Original Article

Comparison of Image Quality Criteria between Digital Storage Phosphor Plate in Mammography and Full-Field Digital Mammography in the Detection of Breast Cancer

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Abstract

Background: **Digital mammography is slowly replacing screen film mammography. In digital mammography, 2 methods are available in acquiring images: digital storage phosphor plate and full-field digital mammography. The aim of this study was to compare the image quality acquired from the 2 methods of digital mammography in the detection of breast cancer.**

Methods: **The study took place at the National Cancer Society, Kuala Lumpur, and followed 150 asymptomatic women for the duration of 1 year. Participating women gave informed consent and were exposed to 4 views from each system. Two radiologists independently evaluated the printed images based on the image quality criteria in mammography. McNemar's test was used to compare the image quality criteria between the systems.**

Results: **The agreement between the radiologists for the digital storage phosphor plate was $\kappa = 0.551$ and for full-field digital mammography was, $\kappa = 0.523$. Full-field digital mammography was significantly better compared with the digital storage phosphor plate in right and left mediolateral oblique views ($P < 0.05$) in the detection of microcalcifications, which are early signs of breast cancer. However, both systems were comparable in all other aspects of image quality.**

Conclusion: **Digital mammography is a useful screening tool for the detection of early breast cancer and ensures better prognosis and quality of life.**

Keywords: *breast cancer, comparative studies, early detection of cancer, mammography, radiology*

Introduction

Breast cancer is a common cancer in women throughout the world and is the leading cause of cancer death among Malaysian women (1). While metastasis to other parts of the body can occur through lymphatic and blood vessels (2) and causes fatalities, early detection can save lives. Therefore, various methods have been used for early detection, such as breast self-examination, mammography, ultrasound, and magnetic resonance imaging.

Digital mammography was developed from screen film mammography (SFM) over 4 decades ago. However, mammography has been used to detect, diagnose, and manage a variety of breast diseases (3). Mammography is a procedure used to produce X-ray images of the breast and is widely used as a screening procedure for the early detection of breast cancer (4). The main objective of a mammography examination is to demonstrate the internal structures of the breast in order to detect abnormalities (5) in both symptomatic and asymptomatic women.

However, no one modality is 100% accurate, and most SFM interpretations are reportedly in the range of 68%–92% accuracy (6). Therefore, cancers may have been missed due to false negative interpretations, resulting in an increase in the mortality rate of breast cancer patients. Thus, there is an urgent need to determine a modality that is more accurate for breast cancer detection

with the introduction of digital technology. The transition of SFM to digital mammography has gradually shifted to the use of digital storage phosphor plate (DSPM), which indirectly converts X-rays to light and subsequently to digital signals, which may cause degradation of the image. However, full-field digital mammography (FFDM) directly converts X-ray energy to a digital signal without a loss in image resolution. Thus, there is a need to determine which digital mammography system is able to produce superior quality in mammography.

The term "image quality" is described as the ability to visualise the anatomy of the breast sufficiently. Early works reported in the European Guidelines on Quality Criteria for Diagnostic Radiographic Images for conventional mammography were released in 1996 (7) to address the criteria required for image quality, which is of paramount importance in mammography. The following year, the 3 image quality criteria most important in radiography were reported to be sharpness, contrast, and noise, which are also important criteria in mammography (8). With the technological advancement in the field of breast imaging, improvement in image quality criteria was observed.

Thus, the European Commission further redefined the criteria to incorporate the changes in mammographic clinical image quality of FFDM consisting of 12 image quality criteria and 8 physical characteristics of the image (9). The image quality criteria here refer mainly to the depiction of internal structures of the breast, whereas physical attributes consisted of contrast, sharpness, artefacts, and visualisation of microcalcifications and opacities. Similarly, in an article by the United States Food and Drug Administration (10), it is stated that image quality is affected by sharpness, contrast, brightness, artefacts, noise, and anatomical structures such as skin, glandular tissue, retromammary space, and microcalcifications.

Though there are multitudes of definitions on image quality, the ultimate goal of high quality mammograms are to enable "detection of lesions or microcalcifications suggesting of malignancy" (11). Hence for this study, image quality criteria were adopted from the Schueller et al.'s study (12), which consisted of brightness, sharpness, contrast, noise, artefacts, and detection of anatomical structures, such as skin, glandular tissue, retromammary space, and microcalcifications.

Sharpness refers to the outline or edges of structures that are clearly depicted. It has also been defined as the delineation of linear structures, feature margins, and microcalcifications, whereas noise was described as a visually striking mottle pattern (13). Noise causes interference with the appearance of an image that impairs the radiologist from interpreting the mammogram. Noise in SFM due to "quantum mottle" (14) was because of "fluctuation in the X-ray photons that are absorbed in the intensifying screen", but in digital mammography, it appears as graininess on soft copy display. Brightness refers to the clarity of the breast parenchyma that is being demonstrated.

Artefacts are foreign objects that are present in the area of interest (breast and armpit), such as talcum, antiperspirant, or "crimp marks" that are caused during film handling, which should not be present on the mammography image. Clinical presentation of artefacts was divided into the following 5 groups: related to patient, technologist, mammography unit, software and viewing condition, and others (15). The detection of microcalcifications, when present within the breast parenchyma, is suggestive of malignancy (5).

The image quality of mammograms is affected by the 9 criteria mentioned above (12), and when it is lacking in one of the image quality criteria, it affects the overall outcome of the image. It is believed that the shortcomings of SFM have been overcome with digital mammography. Ultimately, the goal of the chosen digital modality is based on its higher performance in detecting and diagnosing breast cancer with the intention of reducing mortality rate and providing various treatment options. Thus, the aim of this study was to compare the image quality of FFDM, which involves direct conversion, with that of DSPM, which involves indirect conversion in acquiring images.

Materials and Methods

A diagnostic comparative study was conducted at the National Cancer Society, Kuala Lumpur, for the duration of 1 year. Prior ethical approval was obtained from the Medical Research Ethics Committee, Ministry of Health, and the Research and Ethics Committee, Universiti Kebangsaan Malaysia. Recruited women were between 40 (16) to 69 years old for this study. The exclusion criteria were having a previous history of cancer, having breast implants, pregnant, or being on hormone replacement therapy.

The present study replicates the study design and methods previously employed in Vienna (12).

For the present study, a sample size calculation was based on the formula for sensitivity and specificity of the mammography system (17). A confidence interval of 95% with a level of accuracy of 10% was considered; the expected sensitivity/specificity was 70%/92%, as obtained from a previous study (18).

The calculated sample size required for sensitivity and specificity were 259 and 41 women, respectively. However, the estimated sample size possible for this study was 150 women due to the limited budget, manpower, and time. The sampling method used for this study was convenience sampling. Women who participated in this study gave informed consent and filled out a demographic form on personal data and risk factors. Two routine projections of each breast using both DSPM and FFDM were performed.

The mammography images were rated by 2 blinded, independent radiologists with 16–20 years of experience in the field of radiology. Image quality was evaluated based on 9 criteria: brightness, contrast, sharpness, noise, artefacts and detailed depiction of anatomical structures, such as skin, retro-mammary space, glandular tissue, and the detection of microcalcifications. Occasionally, a magnifying glass was utilised to verify the visualisation of microcalcifications in the breast.

The radiologists were given a guideline for image quality assessment using a 4-level ordinal scale (0 = not applicable, 1 = inadequate, 2 = moderate, 3 = excellent) to improve understanding and reduce discrepancies in the ratings between the radiologists. Level 1 (inadequate) indicates that the image quality criteria were insufficiently displayed on the mammography images. The differences in image quality assessment for level 2 (moderate) and level 3 (excellent) were moderately shown for the former yet were excellent for the latter in image quality criteria. Besides the 3 levels mentioned above, for the detection of microcalcification, level 0 (not applicable) was an extra score added to indicate absence or presence of microcalcifications, which was important to verify the status of malignancy in a mammography examination.

Statistical analysis

Statistical analysis was performed using SPSS version 16.0 (SPSS Inc., Chicago, Illinois, US). Descriptive and inferential statistics were performed for the data. For descriptive statistics, the frequency (percentage) of frequently appearing scores was computed, and for the inferential statistics, the McNemar's test for *P* value was performed to evaluate the association between the digital mammography systems and the image quality. A *P* value of less than 0.05 was considered statistically significant. The inter-rater agreement of observations was compared using an unweighted kappa and weighted kappa (19) using κ statistics, and $\kappa \geq 0.8$ was considered perfect, $\kappa = 0.61–0.8$ was considered good, $\kappa = 0.41–0.60$ was considered moderate, $\kappa = 0.21–0.40$ was considered fair, and $\kappa \leq 0.20$ was considered poor. With reference to the score of the radiologists, when both scored (0:0), (1:1), (2:2), or (3:3), the weightage is 100%. If there was a 1-level difference in scoring and the scoring was (0:1), (1:2), or (2:3), the weightage is 75%. If there was a 2-level difference in scoring and the scoring was (0:2) or (1:3), the weightage is 50%. Finally, if there was a 3-level difference in scoring and the scoring was (0:3), the weightage is 25%. The weighted kappa was used because of the ordinal scoring used for the image quality criteria and the detection of anatomical structures (detection of microcalcification).

Results

A total of 1200 mammography images from 150 participants were assessed independently by 2 radiologists. The number of women who participated in the study according to the age groups are shown in Figure 1. The frequencies of the excellent rating (score 3) for each mammographic view and image quality criteria for DSPM and FFDM are presented in Figure 2. DSPM and FFDM did not have excellent scores in noise, retromammary space, glandular tissue, and detection of microcalcifications in all views. However, Figure 3 shows a comparison of the total scores between DSPM and FFDM, in which 6 of the criteria are similar, while FFDM is superior to DSPM in brightness, depiction of anatomical structures and skin line, and detection of microcalcifications (Table 1).

There was moderate agreement with unweighted kappa (inter-rater agreement), $\kappa = 0.551$ and $\kappa = 0.523$ for DSPM and FFDM, respectively, between the 2 radiologists for image quality, but no weighted kappa could be computed. For the detection of microcalcifications, the present study showed a significant difference only in the mediolateral oblique views using McNemar's test ($P < 0.05$) where FFDM showed better detection. There was fair agreement with unweighted kappa for DSPM and FFDM between the radiologists whereby $\kappa = 0.259$ and $\kappa = 0.222$, respectively, for the detection of

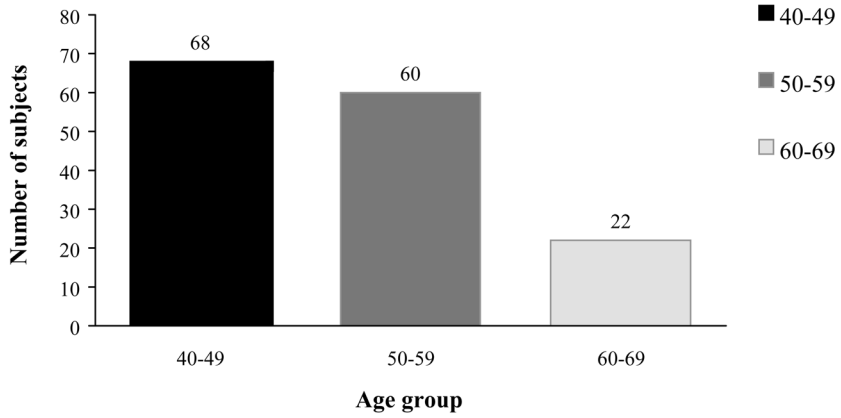

Figure 1: Distribution of subjects according to age group.

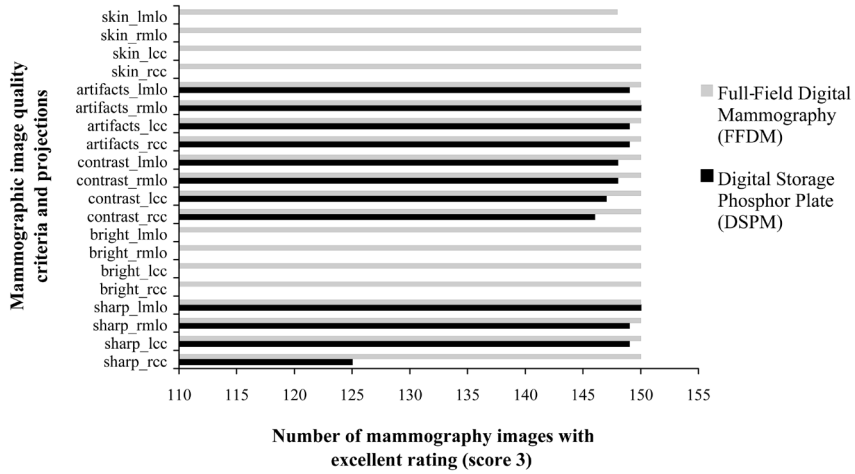

Figure 2: Frequency of the mammography image quality criteria with excellent rating (score–3). Abbreviation: RCC = right craniocaudal, LCC = left craniocaudal, RMLO = right mediolateral oblique, LMLO = left mediolateral oblique.

microcalcifications. Similarly, the weighted kappa also showed fair agreement (κ =0.300) for the detection of microcalcifications. All other image criteria did not show any significant differences ($P > 0.05$).

Discussion

All image quality criteria used in the current study are equally relevant to obtain a diagnostic mammogram. However, the detection of microcalcifications is an important criterion for the early detection of breast cancer. Though the presence of microcalcification itself is not cancerous, if it appears pleomorphic, linear, or fine and branching calcifications are observed, it is highly suggestive of malignancy (5).

Although the study hypothesis suggested that FFDM would be able to demonstrate superior image criteria to DSPM, the present study showed that FFDM presented better only in certain criteria ($P < 0.05$) compared with DSPM. In right and left mediolateral oblique views, FFDM was significantly better than DSPM in detecting microcalcifications ($P < 0.001$).

The number of samples used in the present study and the methodology employed were similar to the Schueller et al.'s study (12). However, the findings of this study did not replicate the findings of the former study. Contributory factors may have been that symptomatic subjects were used as well as a different study design in the former study (12).

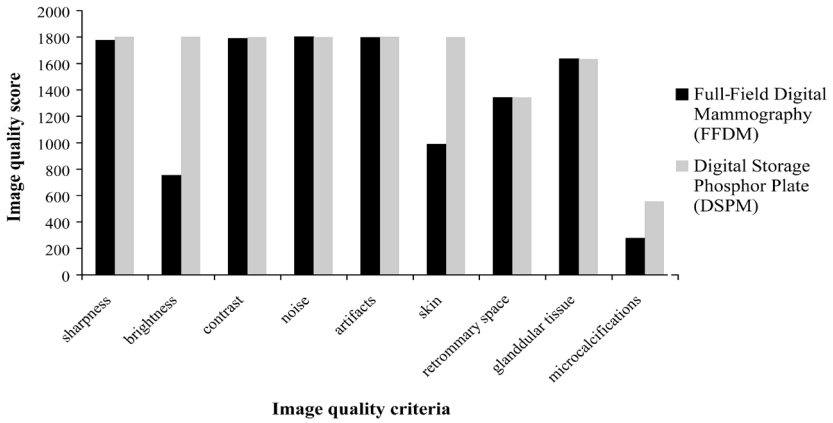

Figure 3: Image quality scores between digital storage phosphor plate and full-field digital mammography.

Table 1: Detection of microcalcifications within the digital mammography systems

Mammography projection	Mammography system	Percentage (%)	Number of subjects
RMLO	DSPM	14. 4	21
	FFDM	26. 0	38
LMLO	DSPM	12. 0	18
	FFDM	23. 3	35

Abbreviations: RMLO = right mediolateral oblique, LMLO = left mediolateral oblique, DSPM = digital storage phosphor plate, FFDM = full-field digital mammography.

In this current study, FFDM was only better in the detection of microcalcifications, whereas in the Schueller et al.'s study (12), FFDM scored significantly better in sharpness, contrast, and the detection of all anatomical structures ($P < 0.05$). They found FFDM to be significantly better in detecting microcalcifications, as detected in 85 women using FFDM compared with in 75 women using DSPM (12). Similarly, the present study also detected microcalcifications in 73 asymptomatic women using FFDM and 39 women with DSPM.

The American College of Radiology developed a landmark screening trial (18), which showed no significant difference between FFDM and SFM. However, FFDM was beneficial for women below 50 years of age, peri- or pre-menopausal women, and women with dense or extremely dense breasts. FFDM was significantly better in the depiction of microcalcifications, nipple, and skin, which is consistent with the current study (20).

Several studies comparing FFDM with SFM were conducted to assess the diagnostic efficacy within a screening population. To date, 4 landmark studies comparing the SFM with FFDM have been performed, and the cancer detection rate was not statistically significant (21–23). Furthermore, digital mammography was found to be equivalent to SFM (24,25) in breast cancer detection rate.

Breast cancer in dense tissue is difficult to detect especially with SFM. However, digital mammography with post-processing features easily overcomes this problem. A study performed in Japan (26) revealed that the detection of microcalcifications was better with SFM compared with DSPM, and later in 2003, improvement to the imaging plates resulted in comparable detection of microcalcifications between the 2 modalities. Continuous advancement has been ongoing to improve the capabilities of DSPM. The Healthcare's DX-S was introduced by Agfa, which provides better detail and improved image quality, reduction in patient dose, increased productivity, and shorter examination time for the patient (27).

The mammography imaging system alone will not be sufficient for acquiring high quality mammograms. Radiographers play a role in producing mammography images of good diagnostic value, which influences

the interpretation of the radiologist. Thus, radiographers involved in the imaging chain must be proactive to learn, unlearn, and re-learn their skill in performing mammography examinations. As for the radiologist, reader training is important to keep abreast with the dynamic changes in the field of imaging to ensure that standards are maintained, as they influence the outcome of the mammography examination (12).

The clinical importance of the findings of the present study revealed that both DSPM and FFDM were capable of depicting nearly all the image quality criteria specified, thus making it a suitable system for screening mammography. Furthermore, the capability of performing post-processing to manipulate the density and contrast with digital mammography makes it an exceptional system for women with dense breast tissue, which was previously a challenge for SFM.

The determination of whether these 2 digital mammography technologies are comparable or whether one is superior over another was a challenge. Based on the findings of the present study, DSPM and FFDM were comparable in image quality. Thus, the decision to select a system depends on the affordability, workload, and the future plans of the mammography facility. A screening centre would benefit from a digital mammography system because many women with dense breast tissue (below the age of 50 years) would be screened for early detection of breast cancer.

The major impediment in acquiring the FFDM is its exorbitant cost, which is approximately 3 to 5 times more than the SFM (28); however, the cost effectiveness of the equipment for the future and the continually evolving technology makes it a good investment. To join the trend towards using digital mammography at an affordable cost, DSPM is an option that should be considered. The results from various randomised clinical trials have suggested that the quality of mammograms affects cancer detection rates, the stage of detection and interval cancer rates, and FFDM has been shown to be beneficial for certain women, especially those with dense breast tissue. The benefits of FFDM was noted in the Digital Mammographic Imaging Screening Trial (29).

The limitation of this study is that there was no radiologist workstation for the DSPM system, and it was not compatible according to the Digital Imaging and Communications in Medicine standard to be networked to the FFDM workstation. To overcome this challenge, the DSPM images were compressed and saved into JPEG formats, but the resolution of the images were affected, and the interpretation of mammography images were performed on printed copies.

Depiction of fine microcalcifications and subtle soft-tissue masses on mammograms is the key to the detection of early breast cancer (23). Because breast cancer is the leading cause of death among women aged 40 to 50 years (2), an imaging tool that is accurate and reliable would definitely assist in the early detection of breast cancer. For this study to be more powerful, more time, a greater budget, and a larger sample size may have given a true reflection of the performance of these units among Malaysian women.

Conclusion

Digital mammography is rapidly replacing SFM because it is able to overcome the challenges of the SFM, the gold standard in breast imaging. Based on the image quality criteria of this study, both DSPM and FFDM systems were similar in most image quality criteria except for in the early detection of microcalcifications. In conclusion, both digital mammography systems were capable of producing mammography images of comparable quality due to their digital capabilities. Because mammography is a diagnostic tool to screen for the presence of abnormalities, further investigations, such as biopsy, should be performed on subjects with microcalcifications to confirm the status of true positives or the presence of cancer.

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Authors' Contributions

Conception and design, critical revision of the article: TRP, KCK
Analysis and interpretation of the data: TRP, KV, TS, KCK
Collection and assembly of the data, drafting of the article: TRP

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