taken daily in the clinic and the information system of the clinic are also important in the selection of resolution, since the choice of resolution during scanning affects the scanning time and storage area. This study examines the relationship between spatial resolution and image quality by using four different scanning protocols offered by the VistaScan Mini Easy (Dürr Dental, Bietigheim-Bissingen, Germany) scanner with different exposure times.

## Material and Methods

In this study, four never used VistaScan (Dürr Dental, Bietigheim-Bissingen, Germany) branded size-2 PSP were used. PSPs were first scanned with a strong light source in the scanner to clear them of background effects. To standardize the distance between the X-ray device and the PSP, a setup consisting of a parallel technical apparatus was made. This setup allowed a repeatable vertical constant distance of 27.2 cm between the X-ray device and the PSP ( Figure 1). All radiographic exposures included a 9-step wedge made of a 99.5% pure aluminum (Al) scale (each step of a thickness of 1 mm). An X-ray device with a total filtration of 1.5 mm Al equivalent (CCX Radiography Unit, Trophy, Instrumentarium, Tuusula, Finland) in the radiology clinic of Gazi University Faculty of Dentistry was used for radiographic imaging. All exposures were performed using five different exposure times (0.10 s, 0.16 s, 0.20 s, 0.34 s, and 0.40 s) in which 70 kV and 8 mA parameters were kept constant. The exposed PSPs were transported in a closed, opaque box and without waiting after exposure. PSPs were scanned with the VistaScan Mini Easy (Dürr Dental, Bietigheim-Bissingen, Germany) scanner with four different scanning protocols as 10 lp/mm, 20 lp/mm, 25 lp/mm, and 40 lp/mm.

Minimal ambient lighting was used in the scanning room. A total of 80 images were obtained using 5 different exposure times × 4 different scanning protocols × 4 PSPs. All exposure and scanning procedures were performed by the same researcher to ensure standardization. The resulting images were downloaded to a personal computer in JPEG (Joint Photographic Experts Group) format and converted to 8-bit TIFF (Tagged Image File Format) files. Images obtained using ImageJ ([National Institutes of Health, Bethesda, MD]; https://imagej.nih.gov/ij/), a publicly available software, were analyzed for gray values. While determining the mean gray value (MGV) in the images, the black was assigned a value of 0 and the white value of 255 by the ImageJ program. MGVs were measured by determining three non-overlapping ROIs (Region of Interest) (40×40 pixels) from each step and background in the acquired images. The value obtained by averaging all MGVs calculated from the steps and background in an image was recorded as the MGV of that plate. The data obtained in the study were analyzed using the SPSS 25.0 (Statistical Package for Social Sciences) program. Descriptive statistical methods (mean, standard deviation, median) were used while evaluating the data. Also, the normal distribution of the data used was tested with Kolmogorov-Smirnov and Shapiro-Wilk tests. In the comparison of measurements of more than two independent groups, analysis of variance (ANOVA) was used for normally distributed measurements, and Kruskal-Wallis analysis was used for non-normally distributed measurements. If there was a statistically significant difference between the groups, Bonferroni analysis was performed to determine if between the two groups the difference.

## Results

When the MGVs of the exposure times were compared, the MGV at 0.10 s was smaller than the other exposure times, but this difference was not statistically significant. MGVs determined according to different scanning protocols at exposure times are shown in Figure 2. The MGVs determined for the background and steps are shown inFigure 3. At 0.20 s and 0.40 s exposure times, the MGVs of the plates scanned with different scanning protocols showed statistically significant differences ($p<0.001$, $p=0.001$ respectively). For 0.20 s, plate MGVs obtained at 40 lp/mm scanning protocol were always lower than the others ($p=0.001$, $p<0.001$) (Table 3). In other compared protocols, only plate MGV obtained at 25 lp/m was statistically significant lower than at 20 lp/m ($p=0.037$, $p<0.05$) (Table 3). For 0.40 s, plate MGVs obtained in the 10 lp/m scanning protocol were always lower than the others (Table 5). Plate MGV in images scanned at 10 lp/mm resolution in 0.40 s is lower than plate MGV in images scanned at 20 lp/mm, 25 lp/mm, and 40 lp/mm resolution ($p=0.015$, $p=0.003$, $p=0.005$, respectively) (Table 5). The MGVs of the images acquired at 0.10 s, 0.16 s, and 0.34 s in different scanning protocols are shown in Table 1, Table 2, and Table 4, respectively.

## Discussion

PSPs are a type of digital image receptor that is similar in size and thickness to conventional periapical films and are widely used in intraoral imaging.[17] The choice of the ideal PSP system depends on digital image-related factors that can directly affect image quality. The spatial resolution, which is defined as the capacity to distinguish fine details in an image, is among these factors. The thickness of the phosphor material and the diameter of the laser beam affect the resolution in PSP systems.[15] According to manufacturers, the higher the lp/mm, the better the image resolution.[17] New PSP systems on the market offer a theoretical resolution option of up to 40 lp/mm. Although there are studies on the effect of spatial resolution on diagnosis, the effect of increased resolution alone on diagnosis is still unclear.[13,16,18]

The effect of spatial resolution in the diagnosis of different cases such as caries lesions, and root fracture, root resorption has been investigated by many researchers.[13,17,19,20] While some studies have shown that the spatial resolution of the PSP system has no effect in detecting proximal caries lesions,[16,21,22] some studies have shown that spatial resolution is effective in detecting caries lesions.[13] Ferreira et al. found higher accuracy in images with a low spatial resolution for carious lesions in enamel.[13] Li et al. evaluated proximal caries using the different spatial resolutions offered by the Digora Optime and Dürr VistaScan PSP systems and found that increased theoretical spatial resolution was not associated with better detection of proximal caries.[19]

De Oliveira et al. suggested using a combination of endodontic filters with high spatial resolution and high contrast resolution to determine file lengths when using the VistaScan PSP system.[23] Lacerda et al. found that higher spatial resolution improved the radiographic diagnosis of external root resorption in multi-rooted teeth.[17] Mauro et al. evaluated the image quality using different exposure times and scanner resolutions in their study to develop a protective device for PSPs. Although there was no statistical difference in terms of MGVs between groups formed according to protective devices, there were differences in exposure times (0.06-0.25 s, 0.06-0.40 s, 0.10-0.40 s).[18]

Similarly, in our study, when the MGVs of the exposure times were compared, the MGV at 0.10 s was smaller than the other exposure times, but this difference was not statistically significant. In our study, plate MGV showed a statistically significant difference in 0.20 s and 0.40 s between scanning protocols according to exposure times. Plate MGV at 40 lp/mm in 0.20 s is lower than that of other scanning protocols. Additionally, in our study, plate MGV at

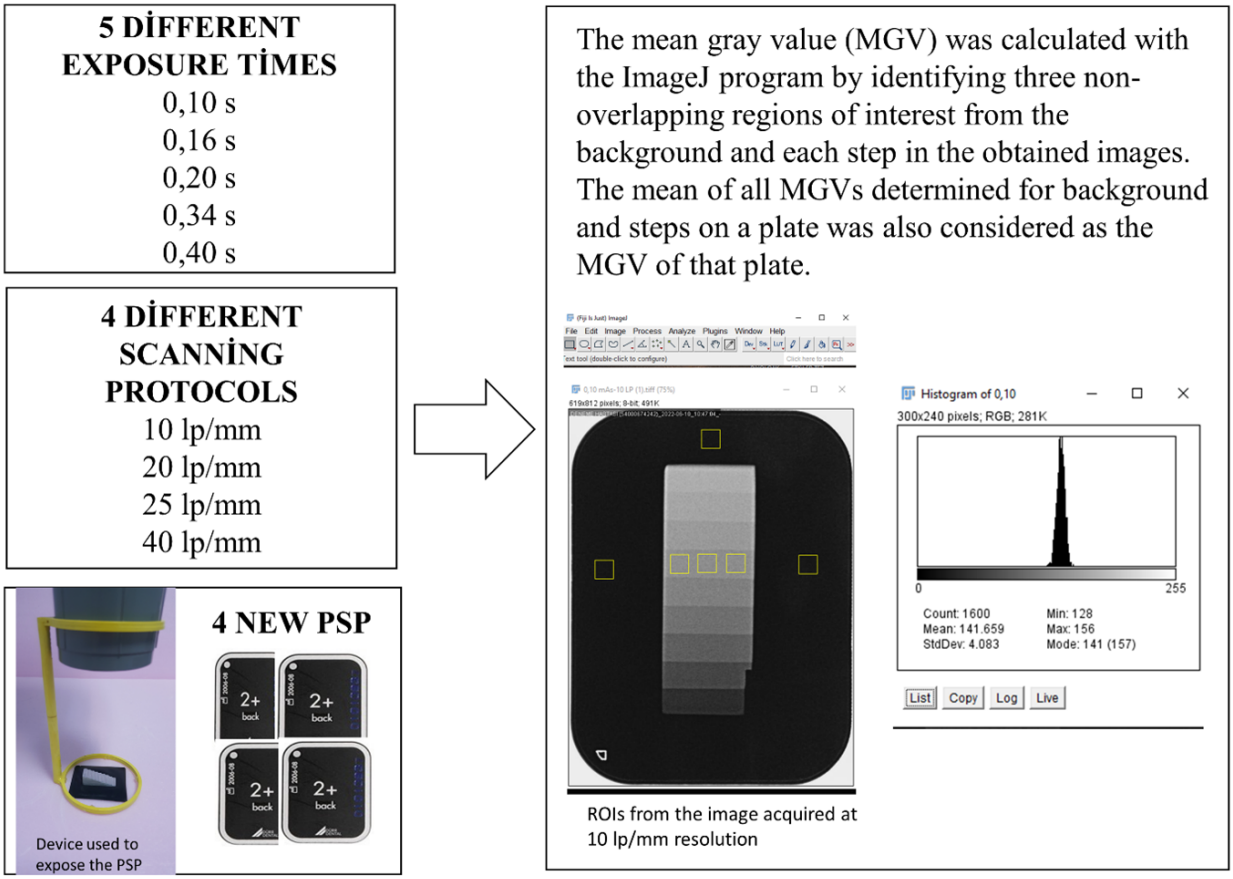


**Figure 1.** Flow chart showing the number of variables and the mechanism and methodology used

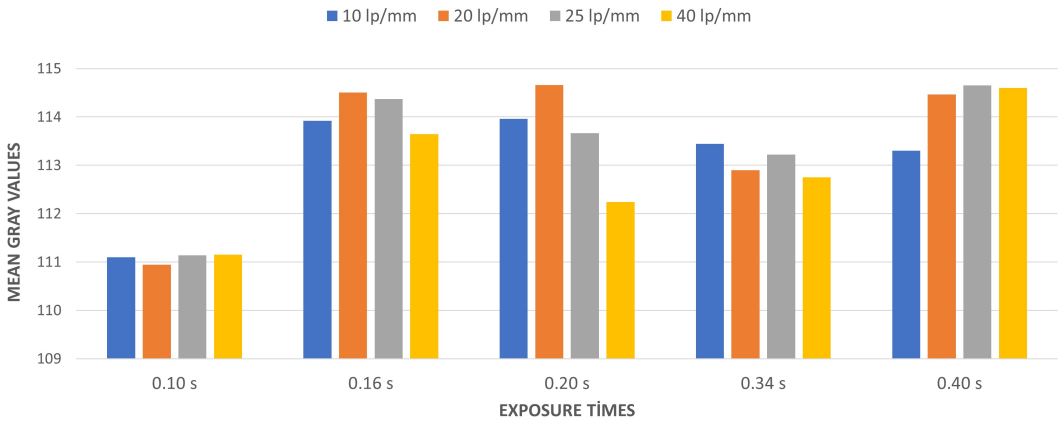


**Figure 2.** MGVs of different scanning protocols at exposure times

20 lp/mm in 0.20 s is statistically significantly higher than that at 25 lp/mm. This result in our study is consistent with the result of Moura et al.'s study that a scanning resolution of 20 lp/mm showed higher MGV than 25 and 40 lp/mm.[18]

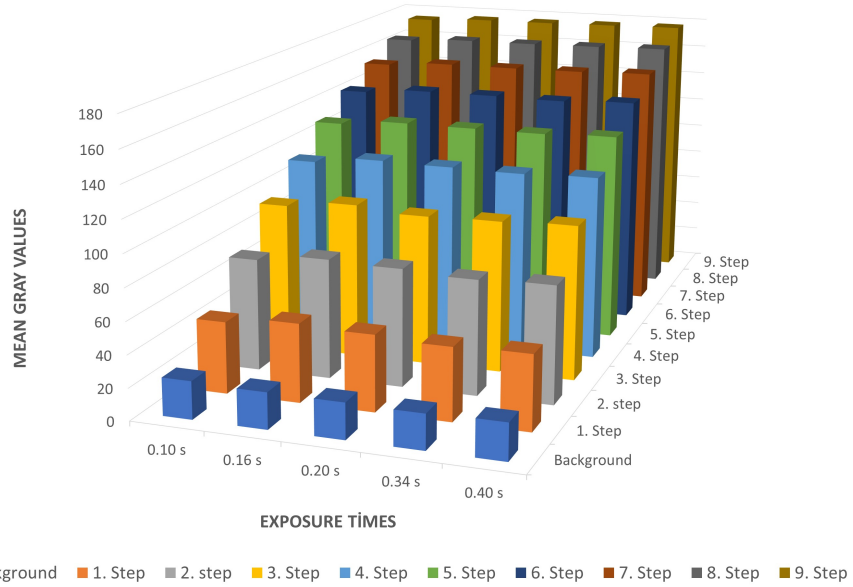


**Figure 3.** Step MGVs at different exposure times

**Table 1.** Comparison of MGVs between scanning protocols at an exposure time of 0.10 s

| | 10 lp/mm (1) | | | 20 lp/mm (2) | | | 25 lp/mm (3) | | | 40 lp/mm (4) | | | Test statistic | p | Bonferroni | p |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | m | x | s | m | x | s | m | x | s | m | x | s | | | | |
| **Background** | 23.64 | 23.81 | 0.82 | 23.72 | 23.78 | 1.13 | 22.85 | 22.83 | 0.94 | 23.52 | 23.80 | 1.24 | F=2.568 | 0.066 | - | |
| **1. Step** | 44.49 | 44.87 | 1.54 | 43.91 | 43.89 | 1.61 | 45.09 | 45.26 | 2.30 | 44.99 | 45.40 | 1.87 | F=1.622 | 0.198 | - | |
| **2. Step** | 70.37 | 70.68 | 1.40 | 70.02 | 69.87 | 1.50 | 70.59 | 70.79 | 1.63 | 70.44 | 71.88 | 3.26 | $X^2$=2.642 | 0.487 | - | |
| **3. Step** | 94.10 | 93.95 | 1.02 | 93.27 | 93.41 | 1.32 | 94.14 | 94.02 | 1.20 | 93.94 | 94.27 | 1.83 | F=0.830 | 0.484 | - | |
| **4. Step** | 112.24 | 112.49 | 0.95 | 112.02 | 112.47 | 1.06 | 112.72 | 112.73 | 0.78 | 112.69 | 112.46 | 1.32 | F=0.188 | 0.904 | - | |
| **5. Step** | 128.22 | 128.65 | 1.23 | 129.04 | 129.08 | 1.36 | 129.16 | 129.28 | 1.52 | 129.45 | 129.23 | 1.34 | F=0.529 | 0.665 | - | |
| **6. Step** | 142.18 | 142.41 | 1.11 | 142.87 | 142.67 | 1.64 | 142.92 | 143.05 | 1.37 | 142.69 | 142.54 | 1.09 | F=0.513 | 0.675 | - | |
| **7. Step** | 154.38 | 154.40 | 1.05 | 154.69 | 154.48 | 1.21 | 154.62 | 154.60 | 0.82 | 154.07 | 154.18 | 1.39 | F=0.295 | 0.829 | - | |
| **8. Step** | 164.75 | 165.30 | 1.25 | 165.54 | 165.62 | 1.43 | 165.10 | 165.04 | 0.79 | 164.13 | 164.53 | 1.65 | F=1.464 | 0.237 | - | |
| **9. Step** | 174.53 | 174.48 | 0.56 | 174.04 | 174.12 | 1.26 | 173.92 | 173.83 | 0.83 | 173.31 | 173.27 | 1.02 | F=3.417 | 0.025* | 4<1 | 0.021 |
| **Plate MGV** | 110.69 | 111.10 | 0.85 | 110.78 | 110.94 | 0.97 | 111.06 | 111.14 | 0.88 | 111.28 | 111.15 | 0.90 | F=0.147 | 0.931 | - | |

*p<0.05 F: Analysis of variance (ANOVA) Test Statistic $X^2$: Kruskal-Wallis Test Statistic

**Table 2.** Comparison of MGVs between scanning protocols at an exposure time of 0.16 s

| | 10 lp/mm (1) | | | 20 lp/mm (2) | | | 25 lp/mm (3) | | | 40 lp/mm (4) | | | Test statistic | p | Bonferroni | p |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | m | x | s | m | x | s | m | x | s | m | x | s | | | | |
| **Background** | 22.64 | 22.47 | 0.76 | 22.52 | 22.67 | 0.84 | 22.72 | 22.82 | 0.84 | 22.81 | 22.49 | 0.73 | F=0.524 | 0.668 | - | |
| **1. Step** | 48.82 | 48.68 | 1.68 | 49.10 | 49.25 | 0.84 | 49.37 | 49.51 | 2.10 | 49.01 | 48.90 | 1.18 | F=0.696 | 0.559 | - | |
| **2. Step** | 75.03 | 75.09 | 1.77 | 75.63 | 75.86 | 1.22 | 75.94 | 75.90 | 1.97 | 75.00 | 75.20 | 1.75 | F=0.752 | 0.527 | - | |
| **3. Step** | 97.99 | 97.99 | 1.74 | 99.01 | 99.15 | 1.52 | 98.14 | 98.76 | 2.33 | 97.27 | 97.61 | 2.35 | F=1.453 | 0.240 | - | |
| **4. Step** | 116.58 | 116.51 | 1.22 | 117.08 | 117.29 | 0.90 | 117.19 | 117.18 | 1.48 | 116.64 | 116.62 | 1.24 | F=1.215 | 0.315 | - | |
| **5. Step** | 132.23 | 132.30 | 1.17 | 132.74 | 132.99 | 1.31 | 132.93 | 132.83 | 1.58 | 131.84 | 132.08 | 1.08 | F=1.313 | 0.282 | - | |
| **6. Step** | 145.61 | 145.58 | 1.21 | 146.18 | 146.12 | 1.27 | 146.09 | 146.08 | 1.52 | 144.96 | 145.37 | 1.37 | F=0.905 | 0.446 | - | |
| **7. Step** | 157.01 | 157.14 | 1.27 | 157.47 | 157.65 | 1.14 | 157.45 | 157.37 | 1.19 | 156.55 | 156.56 | 1.31 | F=1.699 | 0.181 | - | |
| **8. Step** | 166.99 | 167.00 | 1.08 | 167.66 | 167.67 | 0.99 | 167.37 | 167.41 | 1.31 | 166.80 | 166.69 | 1.30 | F=1.640 | 0.194 | - | |
| **9. Step** | 175.95 | 176.39 | 1.24 | 176.16 | 176.32 | 0.75 | 175.96 | 175.89 | 1.02 | 174.96 | 174.89 | 0.88 | F=5.858 | 0.002* | 4<1<br>4<2 | 0.003*<br>0.006* |
| **Plate MGV** | 113.87 | 113.92 | 1.20 | 114.47 | 114.50 | 0.88 | 114.41 | 114.37 | 1.39 | 113.41 | 113.64 | 0.97 | F=1.499 | 0.288 | | |

*p<0.05 F: Analysis of variance (ANOVA) Test Statistic $X^2$: Kruskal-Wallis Test Statistic

In the VistaScan system, Moura et al. recommended the use of a spatial resolution of 25 lp/mm for improved image quality,[18] while Li et al. suggested that the standard spatial resolution should be 20 lp/mm for detecting proximal caries.[19] In our study, plate MGV was found to be lower than the other groups at 10 lp/mm in 0.40 s. In line with the findings of this study, we think that a resolution higher than 10 lp/mm, which is considered standard and fast, should be selected in the VistaScan system.

The choice of spatial resolution in the scan also affects the image processing time and image size. Processing high-resolution images mean more scanning time. Scanning times for the size-2 PSP of the VistaScan Mini Easy (Dürr Dental, Bietigheim-Bissingen, Germany) scanner for resolutions of 10 lp/mm, 20 lp/mm, 25 lp/mm, and 40 lp/mm are 8 s, 16 s, 20 s, and 32 s. respectively. A reason why digital imaging is frequently preferred is that images can be obtained in a short time. In a busy dental clinic, obtaining high-

**Table 3.** Comparison of MGVs between scanning protocols at an exposure time of 0.20 s

| | 10 lp/mm (1) | | | 20 lp/mm (2) | | | 25 lp/mm (3) | | | 40 lp/mm (4) | | | Test statistic | p | Bonferroni | p |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | m | x | s | m | x | s | m | x | s | m | x | s | | | | |
| **Background** | 22.26 | 22.23 | 0.46 | 22.27 | 22.37 | 0.53 | 22.75 | 23.15 | 0.92 | 21.70 | 21.98 | 1.17 | X2=13.438 | 0.004* | 4<3 | 0.007* |
| **1. Step** | 47.63 | 48.23 | 1.17 | 49.05 | 49.22 | 1.28 | 46.77 | 47.19 | 1.34 | 45.47 | 45.68 | 1.56 | F=15.150 | 0.000* | 4<1<br>3<2<br>4<2 | 0.000*<br>0.004*<br>0.000* |
| **2. Step** | 74.68 | 74.61 | 1.48 | 75.76 | 75.72 | 1.58 | 74.45 | 74.19 | 1.34 | 72.69 | 72.71 | 1.01 | F=9.958 | 0.000* | 4<1<br>4<2 | 0.009*<br>0.000* |
| **3.Step** | 97.96 | 97.82 | 1.37 | 98.63 | 98.83 | 1.24 | 96.41 | 96.64 | 1.86 | 95.52 | 95.29 | 1.98 | F=10.336 | 0.000* | 4<1<br>3<2<br>4<2 | 0.003*<br>0.013*<br>0.000* |
| **4. Step** | 116.76 | 116.63 | 0.96 | 117.36 | 117.60 | 0.72 | 115.85 | 116.14 | 0.95 | 114.46 | 114.44 | 0.75 | F=28.841 | 0.000* | 1<2<br>3<2<br>4<2<br>4<3<br>4<1 | 0.046*<br>0.001*<br>0.000*<br>0.000*<br>0.000* |
| **5. Step** | 132.19 | 132.49 | 1.08 | 132.91 | 133.51 | 1.26 | 132.13 | 132.46 | 1.34 | 130.39 | 130.58 | 1.21 | F=11.977 | 0.000* | 4<1<br>4<2<br>4<3 | 0.002*<br>0.000*<br>0.003* |
| **6. Step** | 145.54 | 145.99 | 1.14 | 146.43 | 146.79 | 1.16 | 146.23 | 145.97 | 1.16 | 144.32 | 144.45 | 0.98 | F=9.288 | 0.000* | 4<1<br>4<2<br>4<3 | 0.009*<br>0.000*<br>0.010* |
| **7. Step** | 157.17 | 157.44 | 0.86 | 157.69 | 157.96 | 0.90 | 157.56 | 157.43 | 0.94 | 155.96 | 155.83 | 0.51 | F=15.145 | 0.000* | 4<1<br>4<2<br>4<3 | 0.000*<br>0.000*<br>0.000* |
| **8. Step** | 167.36 | 167.43 | 0.95 | 167.75 | 167.98 | 0.96 | 167.51 | 167.59 | 0.92 | 166.37 | 166.39 | 1.07 | F=5.783 | 0.002* | 4<2<br>4<3 | 0.002*<br>0.026* |
| **9. Step** | 176.78 | 176.77 | 0.72 | 176.74 | 176.65 | 0.47 | 175.82 | 175.86 | 0.45 | 174.90 | 175.06 | 0.54 | F=24.645 | 0.000* | 3<1<br>4<1<br>3<2<br>4<2<br>4<3 | 0.001*<br>0.000*<br>0.007*<br>0.000*<br>0.006* |
| **Plate MGV** | 113.93 | 113.96 | 0.90 | 114.45 | 114.66 | 0.83 | 113.54 | 113.66 | 0.94 | 112.20 | 112.24 | 0.73 | F=17.073 | 0.000* | 4<1<br>3<2<br>4<2<br>4<3 | 0.000*<br>0.037*<br>0.001*<br>0.000* |

*p<0.05 F: Analysis of variance (ANOVA) Test Statistic $X^2$: Kruskal-Wallis Test Statistic

**Table 4.** Comparison of MGVs between scanning protocols at an exposure time of 0.34 s

| | 10 lp/mm (1) | | | 20 lp/mm (2) | | | 25 lp/mm (3) | | | 40 lp/mm (4) | | | Test statistic | p | Bonferroni | p |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | m | x | s | m | x | s | m | x | s | m | x | s | | | | |
| **Background** | 22.25 | 22.26 | 0.77 | 21.31 | 21.53 | 0.77 | 22.08 | 22.00 | 0.80 | 21.73 | 21.80 | 0.59 | F=2.083 | 0.116 | | |
| **1. Step** | 45.80 | 46.01 | 0.90 | 45.22 | 45.73 | 1.32 | 46.15 | 45.88 | 1.56 | 44.64 | 44.68 | 0.88 | F=3.046 | 0.039* | 4<1 | 0.05* |
| **2. Step** | 72.47 | 72.68 | 1.31 | 71.78 | 72.25 | 1.23 | 72.21 | 72.59 | 1.25 | 71.97 | 71.62 | 1.64 | F=1.489 | 0.231 | | |
| **3. Step** | 96.06 | 96.27 | 1.50 | 95.83 | 96.31 | 1.41 | 96.08 | 96.29 | 1.26 | 95.04 | 95.41 | 1.42 | F=1.171 | 0.332 | | |
| **4. Step** | 115.62 | 115.90 | 1.11 | 115.38 | 115.32 | 1.04 | 115.66 | 115.98 | 1.05 | 115.13 | 115.18 | 1.04 | F=1.713 | 0.178 | | |
| **5. Step** | 132.17 | 132.27 | 1.09 | 131.37 | 131.74 | 1.05 | 132.18 | 132.73 | 1.20 | 130.82 | 131.32 | 1.16 | $X^2$=9.503 | 0.023* | 4<3 | 0.028* |
| **6. Step** | 145.97 | 145.95 | 1.20 | 145.48 | 145.53 | 1.06 | 145.91 | 143.74 | 9.20 | 145.62 | 145.70 | 1.21 | $X^2$=2.362 | 0.501 | | |
| **7. Step** | 157.67 | 157.80 | 0.94 | 157.06 | 157.09 | 0.81 | 157.40 | 157.68 | 0.94 | 157.44 | 157.42 | 0.80 | F=1.547 | 0.216 | | |
| **8. Step** | 168.04 | 168.09 | 0.89 | 167.42 | 167.40 | 0.99 | 168.03 | 168.20 | 0.92 | 168.21 | 167.89 | 0.97 | F=1.692 | 0.182 | | |
| **9. Step** | 177.05 | 177.14 | 0.65 | 176.33 | 176.11 | 0.47 | 177.08 | 177.08 | 0.59 | 176.78 | 176.42 | 0.78 | F=7.732 | 0.000* | 2<1<br>4<1<br>2<3 | 0.001*<br>0.046*<br>0.003* |
| **Plate MGV** | 113.46 | 113.44 | 0.94 | 112.77 | 112.90 | 0.88 | 113.42 | 113.22 | 1.55 | 112.45 | 112.74 | 0.68 | F=1.029 | 0.389 | | |

*p<0.05 F: Analysis of variance (ANOVA) Test Statistic $X^2$: Kruskal-Wallis Test Statistic

resolution images requires 4 times longer waiting time.

Additionally, the increase in scanning resolution causes a large increase in the file size. In our study, high-resolution images required almost 10 times more storage space than low-resolution images. Factors such as processor capacity and storage space in the dental clinic should be considered in determining the scanner resolution.

Today, many companies produce PSP scanners that allow the user to scan in low and high-resolution. Studies investigating the effect of changing spatial resolution with different scanning protocols in PSP systems on diagnosis show different results. Another important factor affecting the detection of details in radiographic images is the human visual system. Although high-resolution image detectors can produce images with high detail and contrast, the human visual system can limit this.[13] Therefore, the effect of acquiring high-resolution images on clinical diagnosis is still unclear.

In this study, it was observed that step MGVs differed statistically in terms of scanning protocols at different exposure times. This suggests that the choice of spatial resolution may be effective in determining the lesions of dental tissues with different densities such as enamel, dentin, and pulp tissue. Ferreira et al. found that a spatial resolution of 10 lp/mm was significantly superior to other resolutions in detecting enamel lesions, while spatial resolution did not affect the detection of carious lesions in dentin.[13] The limitation of this study is that while examining the effect of spatial resolution on MGV, it did not evaluate its effect on the detection of lesions in dental tissues.

## Conclusion

When the MGVs of the exposure times were compared, the MGV at 0.10 s was lower than the other exposure times, but this difference was not statistically significant. At 0.20 s and 0.40 s exposure times, the MGVs of the plates scanned with different scanning protocols showed statistically significant differences. It was determined that the difference in plate MGV at 0.20 s was caused by the 40 lp/mm group and the plate MGV of 40 lp/mm was lower compared to other

**Table 5.** Comparison of MGVs between scanning protocols at an exposure time of 0.40 s

| | 10 lp/mm (1) | | | 20 lp/mm (2) | | | 25 lp/mm (3) | | | 40 lp/mm (4) | | | Test statistic | p | Bonferroni | p |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | m | x | s | m | x | s | m | x | s | m | x | s | | | | |
| **Backround** | 22.61 | 22.58 | 0.55 | 23.09 | 23.03 | 0.70 | 23.38 | 23.07 | 0.80 | 22.64 | 22.76 | 0.96 | F=1.074 | 0.370 | | |
| **1. Step** | 45.35 | 45.35 | 0.82 | 47.18 | 47.11 | 1.36 | 46.80 | 47.19 | 1.26 | 47.34 | 47.29 | 1.29 | F=7.118 | 0.001* | 1<2<br>1<3<br>1<4 | 0.005*<br>0.003*<br>0.002* |
| **2. Step** | 72.47 | 72.53 | 1.00 | 73.79 | 73.95 | 1.19 | 74.10 | 74.14 | 1.23 | 74.65 | 74.10 | 1.71 | F=4.149 | 0.011* | 1<3<br>1<4 | 0.026*<br>0.032* |
| **3. Step** | 96.04 | 96.47 | 1.25 | 97.77 | 97.84 | 1.32 | 97.69 | 98.08 | 1.50 | 97.58 | 98.11 | 1.33 | F=3.970 | 0.014* | 1<3<br>1<4 | 0.034*<br>0.030* |
| **4. Step** | 115.63 | 115.68 | 1.12 | 116.97 | 117.22 | 0.99 | 117.05 | 117.38 | 1.08 | 116.60 | 116.74 | 1.25 | F=5.731 | 0.002* | 1<2<br>1<3 | 0.009*<br>0.003* |
| **5. Step** | 132.16 | 132.22 | 1.35 | 133.38 | 133.66 | 1.35 | 133.47 | 133.80 | 1.64 | 133.07 | 133.46 | 1.37 | F=3.053 | 0.038* | 1<3 | 0.050* |
| **6. Step** | 145.68 | 145.94 | 1.25 | 146.64 | 146.98 | 1.28 | 147.20 | 147.57 | 1.30 | 147.11 | 147.35 | 1.09 | F=4.131 | 0.012* | 1<3<br>1<4 | 0.013*<br>0.045* |
| **7. Step** | 157.45 | 157.59 | 1.00 | 158.31 | 158.75 | 0.92 | 158.65 | 158.90 | 1.12 | 158.90 | 159.07 | 0.83 | F=5.710 | 0.002* | 1<2<br>1<3<br>1<4 | 0.033*<br>0.012*<br>0.003* |
| **8. Step** | 167.58 | 167.88 | 0.93 | 168.40 | 168.67 | 1.17 | 168.58 | 168.88 | 1.35 | 169.64 | 169.40 | 0.95 | F=3.873 | 0.015* | 1<4 | 0.010* |
| **9. Step** | 176.58 | 176.70 | 0.64 | 177.45 | 177.42 | 0.62 | 177.42 | 177.44 | 1.01 | 177.68 | 177.66 | 0.51 | F=4.085 | 0.012* | 1<4 | 0.012* |
| **Plate MGV** | 113.11 | 113.30 | 0.93 | 114.11 | 114.46 | 0.91 | 114.57 | 114.65 | 1.04 | 114.57 | 114.60 | 0.63 | F=6.234 | 0.001* | 1<2<br>1<3<br>1<4 | 0.015*<br>0.003*<br>0.005* |

*p<0.05 F: Analysis of variance (ANOVA) Test Statistic $X^2$: Kruskal-Wallis Test Statistic

scanning protocols. It was determined that the difference in plate MGV at 0.40 s was due to the 10 lp/mm scanning protocol and was lower than the other groups.

As a result, while determining the scanner resolution in PSP systems, appropriate scanning protocols should be created according to the cases, considering the factors such as the busyness of the clinics, processor capacity, and storage space. More objective and subjective studies with more clinical and laboratory studies are needed to evaluate the effect of spatial resolution alone on image quality.

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## Conflict of Interest

The authors deny any conflicts of interest related to this study.

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