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Using a mobile device for margin assessment of specimen mammography in breast-conserving surgery

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Abstract

To compare the performance of margin assessment of specimen mammography (SM) in patients with breast-conserving surgery (BCS) on mobile devices and 5-megapixel (5M) thin film transistor liquid crystal display (TFT-LCD) monitors based on the safety margin for pathologic results.

This retrospective study was approved by the institutional review board, and the requirement for informed consent was waived. A total of 105 consecutive breast cancer SM samples from 104 women who underwent BCS were included in the study. The SM were independently reviewed by two radiologists using mobile devices and by two additional radiologists using 5M TFT-LCD monitor. Each reader was asked to measure the shortest distance between the lesion and the lesion margin. The interpretation time was recorded. The sensitivity, specificity, and interobserver agreement were analyzed.

In total, 19% (20/105) breast specimens had a positive surgical margin (<1 mm). The mean absolute difference from the pathologic margin was 0.60 ± 0.57 cm and 0.54 ± 0.47 cm using the 5 M TFT-LCD monitor and the mobile device, respectively (without any statistical significance, $P = .273$). The mean interpretation time was 49.5 and 47.6 s for the 5M TFT-LCD monitor and the mobile device, respectively ($P = .012$). The pooled sensitivity and specificity were 60% and 74% for 5M TFT-LCD monitor, and 60% and 69% for the mobile device ($P = 1.00$ and $P = .190$, respectively). The kappa coefficient indicated moderate agreement for both the displays.

The diagnostic performance for margin assessment of SM in BCS patients on mobile devices and 5M TFT-LCD monitors are showed not statistically difference. The findings of the study provide evidence of the benefit of the mobile device for SM interpretation in patients who underwent BCS. However, a large sample size study is warranted before using a mobile device for margin evaluation on SM.

The mobile device showed comparable diagnostic performance with 5M TFT-LCD monitor in the evaluation of SM margin in patients with BCS and could be used as a display tool for immediate assessment when a dedicated LCD monitor is unavailable.

Abbreviations: κ = kappa statistics, 5M TFT-LCD = 5-megapixel thin film transistor liquid crystal display, BCS = breast-conserving surgery, DCIS = ductal carcinoma in situ, GEE = generalized estimating equation, PACS = picture archiving and communication system, SM = specimen mammography.

Keywords: breast cancer, breast conservation, specimen radiography, surgical margin

1. Introduction

Long-term follow-up studies have demonstrated equivalent survival following breast-conserving surgery (BCS) and radiation therapy as well as following total mastectomy.[1–3] However, adequate surgical margins are vital for low local recurrence rates and cosmetic outcomes.[4] Specimen mammography (SM) is essential for evaluating surgical margins in non-palpable breast cancer. Generally, a mass or microcalcification is observed in breast cancer lesions on mammographic examinations. Although assessment of the final pathological margin is important for

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determining the outcome and decision making for reoperation, SM and frozen section examination are methods to ensure that the cancer is completely removed with sufficient margins intraoperatively. Some studies have found that if microcalcification is present in SM, additional resection can reduce the reoperation rate from 12% to 5%.[5]

Assessment of a surgical specimen with SM adds to the total surgical time owing to the time required for tissue transfer, image acquisition, and interpretation. Delay in interpreting SM prolongs the surgical time since performing an additional resection depends on margin assessment through SM. To minimize the delay in operation, a radiologist usually waits in the reading room. However, it is difficult for a radiologist to stand by to read SM results since it is uncertain when a specimen would arrive. Ideally, the SM should be reviewed and communicated by the radiologist to the surgeon. However, in many hospitals, it is quite challenging due to the lack of radiologists. Hence, the SM is sometimes reviewed only by a surgeon.

Recently, a mobile device-based picture archiving and communication system (PACS) was developed, allowing users to operate even in a non-PC environment. A Mobile device such as a tablet PC is convenient and allows instant reading anywhere. However, the use of mobile devices to interpretation in the breast radiology field is very limited. Digital imaging systems require a resolution of more than 2048×2560 pixels to read mammography scans, conventional mammography should not be interpreted on mobile devices with a lower resolution. However, the need to use high-resolution monitors for SM interpretation is diminished compared to the use for mammography interpretation since SM interpretation focuses on assessing the distance between resection boundaries and mass or microcalcification, unlike mammography interpretation, which focuses on mass shape and margin or microcalcification morphology. If a mobile device could be used for SM interpretation, it could help radiologists overcome the spatial and temporal limitations of the reading room. However, to our knowledge, there is no study comparing the performance of SM interpretation on mobile devices and high-resolution monitors. Therefore, this study compared the performance of SM interpretation on mobile devices and high-resolution monitors with a safety margin on the pathological result as the reference standard.

In this paper, we analyzed the morphological pattern of the specimen to show the characteristics of the breast cancer specimen and compared the difference between the radiological margin and pathologic margin, followed by a diagnostic performance analysis to compare the results of the mobile devices and high-resolution monitors for margin evaluation. This further analysis was conducted not only for each reader individually but also for each display, making it easy to compare the results. The difference in the time required for diagnosis was also compared. Finally, by examining the agreement between the readers for each display and evaluating the reliability, we compared the margin evaluation performance of the mobile device and the high-resolution monitor in various ways.

2. Materials and methods

2.1. Study subject

This retrospective study was approved by the Institustional Review Board (IRB) of Seoul National University Bundang Hospital (IRB NO: B-1208-167-102), and the requirement for informed consent was waived.

A total of 257 patients underwent SM examinations from January 2012 to May 2013 at our institution. Among these patients, only those who underwent SM for BCS were included (n = 159). In case, multiple SM was performed at the same day, only first SM was included. Women who underwent BCS after vacuum-assisted excision or excisional biopsy (n = 4), and BCS after neoadjuvant systemic therapy (n = 51) were excluded. Finally, 104 patients (median age, 50 years; age range, 32–76 years) with 105 breast lesions in were enrolled in this study (Fig. 1). The final pathological results of the breast cancers were invasive ductal cancer (n = 58, 55%), ductal carcinoma in situ (DCIS; n = 39, 37%), mixed DCIS and lobular carcinoma in situ (LCIS) (n = 2, 2%), mucinous carcinoma (n = 2, 2%), invasive lobular cancer (n = 2, 2%), invasive micropapillary cancer (n = 1, 1%), and metaplastic carcinoma (n = 1, 1%).

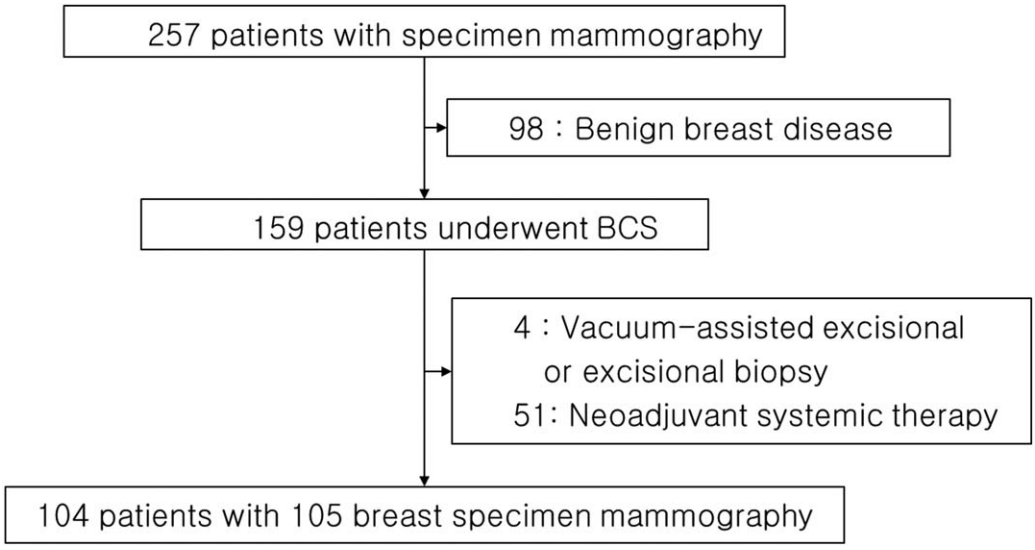

Figure 1. Patient inclusion diagram. BCS, breast-conserving surgery.

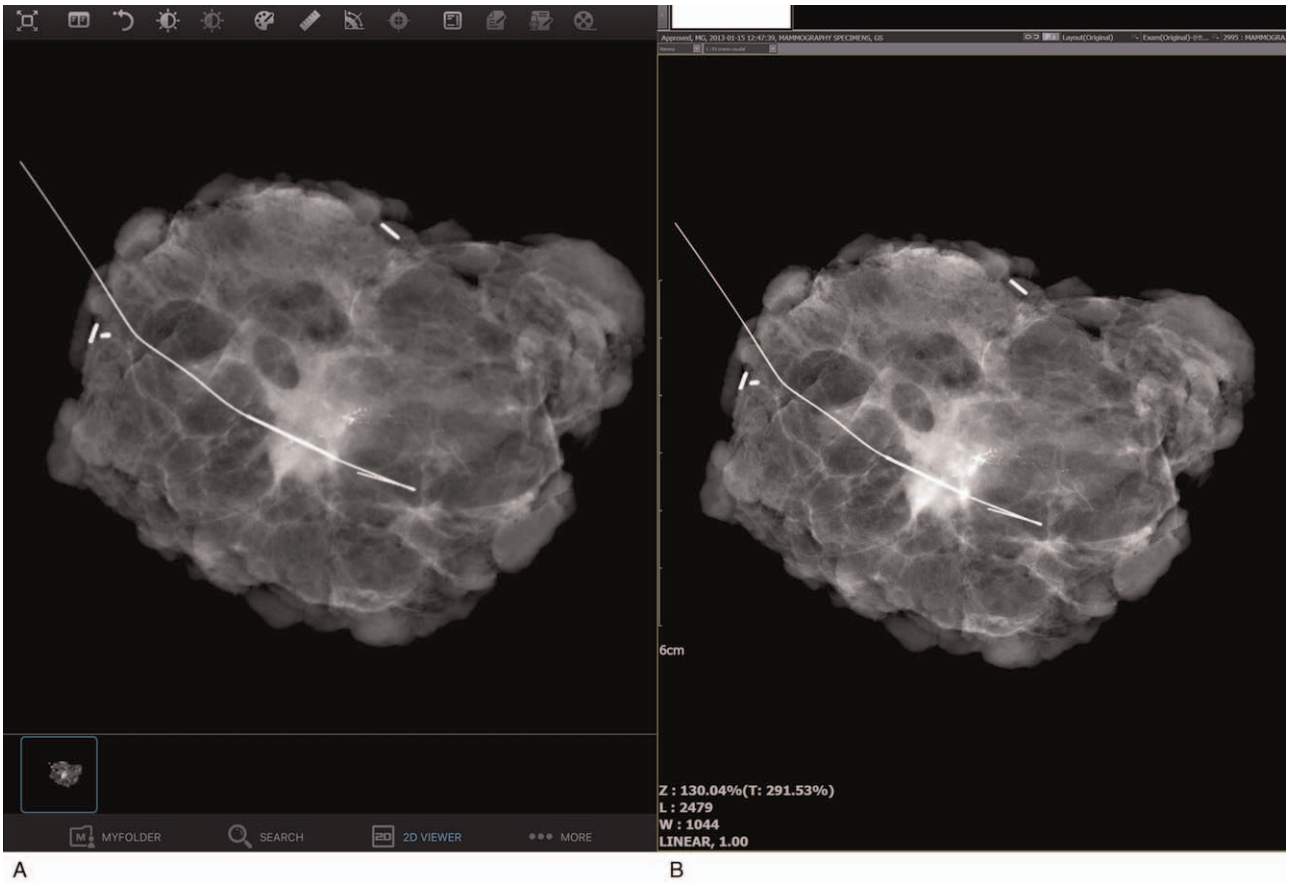

Figure 2. Example of a specimen mammography from a mobile device using the mobile PACS application (A) and from a 5-megapixel thin film transistor liquid crystal display using the PACS program (B).

2.2. Specimen mammography

The BCS specimen was oriented by the surgeon. A tagging suture with one metallic clip indicated the upper margin and that with two clips indicated the lateral margin. The superficial margin was tagged without a clip. Spot magnification and compression SM were performed, maintaining anatomical position in the breast imaging department using two digital mammography systems (Senographe 2000D, GE medical system, WI, USA and Brestige, Medi-future, Seongnamsi, Korea).

2.3. Displays and mobile PACS

The mobile PACS used in this study has been previously described.[6] The interface of mobile PACS was similar to that of a PACS workstation (Fig. 2). It allowed image magnification, window level and width adjustment, zooming, panning, and length measurement. To compare the dedicated monitor and the mobile device, a 5-megapixel (5M) thin film transistor liquid crystal display monitor (TFT-LCD; WIDE, Korea) and New iPad (Apple Inc., CA) were used. The detailed specifications of both display are listed in Table 1.

2.4. Image analysis and reference standard

The study images were reviewed by four radiologists—2 radiologists used the 5M TFT-LCD monitor (B.L.Y and M.Y. K, four years of experience), and the two other radiologists used mobile devices (H.S.A and M.J.J, 2 and 7 years of experience, respectively). All the readers analyzed the direction (upper, upper outer, outer, lower outer, lower, lower inner, inner, and upper inner) and distance of the nearest margin from cancer lesion, confidence (from 0 to 10) of positive margin, and interpretation time. The morphological pattern was assessed by two readers with the 5M TFT-LCD monitor in consensus after the study image review. The surgical margin status was evaluated based on the pathological report. In order to ensure true positives, the margin direction was also checked based on the pathologic report (e.g., outer, lower outer, and upper outer for positive outer margin on the pathological report). A positive radiological margin was defined as a margin of ≤ 5 mm, and a positive pathological margin was defined as a margin of <1 mm.

Table 1

Display device specification.

	New iPad (Apple Inc., CA)	5M TFT-LCD* (WIDE, Korea)
Size (inch)	9.7	21.3
Aspect ratio	4:3	4:3
Display type	LCD	LCD
Resolution	2048x1536	2560x2048
Pixel density (pixel per inch)	264	154

5M TFT-LCD = 5-megapixel thin film transistor liquid crystal display.

2.5. Statistical analysis

All statistical analyses were performed using IBM SPSS software (version 25). The difference between radiological margins, measured with both the displays, and pathological margins was compared using a paired Student's *t* test. The mean absolute difference was measured as the absolute difference between the radiological distances measured on SM and the pathological margin. The mean absolute difference was compared using a paired Student's *t* test. The interpretation time between displays was compared using the Student's *t* test. The generalized estimating equation (GEE) was used to compare the sensitivities and specificities. The area-under-the-curve was calculated to assess diagnostic performance for each reader using confidence of positive margin. In addition, we evaluated interobserver agreement using kappa statistics (κ) value for margin assessment by the 5M TFT-LCD monitor and the mobile device each. The κ value strength was defined as follows: 0.0, poor agreement; 0.0 to 0.20, slight agreement; 0.21 to 0.40, fair agreement; 0.41 to 0.60, moderate agreement; 0.61 to 0.80, substantial agreement; and >0.81, excellent agreement.[7] A two-tailed *P* value of <0.05 was considered statistically significant. A Bonferroni correction was used to control for multiple comparisons.

3. Results

A total of 20 (19%) specimens out of 105 had positive pathologic margins (<1 mm). Among the morphological patterns of the specimen, mass with microcalcification was the most common (57%, 60/105), followed by microcalcification (38%, 40/105) and mass (5%, 5/105). Dividing whole into the *in-situ* group (DCIS and mixed DCIS and LCIS, n = 41) and the invasive cancer group (n = 64), 11 in the *in-situ* group and 9 in the invasive group had positive surgical margin without statistical significant difference ($P = .104$). The *in-situ* group was more frequently showed as microcalcification than the invasive group, and the invasive group mainly showed as mass with microcalcification ($P < .001$). By morphological patterns, microcalcification had positive margin more frequently than mass with microcalcification ($P < .001$).

The mean pathological margin was 0.71 ± 0.59 cm. The radiological margin was significantly longer than the pathological margin except for that measured by one reader using the mobile device (Table 2). Figure 3 illustrates the difference in the radiological margin and the pathological margin in the same patient according to each reader. The difference range from −1.7 cm to 4.2 cm. The mean difference was not statistically different except for one reader using the mobile device. To analyze the descrepancy between surgical margin and radiological margin, the mean absolute difference were measured. It was ranged from 0.53 to 0.60 cm among all the readers, without statistical significance. The mean interpretation time was 49.5 ± 24.9 s for the 5M TFT-LCD monitor and 47.6 ± 22.16 s for the mobile device ($P = .012$).

Table 2

Pathologic margin and radiological margin according to the each reader.

	Mean ± SD (cm)	*P*
Pathologic margin (cm)	0.71 ± 0.59	
5M TFT-LCD R1	0.94 ± 0.62	.0021
5M TFT-LCD R2	0.90 ± 0.74	.0204
Mobile R1	0.92 ± 0.60	.0038
Mobile R2	0.71 ± 0.49	.9502

5M TFT-LCD = 5-megapixel thin film transistor liquid crystal display, Mobile = mobile device.

The diagnostic performance of the mobile device and 5M TFT-LCD monitor for margin assessment of specimen mammography are compared in Table 3. Considering the location of the positive pathological margin, the sensitivity of both the displays ranged from 65% to 55%, and the pooled sensitivity using GEE was not significantly different between the 5M TFT-LCD monitor and the mobile device ($P = 1.000$). The specificity of both displays ranged from 76.47% to 62.35%, which were not statistically significantly different ($P = .190$). The diagnostic performance was evaluated by a receiver operating characteristic (ROC) curve using the confidence of positive margin. When the ROC curves were obtained, the cases where the reader evaluated the opposite direction of the surgical margin were excluded. Statistical comparison of area under the curves (AUC) between readers was difficult because the patient groups in whom the closest margin location was correctly rated differed from reader to reader. The AUCs ranged from 0.6089 to 0.6699 on the mobile device and from 0.6241 to 0.7271 on 5M TFT-LCD monitor. Comparing the diagnostic performance of two displays in cancer groups, the *in-situ* group and invasive group showed no significant difference in sensitivity and specificity (Table 4). The subgroup analysis was conducted based on the morphologic pattern of the cancer. The sensitivity was higher in the microcalcification pattern and the specificity was higher in the mass with microcalcification pattern. However, between the two morphologic patterns, the sensitivity and specificity showed no statistical difference between the two displays (Table 5). The mobile device readers showed moderate agreement for the assessing margin positivity [κ value, 0.541 (95% CI, 0.381–0.700)] and the 5M TFT-LCD monitor readers also showed moderate agreement [κ value, 0.590 (95% confidence interval (CI), 0.425–0.755)].

4. Discussion

This study compared the diagnostic performance of the 5M TFT-LCD monitor and the mobile device for assessing the surgical margin. Four readers interpreted a total of 105 SM on both displays. It demonstrated that the sensitivity and specificity of both displays were comparable. The interobserver agreement was moderate for each display. Both displays had similar assessment times. However, a discrepancy between the pathological and radiological margins existed, regardless of the mobile and the dedicated displays.

Most of the previous radiologic imaging studies using mobile devices targeted CT and MR, which are low-resolution images.[8] Generally, the screen resolution and luminance of mobile devices are not suitable for the interpretation of radiography or mammography. However, three studies used conventional radiography, which is high-resolution images.[9–11] In the case of a study based on the diagnosis of urolithiasis on abdominal radiography, the result showed no difference using the mobile device and a dedicated monitor. In addition, there was no difference in the pulmonary nodule detection performance and the tuberculosis diagnosis, in the studies comparing off-the-shelf monitor and mobile devices on chest radiography. In some of these limited conditions, the diagnostic performance using a mobile device was comparable to that of a dedicated monitor. In

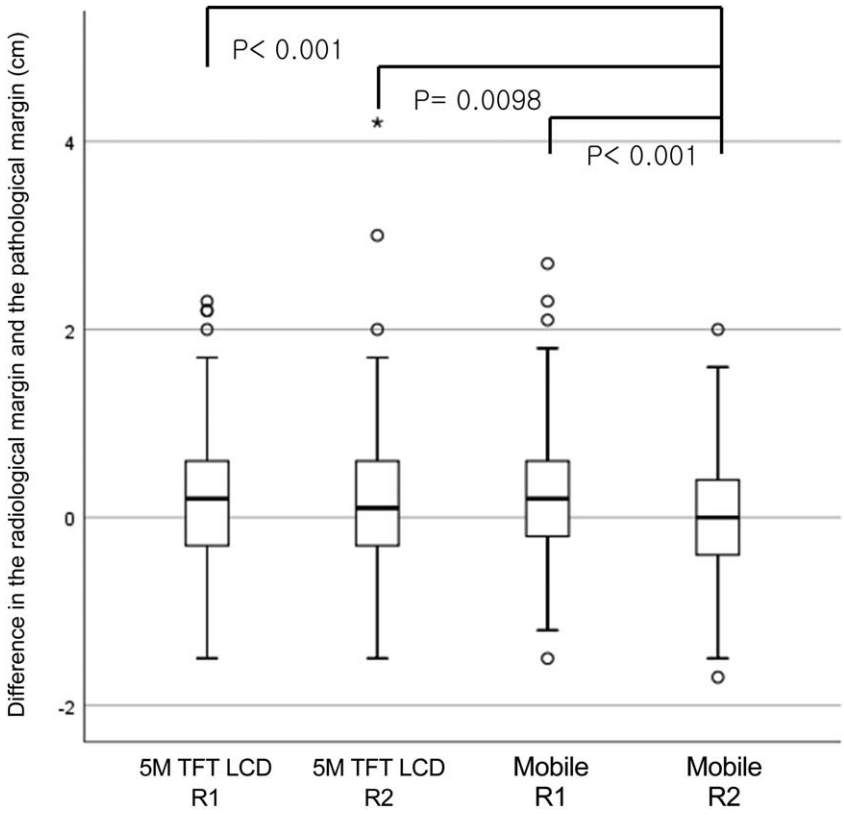

Figure 3. Box and whisker plot showed the distribution of the difference in the radiological margin and the pathological margin of the same patient according to each radiologist. A reader using mobile device showed statistical difference compared with the other readers.

Table 3

Comparison of the diagnostic performance between mobile devices and dedicated monitors for margin evaluation of specimen mammography.

	Sensitivity (%)		Specificity (%)		AUC (95% confidence interval)
		Pooled		Pooled	
5M TFT-LCD R1	55 (11/20)	60	71.76 (61/85)	74.12	0.6241 (0.4782, 0.7678)
5M TFT-LCD R2	65 (13/20)		76.47 (65/85)		0.7271 (0.5944, 0.8597)
Mobile R1	55 (11/20)	60	76.47 (65/85)	69.41	0.6699 (0.5166, 0.8231)
Mobile R2	65 (13/20)		62.35 (53/85)		0.6089 (0.4201, 0.7678)
P-value		1.000		0.190	

AUC = area-under-the-curve, 5M TFT-LCD = 5-megapixel thin film transistor liquid crystal display, Mobile =mobile device.

Table 4

Subgroup analysis of diagnostic performance between mobile devices and dedicated monitors for margin evaluation of specimen mammography in the cancer groups.

	In-situ group (n = 41)				Invasive group (n = 64)			
	Sensitivity (%)		Specificity (%)		Sensitivity (%)		Specificity (%)	
		Pooled		Pooled		Pooled		Pooled
5M TFT-LCD R1	72.73 (8/11)	72.73	60 (18/30)	68.33	33.33 (3/9)	44.44	78.18 (43/55)	77.27
5M TFT-LCD R2	72.73 (8/11)		76.67 (23/30)		55.56 (5/9)		76.36 (42/55)	
Mobile R1	72.73 (8/11)	72.73	66.67 (20/30)	61.67	33.33 (3/9)	44.44	81.82 (45/55)	73.64
Mobile R2	72.73 (8/11)		56.67 (17/30)		55.56 (5/9)		65.45 (36/55)	
P-value		1.000		0.307		1.000		0.393

5M TFT-LCD = 5-megapixel thin film transistor liquid crystal display, Mobile = mobile device.

Table 5

Subgroup analysis of the diagnostic performance between mobile devices and dedicated monitors for margin evaluation of specimen mammography in the morphologic patterns.

	Microcalcification (n = 40)				Mass with microcalcification (n = 60)			
	Sensitivity (%)		Specificity (%)		Sensitivity (%)		Specificity (%)	
		Pooled		Pooled		Pooled		Pooled
5M TFT- LCD R1	71.43 (10/14)	75	61.54 (16/26)	65.38	20 (1/5)	30	78.18 (43/55)	79.09
5M TFT- LCD R2	78.57 (11/14)		69.23 (18/26)		40 (2/5)		80 (44/55)	
Mobile R1	64.29 (9/14)	67.86	61.54 (16/26)	59.62	40 (2/5)	50	81.82 (45/55)	72.73
Mobile R2	71.43 (10/14)		57.69 (15/26)		60 (3/5)		63.64 (35/55)	
P-value		0.154		0.392		0.212		0.144

5M TFT-LCD = 5-megapixel thin film transistor liquid crystal display, Mobile = mobile device.

this study, there was no difference in sensitivity and specificity between the mobile device and the dedicated monitor in the margin evaluation of SM. The diagnostic performance did not differ between the two displays even when the morphologic pattern was a microcalcification and a mass with microcalcification; there was also no difference between the two displays when the diagnostic performance was evaluated by dividing them into *in-situ* and invasive groups. The inter-observer agreement was similar in both displays. When evaluating margins for SM, the mean absolute difference, sensitivity, and specificity between mobile devices and dedicated monitors were not significantly different. However, this analysis is only for patients with breast cancer, excluding the patients who had benign lesions; it was the result of comparing diagnostic performance without previous images or patients' medical information. Therefore, consideration should be placed on the interpretation of the results.

The reoperation rate of BCS is approximately 20% and ranges from <10% to >70%.[12–17] To reduce this high reoperation rate, the collaborative attempt to lower lumpectomy reoperation rates conferences recommended a "toolbox" of multiple processes. These multiple processes cover the intraoperative margin assessment tools, wherein SM is strongly recommended.[18,19] In our study, the sensitivity and specificity for both displays were approximate 55% to 65% and 62% to 76%, respectively. It is difficult to compare the detailed diagnostic performance with other previous studies because each study used a different radiologic cut-off and definition of the surgical margin.[20–23] However, our results in both displays were consistent with the meta-analysis data indicating sensitivity and specificity of 0.53 (95% CI, 0.45–0.61) and 0.84 (95% CI, 0.77–0.89), respectively.[24] They found that the diagnostic performance of SM is relatively low compared with those of the frozen section (sensitivity: 0.86 and specificity: 0.96) and cytology examinations (sensitivity: 0.91 and specificity: 0.95). Although SM has low accuracy, it is a valuable tool to ensure that the entire lesion has been excised with a clear margin in non-palpable breast lesions before the end of surgery. Multiple other modalities for intraoperative specimen imaging are being investigated, such as US, MR, micro CT, and optical images.[25] However, insufficient data are available for comparing these new techniques with SM. Therefore, SM has been accepted as a conventionally used, immediate image-review system for BCS. Interpreting SM will be easier and more convenient if the radiologist using a mobile device. Radiologists can immediately interpret SM anytime, anywhere, which will be valuable, especially in institutions with a limited number of radiologists. The potential benefits of mobile devices interpretation are shortened operation times and decreased anesthetic time through reduced reading time. This will reduce operation cost and patient morbidity. Additionally, the accuracy of SM can be improved by using two views at orthogonal angles.[18,20] According to European guidelines, two-view SM can be used to check the completeness of excision. Furthermore, adding an orthogonal view may improve margin evaluation accuracy on mobile devices than this study.

Our study has several limitations. First, it was difficult to directly compare the performance of the 5M TFT-LCD monitor and the mobile device. This was because two groups of readers with different years of experience evaluated both methods. However, the readers were all breast specialists and SM evaluation is a simple task, making it less likely for inaccurate interpretation. The difference in performance between readers based on their experience may not be significant. Second, it is possible that the orientation of the specimen and margin labels were inaccurate. The breast tissue did not have a clear anatomical landmark; thus, a possibility of misplacing when clipping a specimen, acquiring an image, reading an image, or analyzing the pathological specimen existed. Margin positivity was assessed considering both location and distance. Although similar directions were recognized as correct, a possibility of errors still exists. Third, it is unable to evaluate specimens using two-view SM, which has better performance for margin evaluation, or three-dimensional tomosynthesis, because only one-view SM is performed in our institution. This warrants further research. Fourth, we only evaluated specimen mammography in specific conditions. Different imaging techniques, such as tomosynthesis, or different manufactures' equipment may lead to different results.

In conclusion, the mobile device showed comparable diagnostic performance with 5M TFT-LCD monitor in the evaluation of SM margin in patients with BCS. The result of our study may provide evidence of the helpfulness of the mobile device for SM interpretation in BCS. However, we believe that a larger sample size study should be warranted before using a mobile device for SM interpretation.

Author contributions

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Visualization: Bo La Yun, Sun Mi Kim.
Writing – original draft: Bo La Yun, Bohyoung Kim, Sun Mi Kim.
Writing – review & editing: Bo La Yun, Mijung Jang, Hye Shin Ahn, Mi Young Kim, Bohyoung Kim, Sun Mi Kim.

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