

Screen-Film Mammography and Soft-Copy Full-Field Digital Mammography: Comparison in the Patients with Microcalcifications

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Index terms:

Radiography, digital
Mammography,
Microcalcification
Screens and films
Breast radiography
Soft copy reading

Korean J Radiol 2005;6:214-220

Received February 24, 2005; accepted after revision August 29, 2005.

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This study was supported by a grant of the Korea Health 21 R&D Project, Ministry of Health & Welfare, Republic of Korea (02-PJ3-PG6-EV06-0002)

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Objective: We wanted to compare the ability of screen-film mammography (SFM) and soft-copy full-field digital mammography (s-FFDM) on two different monitors to detect and characterize microcalcifications.

Materials and Methods: The images of 40 patients with microcalcifications (three patients had malignant lesion and 37 patients had benign lesion), who underwent both SFM and FFDM at an interval of less than six months, were independently evaluated by three readers. Three reading sessions were undertaken for SFM and for FFDM on a mammography-dedicated review workstation (RWS, 2K × 2.5K), and for FFDM on a high-resolution PACS monitor (1.7K × 2.3K). The image quality, breast composition and the number and conspicuity of the microcalcifications were evaluated using a three-point rating method, and the mammographic assessment was classified into 4 categories (normal, benign, low concern and moderate to great concern).

Results: The image quality, the number and conspicuity of the microcalcifications by s-FFDM (on the RWS, PACS and both) were superior to those by SFM in 85.0%, 80.0% and 52.5% of the cases, respectively ($p < 0.01$), and those by the s-FFDM on the two different monitors were similar in 15.0%, 12.5% and 35.0% of the cases, respectively ($p > 0.01$). The mammographic assessment category for the microcalcifications in the three reading sessions was similar.

Conclusion: s-FFDM gives a superior image quality to SFM and it is better at evaluating microcalcifications. In addition, s-FFDM with the PACS monitor is comparable to s-FFDM with the RWS for evaluating microcalcifications.

Imaging the microcalcifications in the breast is very important for detecting non-palpable early breast cancer. Clustered microcalcifications are the primary mammographic abnormality that occurs in approximately 40% of all the patients with non-palpable breast cancer (1).

Mammography is the best method for detecting these early-stage breast cancers and conventional screen-film mammography (SFM) has been shown to have a high sensitivity and specificity for the detection of breast cancer. However, there are several technical limitations for performing SFM that can affect the image quality and hide the fine details.

There has been a great deal of improvement in mammography over the last three decades. Recently, full-field digital mammography (FFDM) systems have been developed and they are being increasingly used to replace conventional SFM (2, 3). However, there is general concern that the lower spatial resolution of FFDM might be an obstacle for the detection and characterization of microcalcifications. Furthermore, people are becoming more concerned about the soft-copy readings, which are

dependent on the quality of the viewing monitors.

The aim of this retrospective study was to compare the ability of SFM and soft-copy FFDM (s-FFDM), with using two different monitors [a mammography-dedicated review workstation (RWS) and a high-resolution PACS monitor] to detect and characterize microcalcifications.

MATERIALS AND METHODS

Patient Selection

From April to June 2003, 3,015 women underwent FFDM in a screening or diagnostic setting. Among them, 40 patients with microcalcifications in a single localized area (clustered, segmental or regional) had received a simultaneous or recent SFM (< 6 months). Additional mammograms with FFDM were obtained before the magnification mammography in nine patients, and these patients had undergone SFMs less than three months prior to the magnification mammography (1-3 month). All the mammograms were done with the patients' consent. The remaining 31 patients underwent additional mammograms with FFDM during the six-month follow-up for suspected benign calcifications. This study included only those patients who had all four standard views. Ten lesions were histopathologically confirmed by surgery or stereotaxic mamotome biopsy. Three lesions were malignant (ductal carcinoma in situ in two patients and infiltrating ductal carcinoma in one patient) and seven lesions were benign. The benign pathological findings were as follows: calcifications in a benign duct in one patient, fibrocystic changes in two patients, stromal fibrosis in three patients and ductal hyperplasia with dystrophic calcification in one patient.

Mammography Systems

A conventional SFM system (Senographe 600T) and a FFDM unit (Senographe 2000D, General Electric Medical Systems, Buc, France) were used and compared in this study. This FFDM unit uses an amorphous silicon-flat-panel detector with Cesium iodide (CsI) as the scintillator. The pixel size was 100 μ m, which gave a spatial resolution of approximately 5 lp/mm (4), and the depth of the bit was a 14-bits; this resulted in 16,384 gray levels. The FFDM images were reviewed on a soft-copy display system with using both a 2 \times 2.5 K mammography-dedicated RWS (General Electric Medical Systems, Buc, France) and a 1.7 \times 2.3 K high-resolution CRT monitor for PACS (Barco, Belgium). The RWS provided preset intensity window options as well as the roam-and-zoom functions with one click of the mouse button (Fig. 1) (5). The high-resolution CRT monitor provides a manual magnifying magic glass instead of the single click roam-and-zoom functions.

The RWS was located only in the mammography reading room, which was quite expensive (about \$80,000) because of its user familiar interface. The high-resolution CRT monitors were used for PACS and could be located in many sites including the reading rooms and outpatient clinics because of the relatively low cost (about \$10,000).

Evaluation

Each reading session consisted of three sets; SFMs on the dedicated viewbox (Mammoviewer, DDP, TX), s-FFDMs on the RWS and s-FFDMs on the PACS monitors. All the readings were performed in a dark environment, and this was suitable for interpreting the mammograms. Each reading session took approximately 1–1.5 hours, and the sessions were done on separate days with one month intervals between the sessions. The radiologists were allowed to magnify each image by using their own method; the magnifying glass for the SFM, a quadrant zoom or the roam-and-zoom function for the RWS and the magic glass for the PACS monitors.

Three readers, who were blinded to the histologic results, independently reviewed all the images. They had used digital mammograms for three months before the beginning of this study. One of the readers had more than five years experience in SFM interpretation and the others were fellow radiologists who had more than six months experience in interpreting SFM images. The readers were given the protocol to evaluate the image quality, the breast composition, the number and conspicuity of the microcalcifications, and the mammographic assessment categories for the SFM, the s-FFDM on the PACS, and the s-FFDM on the RWS. The image quality was divided into three groups; good (3 points); moderate (2 points); and poor (1 point).



Fig. 1. Soft-copy workstation for digital mammography. The figure shows the soft-copy display system using a 2 \times 2.5 K mammography-dedicated review workstation (General Electric Medical Systems, Buc, France).

The breast composition was categorized into one of four patterns according to the American College of Radiology Breast Imaging and Reporting Database System (ACR BI-RADS). The number of microcalcifications was assigned to one of the following groups: 0–5, 6–10, 11–20, 21–40 and more than 40 particles. The conspicuity, including the margin of the microcalcifications, was also divided into three groups; clear (3 points), moderate (2 points), and indistinct (1 point). The microcalcifications were characterized using the BI-RADS assessment categories (6, 7). The assessment categories were divided into four groups: category 1 was normal, category 2 or 3 was benign, category 4a was low concern and category 4b or 4c was moderate to great concern. The category 5 microcalcifications were not included in this study group. Category 1 was assigned when the readers could not identify the calcifications at the reading session even though the initial reading had suggested the presence of calcifications and other readers had also observed them.

The results of the image quality, as well as the number and conspicuity of the microcalcifications obtained from the three readers, were averaged. The mammographic pattern of the breast composition and the mammographic assessment category were determined according to the major opinion of the interpretation results. The results of the s-FFDM on the RWS were compared with those of the SFM and also with those of the s-FFDM on the PACS.

Statistical analysis

The data, except for the mammographic pattern of the breast composition and the assessment category, were analyzed statistically using the mixed model method (8). Statistical analyses using a generalized estimating equation were used because the data concerning the mammographic pattern and the category of the microcalcifications were numerical (absolute) values.

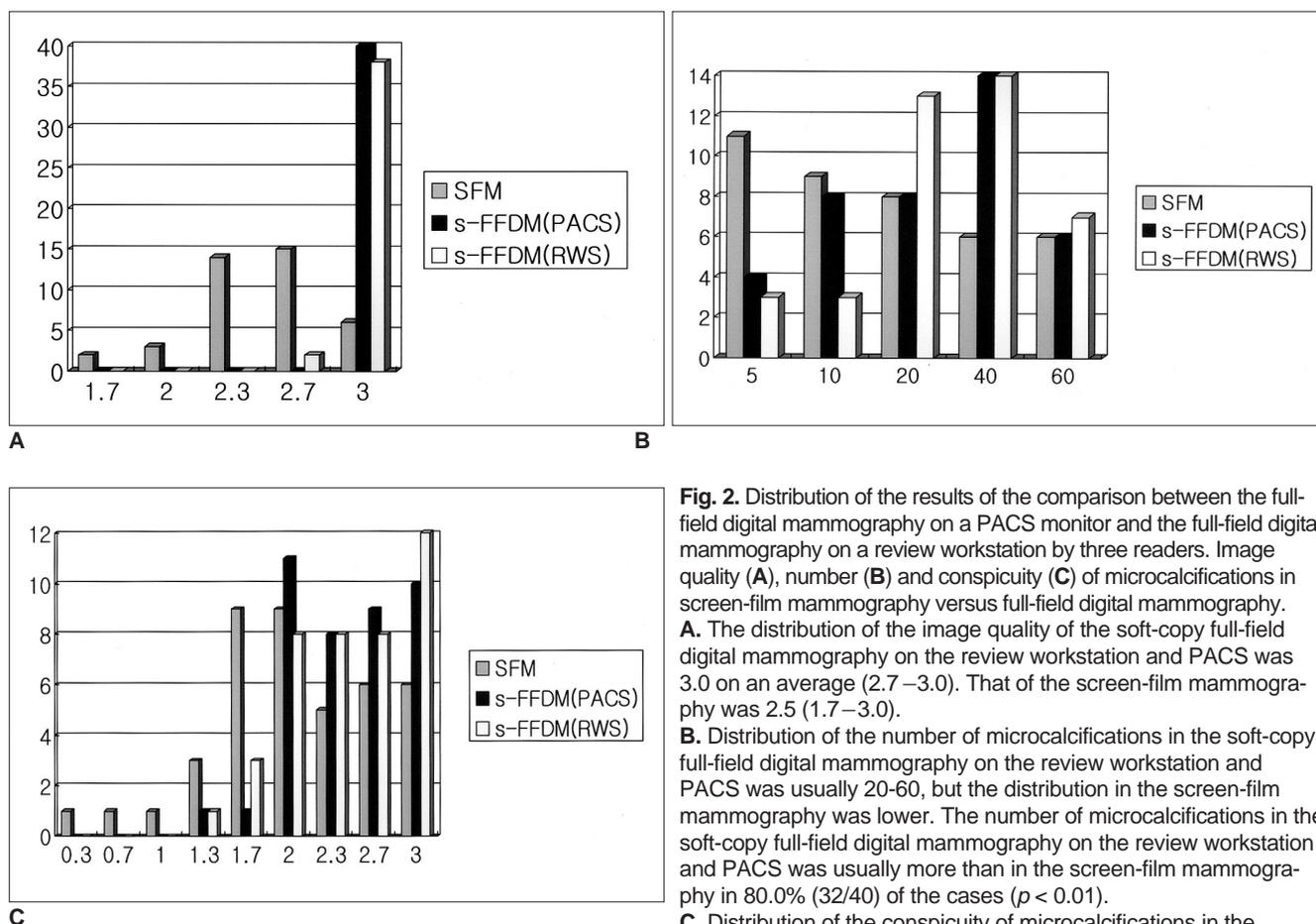


Fig. 2. Distribution of the results of the comparison between the full-field digital mammography on a PACS monitor and the full-field digital mammography on a review workstation by three readers. Image quality (A), number (B) and conspicuity (C) of microcalcifications in screen-film mammography versus full-field digital mammography. **A.** The distribution of the image quality of the soft-copy full-field digital mammography on the review workstation and PACS was 3.0 on an average (2.7–3.0). That of the screen-film mammography was 2.5 (1.7–3.0). **B.** Distribution of the number of microcalcifications in the soft-copy full-field digital mammography on the review workstation and PACS was usually 20-60, but the distribution in the screen-film mammography was lower. The number of microcalcifications in the soft-copy full-field digital mammography on the review workstation and PACS was usually more than in the screen-film mammography in 80.0% (32/40) of the cases ($p < 0.01$). **C.** Distribution of the conspicuity of microcalcifications in the screen-film mammography was 0.3-3.0. Those of the soft-copy full-field digital mammography on the review workstation and PACS were 1.3-3.0, and this was superior to the screen-film mammography in 52.5% (21/40) of cases ($p < 0.01$) and similar in 35.0% (14/40) of cases.

RESULTS

The distribution of the image quality of the mammography according to the three readers was as follows: 2.5 (1.7–3.0) on the SFM, 3.0 on the PACS and 3.0 (2.7–3.0) on the RWS (Fig. 2). The image quality of the s-FFDM on the RWS was superior to that of the SFM in 85.0% (34/40) of the cases ($p < 0.01$) and it was equal to the SFM in 15.0% (6/40) of the cases (Fig. 3). There was no case where the image quality of the s-FFDM was inferior to the

SFM. The image quality of the s-FFDM, RWS and PACS was similar ($p > 0.01$). The mammographic pattern of the breast composition of the s-FFDM on the RWS and SFM and the s-FFDM on the RWS and PACS monitor was similar ($p > 0.01$).

The number of microcalcifications detected by the various techniques was as follows: 18.2 (0.7–70.0) on SFM, 24.4 (1.0–70.0) on the PACS and 24.8 (1.0–70.0) on the RWS. The number of microcalcifications detected in the s-FFDM on the RWS was significantly higher than in the SFM in 80.0% (32/40) of cases ($p < 0.01$) (Fig. 4), and

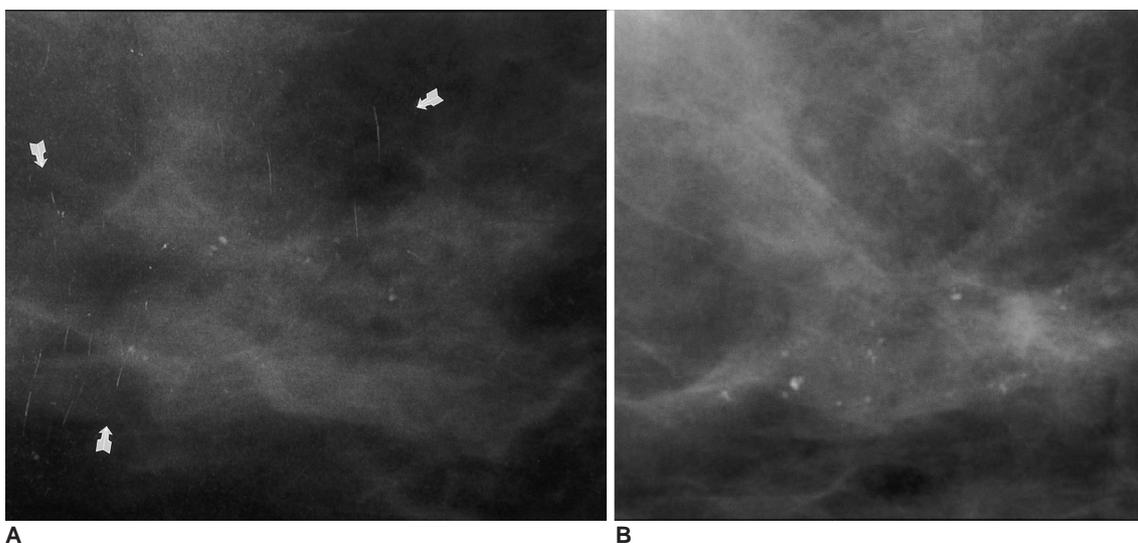


Fig. 3. Comparison of image quality. Scratch and dust artifacts are noted in **A** and it is difficult to differentiate the microcalcification from the dust in **A**, resulting in superior image quality of the full-field digital mammography (**B**).

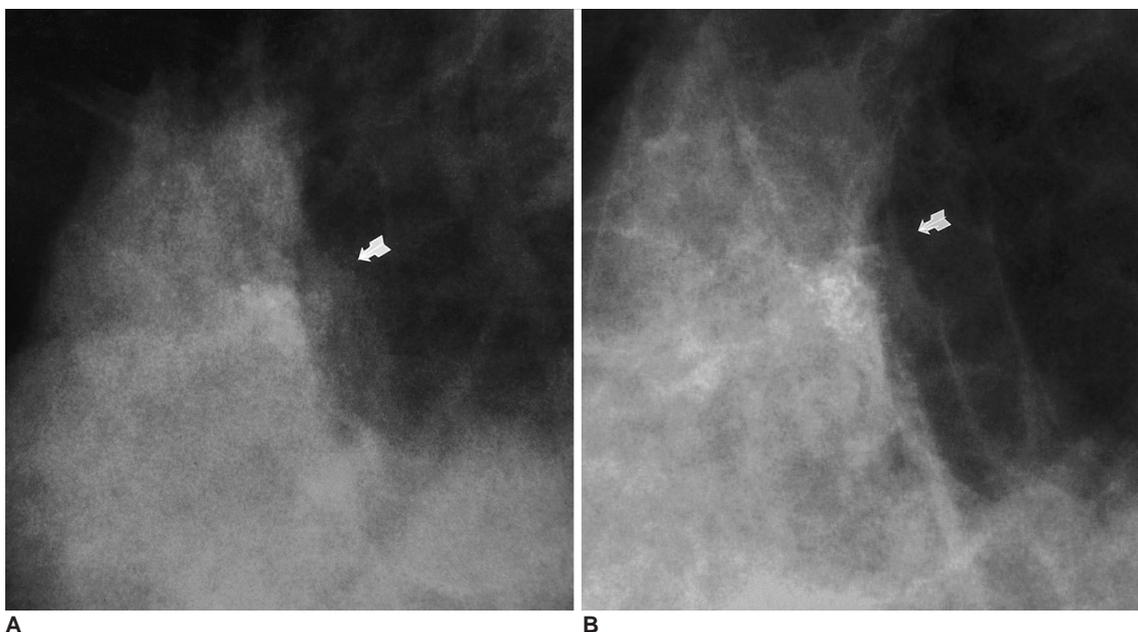


Fig. 4. Comparison of the number and conspicuity of the microcalcifications. Many more calcifications with a clear margin are noted in the full-field digital mammography (**B**) than in a screen-film mammography (**A**).

it was similar to that in the SFM for 12.5% (5/40) of the cases. In the remaining 7.5% cases (3/40), many more microcalcifications were observed in the SFM than in the s-FFDM on the RWS. Although the detection of microcalcifications was superior in the s-FFDM on the RWS to that in the s-FFDM on the PACS monitor in 47.5% of the cases (19/40) and the detection of microcalcifications was superior in the s-FFDM on the PACS to that in the s-FFDM on the RWS in 40.0% of cases (16/40), the number of detected microcalcifications in the s-FFDM on the PACS monitor and on the RWS ($p > 0.01$) was not significantly different. The distribution of the number of microcalcifications was as follows: 2.1 (0.3–3.0) on the SFM, 2.4 (1.3–3.0) on the PACS and 2.5 (1.3–3.0) on the RWS (Fig. 2C).

The conspicuity, including the margin of the microcalcifications in the s-FFDM on the RWS, was superior to that in the SFM in 52.5% (21/40) of the cases ($p < 0.01$) (Fig. 4) and it was similar in 35.0% (14/40) of the cases. The conspicuity was greater in the SFM in 12.5% (5/40) of the cases, but the s-FFDM on the PACS monitor and on the RWS provided similar results.

The mammographic assessment categories of the microcalcifications in the s-FFDM were different from that in the SFM in 27.5% (11/40) of the cases and it was similar in 72.5% (29/40) of the cases. Fifteen percent (6/40) were overestimated in the SFM and 12.5% of the cases (5/40) were underestimated in the SFM (Fig. 5). The mammographic assessment categories were similar in both

Table 1. The Assessment Category of the Mammograms for the Patients with Microcalcifications as Assigned by Three Readers; comparison between FFDM on RWS and SFM

FFDM\SFM	Category 1	Category 2,3	Category 4a	Category 4b,c
Category 1	0	0	0	0
Category 2,3	2	26	6	0
Category 4a	0	3	1	0
Category 4b,c	0	0	0	2

Note.—The mammographic assessment categories were divided into four groups: category 1, normal; category 2 or 3, benign; category 4a, low concern of malignancy; category 4b or 4c, moderate to great concern of malignancy.

Table 2. The Assessment Category of the Mammograms for Patients with Microcalcifications as Assigned by Three Readers; comparison between the FFDM on a PACS monitor and the FFDM on a RWS

PACS\RWS	Category 1	Category 2,3	Category 4a	Category 4b
Category 1	0	0	0	0
Category 2,3	0	32	1	0
Category 4a	0	2	3	0
Category 4b,c	0	0	0	2

Note.—The mammographic assessment categories were divided into four groups: category 1, normal; category 2 or 3, benign; category 4a, low concern of malignancy; category 4b or 4c, moderate to great concern of malignancy.

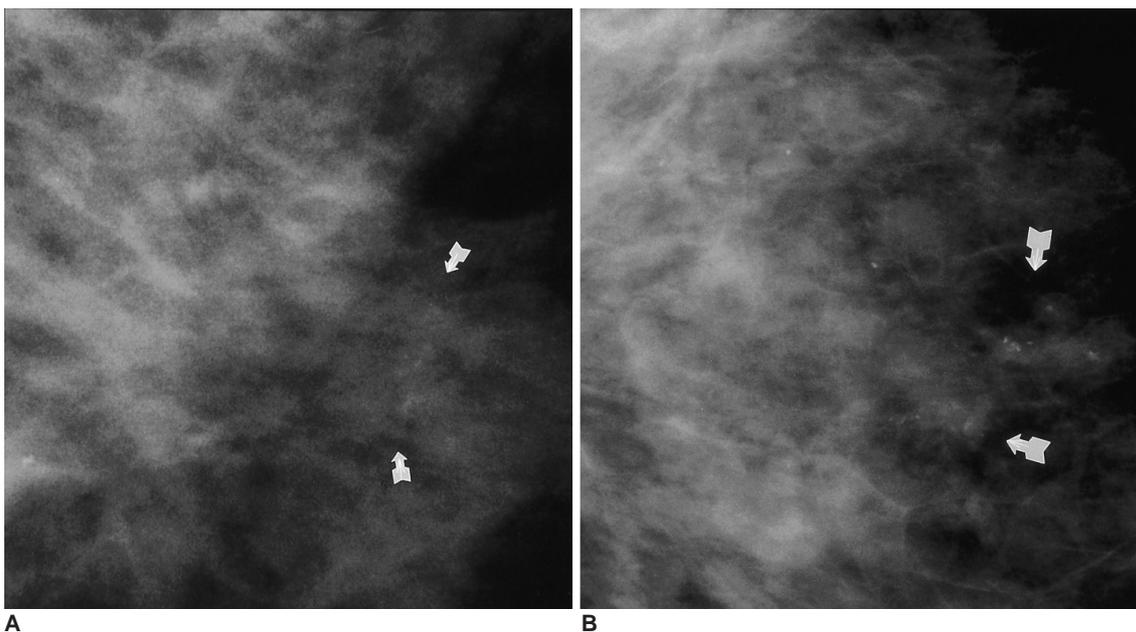


Fig. 5. A 48-year-old woman with an increased number of clustered microcalcifications in the left breast. She underwent breast-conserving surgery for an infiltrating ductal carcinoma of the right breast two years ago. The ACR BI-RADS mammographic assessment category of the microcalcification was more consistent with the pathologic result in the full-field digital mammography (B) than in the screen-film mammography (A), as assessed by all three interpreters. These microcalcifications were confirmed to be mucocoele-like tumor with atypical ductal hyperplasia by a stereotaxic mamotome biopsy. A and B were performed at the same time.

the s-FFDM on the PACS monitor and in the s-FFDM on the RWS (Tables 1, 2).

DISCUSSION

The National Cancer Institute in the USA has designated digital mammography as the imaging technology with the highest potential for improving the detection and diagnosis of breast cancer (9). Direct digital mammography was first performed for stereotaxic biopsies and localizations with using systems that were based on charge-coupled device chips. However, these chips could not be used for full-field imaging on account of the limited detector size. The next attempt in digital mammography was the use of digitized storage phosphor systems. However, this technique was limited due to the low quantum efficiency and the low spatial resolution (6, 10). A combination of a direct magnification technique using a microfocus tube and storage phosphor plates was tried so as to increase the spatial resolution. A later study demonstrated that magnification mammography with using this technique was superior to conventional film-screen magnification mammography (11). There have been further developments in these combinations, and high-resolution digitized storage phosphor systems have recently become available.

The full-field digital mammography system used in this study is based on a flat amorphous silicon array and a CsI scintillator. The potential limitation of this system is the lower spatial resolution of 5 line pairs (lp)/mm compared with that of 12–15 lp/mm for the SFM. The minimal pixel size required for digital mammography is still a subject of debate. The spatial resolution of the flat-panel and the CR systems is determined by this pixel size of 5 lp/mm. However, the flat-panel system has a much higher modulation transfer function at all spatial frequencies below this limit than does the computed radiography systems. This higher resolution is a result of the CsI phosphor producing higher-resolution images than the storage phosphors (3). Although the full-field digital system presented in this paper does not meet the current standards and guidelines that are defined for conventional screen-film mammography (limited spatial resolution), FFDM was shown to be slightly better for detecting and characterizing microcalcifications than the SFM that we used (12, 13). This is due to the increased contrast-detail detection rate of the digital system, which allows better visualization of small high-contrast structures. There is also optimized image processing for the detailed visualization that is needed in digital mammography. The image processing technique optimizes the image quality of the soft-copy display as well as the hard-copy images. The other advantages of the digital

technique are the wider dynamic range, the higher contrast-detail detectability and the superior detective quantum efficiency (4, 9, 14). These factors cause better visualization of the peripheral breast structures such as the skin, subcutaneous tissue and retromammary space, as well as the parenchymal structures that are seen in the FFDM rather than in the SFM (6). Dust and other artifacts that are due to the film developer often appear in the SFM, but they do not exist in the FFDM. These artifacts can hinder the diagnosis of breast cancer. Repeated mammograms due to the over- or underexposure are no longer necessary when using the FFDM (3).

This study also showed a higher image quality and superior detectability, as well as the better characterization of the microcalcifications in the s-FFDM than in the SFM. We think that this was also due to the improved contrast resolution in the digital system.

The results of this study show that the SFM interpretation can give an underestimation; for example, the microcalcifications interpreted as category 4a in the s-FFDM were interpreted as being category 3 in the SFM. In addition, the s-FFDM on the RWS with its better quality is not available to all clinicians. Therefore, this study compared the s-FFDM on the RWS to the s-FFDM on the PACS monitor. The RWS that provided preset intensity windowing options and roam-and-zoom functions with a click of a mouse button was located only in a mammography reading room. This workstation is quite expensive because it has a user familiar interface. In contrast, the high-resolution CRT monitors for the PACS are located at multiple sites, including reading rooms and outpatient clinics, because of their relatively low cost.

Many hospitals have implemented or are considering implementing a PACS. The filmless environment created by the PACS enables more efficient storage, retrieval and transmission of images. It has improved radiology services by allowing complete control of the runaway film problem, i.e., reducing the number of lost films and also reducing the rate of unreported films. Ideally, all the imaging techniques should be connected to the PACS for a hospital's PACS system to be cost-effective. The obvious advantage of digital mammography systems is that they can be directly interfaced with the PACS. Introducing mammography into a PACS system is complicated by the necessity of expensive, high-resolution monitors for the soft-copy reporting of digital mammograms. At the least, 2K monitors are needed for viewing digital mammograms at full resolution (15–17).

This study suggests that digital mammography readings on a PACS monitor and on a RWS have equivalent diagnostic accuracy. This indicates that communication

between the radiologist and clinicians will be facilitated through the PACS system.

There were some limitations in this study. All the SFMs and FFDMs were not taken at the same time, the study involved only a small number of cases and some variations in mammographic compression are inevitable. In addition, most of the selected cases were biased because they were being followed up for the category 3 lesions and only 10 of the studied lesions were confirmed histopathologically. Therefore, a prospective study on a large population will be needed to supplement the results of this study.

In conclusion, the s-FFDM has superior image quality and a superior ability to evaluate microcalcifications as compared with the SFM. In addition, the s-FFDM on a RWS gives an equivalent evaluation of microcalcifications to that obtained on a PACS monitor.

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