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ORIGINAL ARTICLE

Potential impact of tomosynthesis on the detection and diagnosis of breast lesions

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KEYWORDS

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Abstract *Objective:* The aim of this study was to evaluate the clinical performance of 3D tomosynthesis in comparison with Full Field Digital Mammography (FFDM) in the detection and diagnosis of breast lesions.

Material and methods: 132 patients underwent standard digital mammography and tomosynthesis and the likelihood of malignancy was categorized according to (ACR) BI-RADS.

Results: Tomosynthesis images had significantly increased the number of cases with BI-RAD 1 or 2 (normal/benign) to 62 (42.7%) compared to 39 (26.8%) at mammogram ($p < 0.005$). Tomosynthesis helped also in more clarification of benign characters. Tomosynthesis images had significantly decreased the number of indeterminate/suspicious lesions (BI-RADS 3 and 4) from 90 (62%) cases to 39 (26.8%) ($p < 0.005$). In a total of 40 lesions (27.5%) assigned to BI-RADS 5 at tomosynthesis, the tomosynthesis showed better performance in assessment of tumor extension and higher level in detection of clusters of micro-calcifications.

The accuracy, specificity, sensitivity and positive and negative predictive values (%) of mammography alone versus when combined with the tomosynthesis were as follows: 59.3, 62.8, 55.2, 56 and 62 versus 91.7, 92.3, 91, 91, and 92.3 respectively (Table 4).

Tomosynthesis significantly improved the detection of the breast lesions on mammography images especially in the dense breast with significantly higher accurate BI-RADS scoring (P value < 0.005).

Conclusion: Breast tomosynthesis is a promising technology that offers improved diagnostic and screening accuracy, fewer recalls as well as 3D lesion localization. Lesion conspicuity is improved using DBT compared with FFDM with a more confidence in making clinical decisions.

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1. Introduction

Digital mammography has become an accepted standard of care in screening and diagnosis of breast cancer; however, it has some limitations that are mainly attributed to the superimposition of normal breast structures in the path of the X-ray beam that diminishing the positive predictive value and specificity of the examination (1–4).

Breast tomosynthesis is a modality that acquires images of a breast at multiple angles during a short scan. The individual images are then reconstructed into a series of thin, high-resolution slices so eliminating the problem of overlapping structures in the breast as well thereby enhancing margin visibility, particularly in dense breasts (5–9).

The aim of this study was to evaluate the clinical performance of 3D tomosynthesis in comparison with Full Field Digital Mammography (FFDM) in the detection and diagnosis of breast lesions.

2. Material and methods

The study protocol was approved by the Institutional Hospital Ethical Committee. All patients provided informed consent. Study was performed during the period of June 2013 to March 2015 and included 132 consenting women, showing at least one breast lesion discovered by standard digital mammography and/or ultrasound (US). They underwent standard digital mammography in two views the cranio-caudal (CC) and medio-lateral oblique (MLO) views and tomosynthesis in both views (MLO and CC) of both breasts.

Mammography examination: FFDM and 3D tomosynthesis examination was done by GE's SenoClaire 3D breast tomosynthesis system. During a tomosynthesis scan, multiple projections (10–14) of low-dose exposure the breast are acquired at different angles while the X-ray tube moves in an arc fashion across the breast. Then reconstruction into one mm-thickness slices was performed off-line (i.e., at a different time from the image acquisition) to gain about 60–90 that can be further reconstructed to a three dimensional image. Images are displayed in slice or cine loop mode on dedicated high resolution work stations. The monitors were calibrated to the DICOM Gray scale Standard Display function. The radiologists were able to pan, zoom and alter the window level of the images.

A complementary ultrasound examination was done for all patients using Aplio XG device (Toshiba, Japan) using 6–10 MHz high frequency probes.

The reviewers categorized the likelihood of malignancy according to the American College of Radiology (ACR) Breast Imaging Data and Reporting System (BI-RADS) categories (15) in each of FFDM and breast tomosynthesis by radiologists in a consensus reading.

Breast density was assigned according to the BI-RADS edition (2013) to a, b, c and d-categories (a: the breast is almost entirely fatty, b: scattered areas of fibroglandular density, c: the breast is heterogeneously dense, and d: the breast is extremely dense (10)).

Qualitative items, such as mass shape, margins, density, architectural distortion, and calcifications were also recorded.

The radiologists were blinded to the findings of other modalities, to clinical reports, patient history, histology, and clinical follow-up. If the two readers could not reach consensus, datasets were forwarded to a third reviewer.

The golden standard was histology for lesions that had undergone breast biopsy (all of which were classified as malignant lesions ($n = 67$), plus a small proportion of those considered benign ($n = 21$) and fine-needle aspiration cytology (FNAC), whenever available, and 1-year follow-up for benign classified lesions. A one year stable lesion was considered of benign nature.

2.1. Statistical analysis

The data obtained from Full Field Digital Mammography and Digital Tomosynthesis were tabulated and compared as regards detection and diagnosis. Each modality was individually assessed using the Pearson Chi Square tests. The accuracy, sensitivity, specificity and positive and negative predictive values of either modality were also calculated. P value < 0.05 is considered to be significant.

Table 1 Breast lesion visibility at FFDM alone and tomosynthesis.

Mammography	Tomosynthesis		Total
	Yes	No	
Yes	106	0	106
No	32	7	39
Total	138	7	145

Table 2 BI-RADS score at mammography and tomosynthesis.

Mammography BI-RADS	Tomosynthesis BI-RADS						
	1	2	3	4	5	6	Total
1	3	12	2	1	0	0	18
2	3	10	2	4	2	0	21
3	8	20	8	3	2	0	41
4	2	4	2	17	24	0	49
5	0	0	0	0	12	0	12
6	0	0	0	0	0	4	4
Total	16	46	14	25	40	4	149

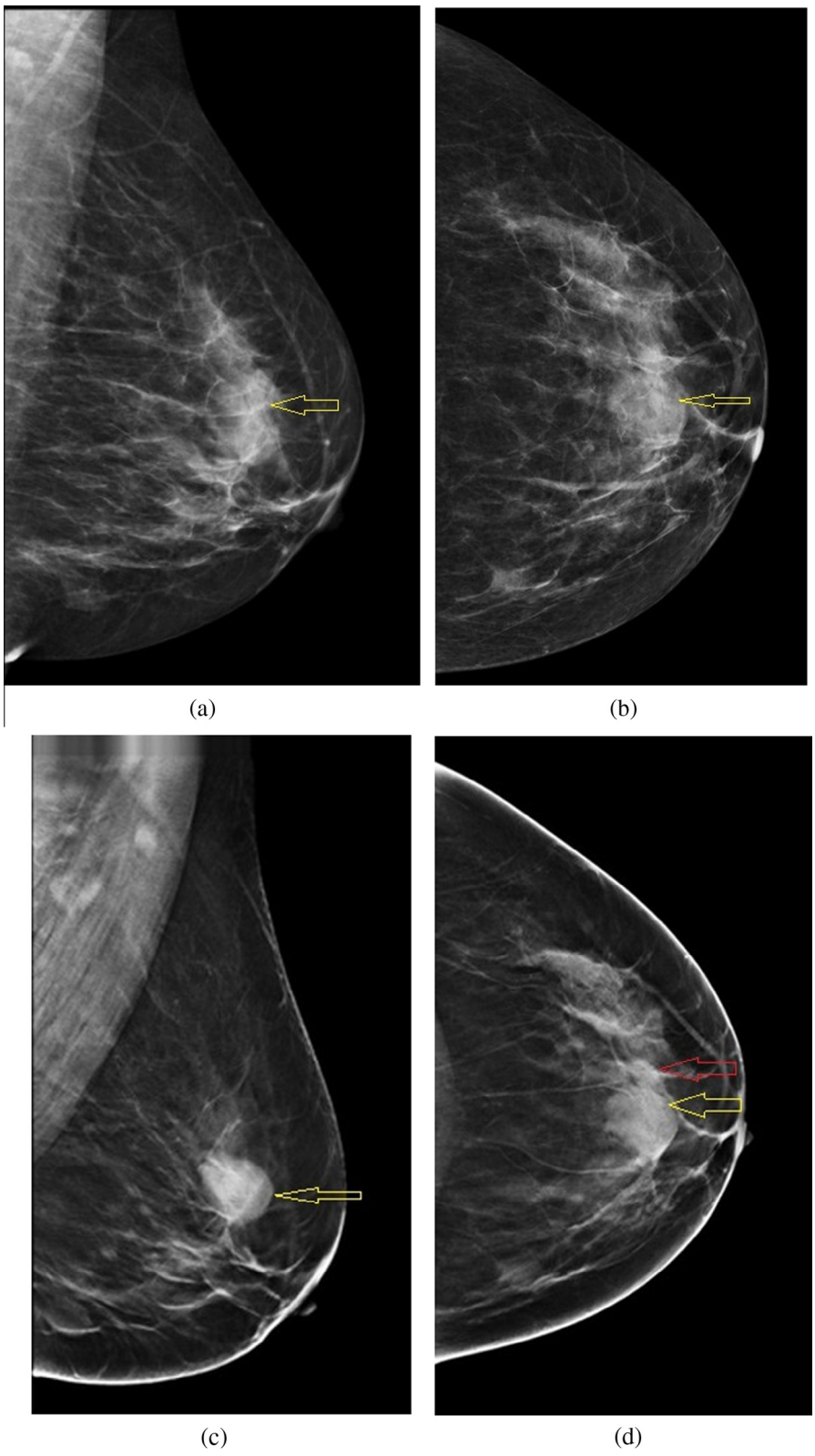


Fig. 1 Full field digital mammography (FFDM) in MLO (a) and CC (b) views showing left retro-areolar mass (yellow arrow). Tomosynthesis in MLO (c) and CC (d) views showed its well-defined margin (yellow arrow) and revealed a smaller adjacent one (red arrow). Final diagnosis is two simple cysts.

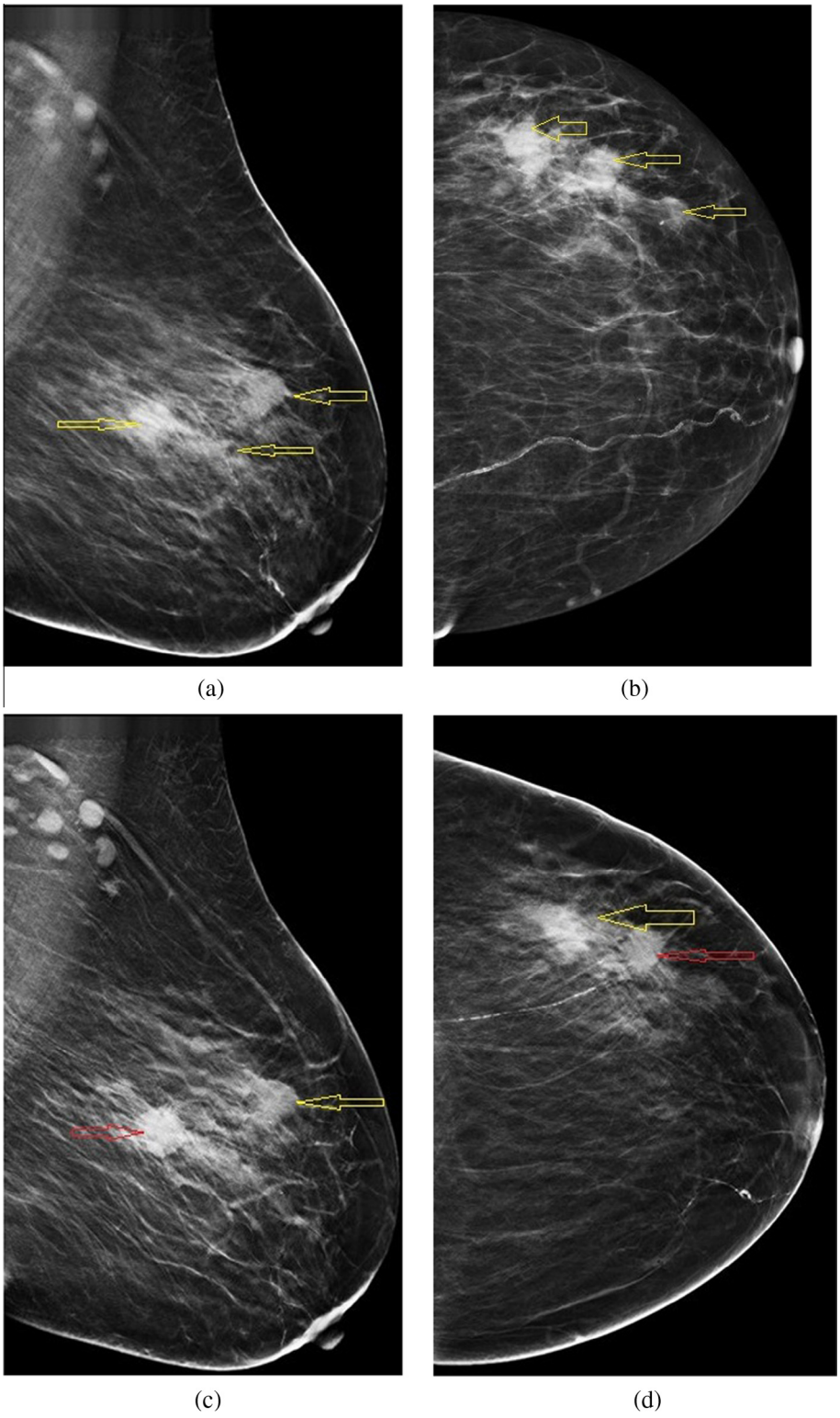


Fig. 2 FFDM in MLO (a) and CC (b) views revealed three ill-defined nodules (yellow arrows) seen at left breast upper outer quadrant (UOQ). Tomosynthesis in MLO (c) and CC (d) views confirmed the presence of only two masses, the first is partly ill-defined (yellow arrow) and other is ill-defined finely speculated nodule (red arrow). Final diagnosis: two malignant masses (NB: multiple axillary lymph nodes).

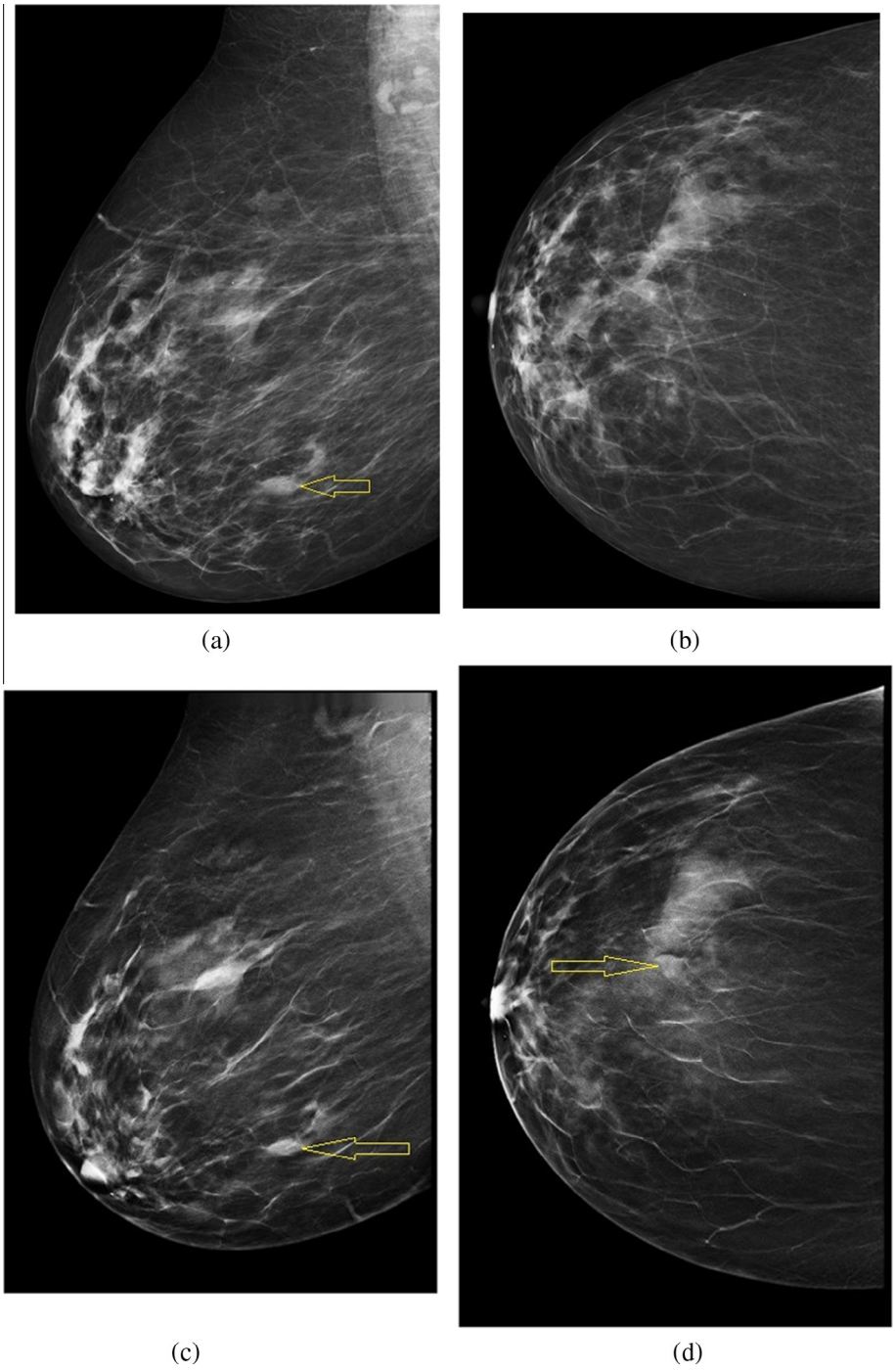
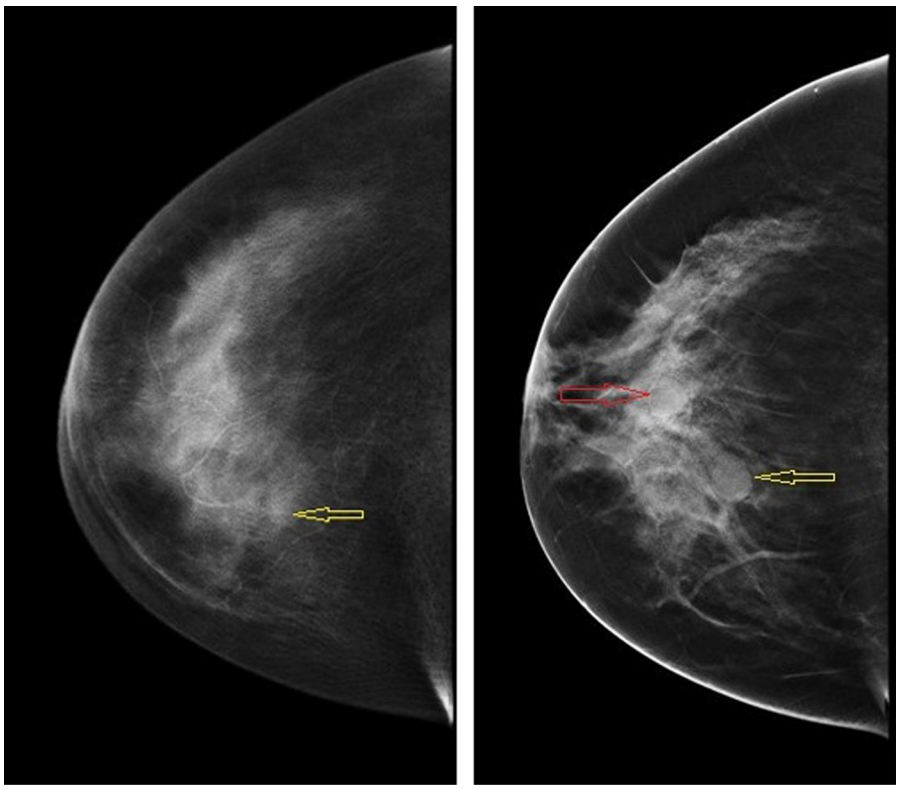


Fig. 3 FFDM in MLO (a) and cc (b) views showed asymmetric density noted at lower half of right breast, seen only in the MLO view (yellow arrow) while Tomosynthesis in MLO (c) and CC (d) revealed a well-defined nodule (yellow arrow). Final diagnosis: Fibroadenoma.

3. Results

This study included 132 patients; average age of 59 years (range 34–74 years old). The dataset according to the final diagnosis included 145 breasts, 67 of them were malignant and 78 were with benign lesions. The analysis was performed per breast, which means that only one finding per breast was counted i.e. the finding with the highest BI-RADS score was taken for the analysis in all cases.

Out of the total 145 breast lesions, 67 were cancers of which 34 (50.8%) were invasive ductal cancers (IDC), 17 (25.4%) invasive lobular cancers (ILC), 7 (10.4%) IDC with ductal carcinoma in situ (DCIS), 3 (4.4%) tubular cancers, 2(3%) associated with DCIS, 2 (3%) DCIS alone, and 2 (3%) intracystic



(a) (b)

Fig. 4 FFDM in MLO (a) and CC (b) views revealed dense breast with no definite masses detected while tomosynthesis in MLO (c) and CC (d) views revealed right breast UOQ deeply seated well defined mass, (yellow arrow). Final diagnosis: Fibroadenoma.

papillary carcinoma. The median tumor size was 13 mm (range 4.5–45 mm). The remaining lesions ($n = 78$) were benign (Table 1).

Initial BI-RADS score was assigned to each mammogram, then re-evaluation and re-adjustment of the score were done after reviewing the tomosynthesis images. The BI-RADS score thus was ranked higher (upgraded), ranked lower (downgraded) or remained the same (Table 2).

Breast density was assigned according to the BI-RADS edition (2013) to a, b, c and d-categories. Categories c and d were assigned to 51 (35.1%) and 33 (27.7%) respectively.

Tomosynthesis images had significantly increased the number of cases with BI-RAD 1 or 2 (normal/benign) to 62 (42.7%) compared to 39 (26.8%) at mammogram ($p < 0.005$). Tomosynthesis helped also in more clarification of benign characters such as the well definition of the mass margin, typical benign radiolucent halo as well as central fat density thus allowing more confident diagnosis of benignity (Figs. 1–3)).

Tomosynthesis images had significantly decreased the number of indeterminate/suspicious lesions (BI-RADS 3 and 4) from 90 (62%) cases to 39 (26.8%) ($p < 0.005$) by supporting either a benign or a malignant diagnosis, and the tomosynthesis mammogram is as follows: 24 was upgraded to BI-RAD 5, while 36 mammograms were downgraded to benign score (Figs. 4 and 5).

In a total of 40 lesions (27.5%) assigned to BI-RADS 5 at tomosynthesis, the tomosynthesis showed better performance in assessment of tumor extension and higher level in detection of clusters of micro-calcifications (Fig. 6).

We had six mammograms that were scored as benign at tomosynthesis (False negative). It included five small breast lesions that were embedded in dense heterogeneous breast parenchymal tissue and were hardly visible on US as a suspicious mass and one case of occult malignancy, a low-grade ductal carcinoma in situ (DCIS) arising in a papilloma that was detected by focal enhancement at contrast-enhanced MRI (Table 3).

On the other hand we had 6 false positive tomosynthesis results (one granulomatous mastitis, 2 benign precancerous lesions, one radial scar, and two cases of post surgical fat necrosis).

The accuracy, specificity, sensitivity and positive and negative predictive values (%) of mammography alone versus when combined with the tomosynthesis were as follows: 59.3, 62.8, 55.2, 56 and 62 versus 91.7, 92.3, 91, 91, and 92.3 respectively (Table 4).

Tomosynthesis significantly improved the detection of the breast lesions on mammography images especially in the dense breast with significantly higher accurate BI-RADS scoring (P value < 0.005) (Fig. 7).

4. Discussion

Breast tomosynthesis is a three-dimensional challenging imaging technology that obtains multiple angles scanning of

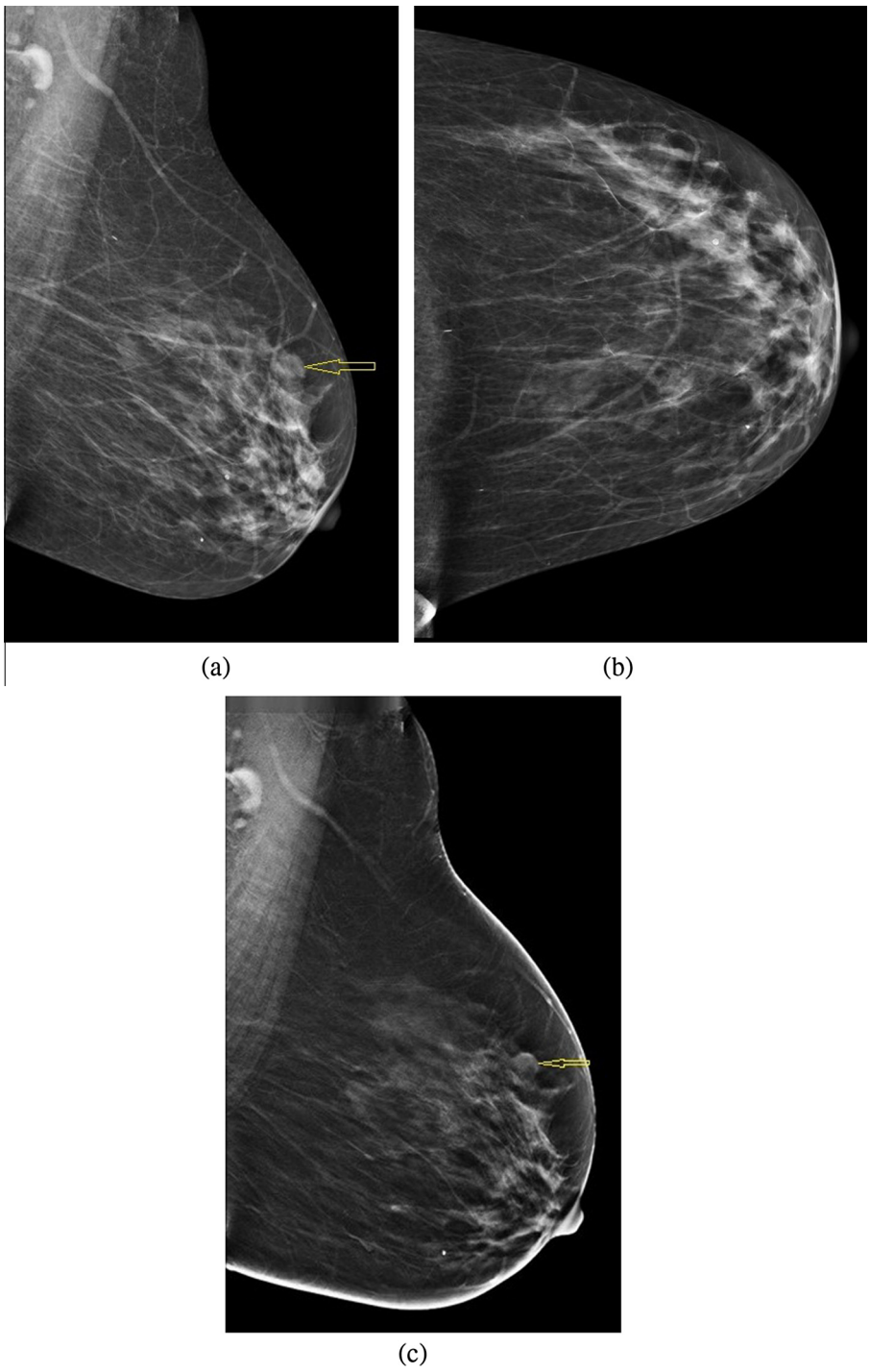


Fig. 5 FFDM in MLO (a) revealed asymmetric density in upper half of left breast (yellow arrow), not detected in CC view (b). Tomosynthesis in MLO view (c) revealed focal increased density with no underlying masses. Final diagnosis was glandular tissue condensation.

a stationary compressed breast with reconstruction of resulted images into a series of thin high-resolution slices so greatly reducing or eliminating the anatomical noise problems caused by tissue overlap in two-dimensional mammography imaging (11–14).

Several studies considered that the tomosynthesis has a potential additional value in both screening and diagnosis of breast lesions with more accurate evaluation of lesions as well as a higher sensitivity and specificity for breast cancer detection than digital mammography (16–23).

In a study carried out by Bernardi et al. (24), they evaluated the effect of integrating 3D mammography with tomosynthesis in breast screening on 158 consecutive recalls, and they showed that combined 2D + 3D mammography is more

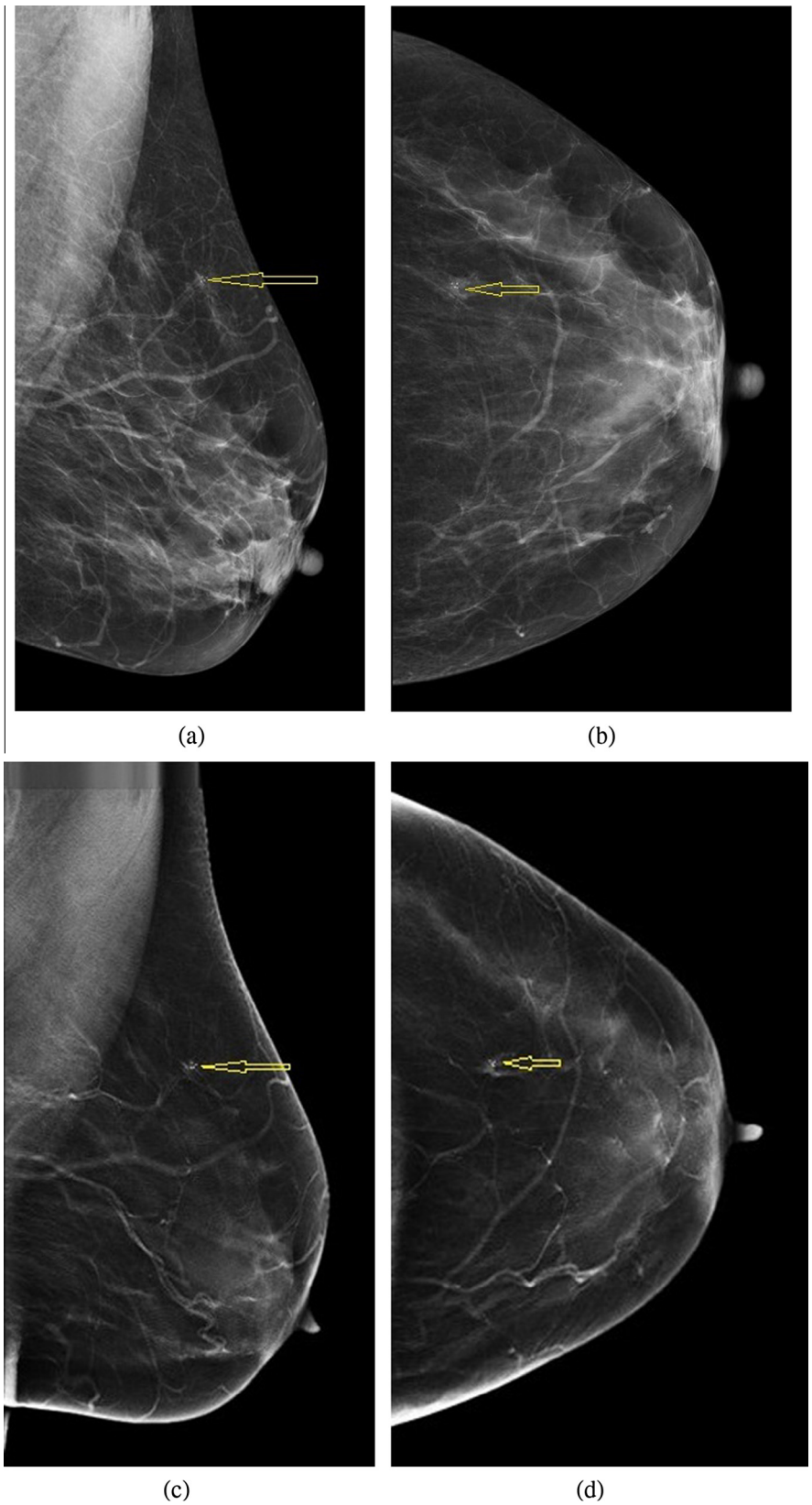


Fig. 6 FFDM MLO (a) and CC (b) views revealed left breast UOQ cluster of micro-calcifications (yellow arrow). Tomosynthesis MLO (c) and CC (d) views confirmed the presence of micro-calcification cluster and excluded any underlying masses or distortion. It was stable at follow-up.

Table 3 Correct diagnosis of malignant breast lesions at mammography and tomosynthesis.

	True +ve	False −ve	True −ve	False +ve
Tomosynthesis	61	6	72	6
Mammography	37	30	49	29

Table 4 Accuracy, specificity, sensitivity and positive and negative predictive values (%) of mammography alone versus when combined with the tomosynthesis.

	Mammography	Tomosynthesis
Accuracy (%)	59.3	91.7
Specificity (%)	62.8	92.3
Sensitivity (%)	55.2	91
Positive predictive values (%)	56	91
Negative predictive values (%)	62	92.3

time-consuming than 2D mammography but it enhanced the accuracy in cancer detection and reduced recall rate.

In addition, Noroozian et al. (9) issued a study to compare the breast mass characterization using Digital Breast Tomosynthesis (DBT) and mammographic spot views (MSV) in 67 masses (30 malignant, 37 benign). They found that the mean mass visibility ratings were slightly better with DBT than with MSV with characterization of seven additional malignant masses as BI-RADS 4 or 5 with DBT than with MSV.

In the report of Tingberg et al. (25), they reviewed digital breast tomosynthesis and FFDM examinations in over 2000 women and showed higher sensitivity of BT in comparison with single-view and 2-view digital mammography in the detection of breast cancer ($p < 0.01$).

In the current work, we also noticed that tomosynthesis had a higher capability to detect breast lesions (138 lesions, 95%) in comparison with mammogram ($n = 106$, 73%). Also a notable improvement of malignant lesions detection by tomosynthesis is achieved as of 67 lesions that proved to be malignant, and tomosynthesis had correctly diagnosed 61 lesions (91%) while the estimation was lower by mammography alone (37 lesions, 55.2%).

The current study included 84 lesions (57.9%) with dense parenchymal texture (category c and d), in which we had five lesions that showed false negative result at tomosynthesis, that were small breast lesions that embedded in dense heterogeneous breast parenchymal tissue and that were not associated with architectural distortion. it was shown at breast US and confirmed by biopsies.

These results are also consistent with those achieved by Skaane et al. (26) who carried out a study for 129 women and showed that there were higher conspicuity scores for tomosynthesis compared to conventional 2D for cancers presenting.

In addition, this is in agreement with results of Poplack et al. (1) who studied the impact of using DBT in 99 digital screening recalls for 98 women with abnormal digital screening mammography. They found that DBT image quality was equivalent ($n = 51$) or superior ($n = 37$) to diagnostic mammography in 89% (88/99). Thus they concluded that DBT has the potential to decrease the recall rate by 40% (37/92) when used adjunctively with digital screening mammography.

Andersson et al. (12) compared the visibility of breast cancer in one-view digital breast tomosynthesis versus one- or two-view Full-Field Digital Mammography (FFDM). They reported a statistically significant upgrade rate of BI-RADS assessments as they found that the cancer visibility on digital breast tomosynthesis was greater in more than 50% of lesions (22/40) compared with single-view FFDM.

Similar results were confirmed in the current work, as tomosynthesis images significantly increased the number of cases with BI-RADS 1 or 2 (normal/benign) to 62 (42.8%) compared to 39 (26.9%) at mammogram. This can be attributed to the fact that tomosynthesis helped in more clarification of benign characters such as the well definition of the mass margin, typical benign radiolucent halo and central fat density thus allowing more confident diagnosis of benignity.

In addition, tomosynthesis images significantly decreased the number of indeterminate/suspicious lesions (BI-RADS 3 and 4) from 90 lesions (62%) to 39 (26.9%) ($P < 0.005$), by supporting either a benign or a malignant diagnosis as follows: 24 mammograms were upgraded to BI-RAD 5, while 36 mammograms were downgraded to benign score.

In a total of 40 lesions (27.6%) assigned to BI-RADS 5 at tomosynthesis, tomosynthesis showed better performance in assessment of tumor extension and higher level in detection of clusters of micro-calcifications.

These results match also with the results of Gur et al. (27) who analyzed a previously reported study of eight experienced radiologists who interpreted 125 examinations, 35 of them with verified cancers. On comparison of using a combined FFDM and digital breast tomosynthesis to the FFDM alone, about 16% improvement in performance was achieved (95% CI, 7%–26%; $p < 0.01$).

In addition, this agrees with the study of Hakim et al. (11), who reviewed the imaging studies, including FFDM, additional diagnostic views, and digital breast tomosynthesis of 25 women with known masses. Combined FFDM and digital breast tomosynthesis were shown to be better for diagnosis in 50% (50/100) of the BI-RADS ratings compared with FFDM alone and additional views.

In the current study, tomosynthesis significantly enhanced the cancer detection rate and showed a higher capability of correct categorization of lesion into a benign or malignant entity as it showed an accuracy of 91.7% compared to only 59.3% in mammography alone. This was associated with the enhancement of the sensitivity to 91% compared with 55.2% for mammography alone. Also, tomosynthesis images had increased the specificity, positive and negative predictive values (%) from 62.8, 56 and 62 to 92.3, 91 and 92.3 for mammogram respectively.

The present study had some limitations as follows: (a) the number of malignant tumors and benign lesions is limited, (b) the lack of compressions or magnification that may improve the diagnostic accuracy of the two-view FFDM, and (c) non-screening methods as most of the patients present with diagnosed breast pathology.

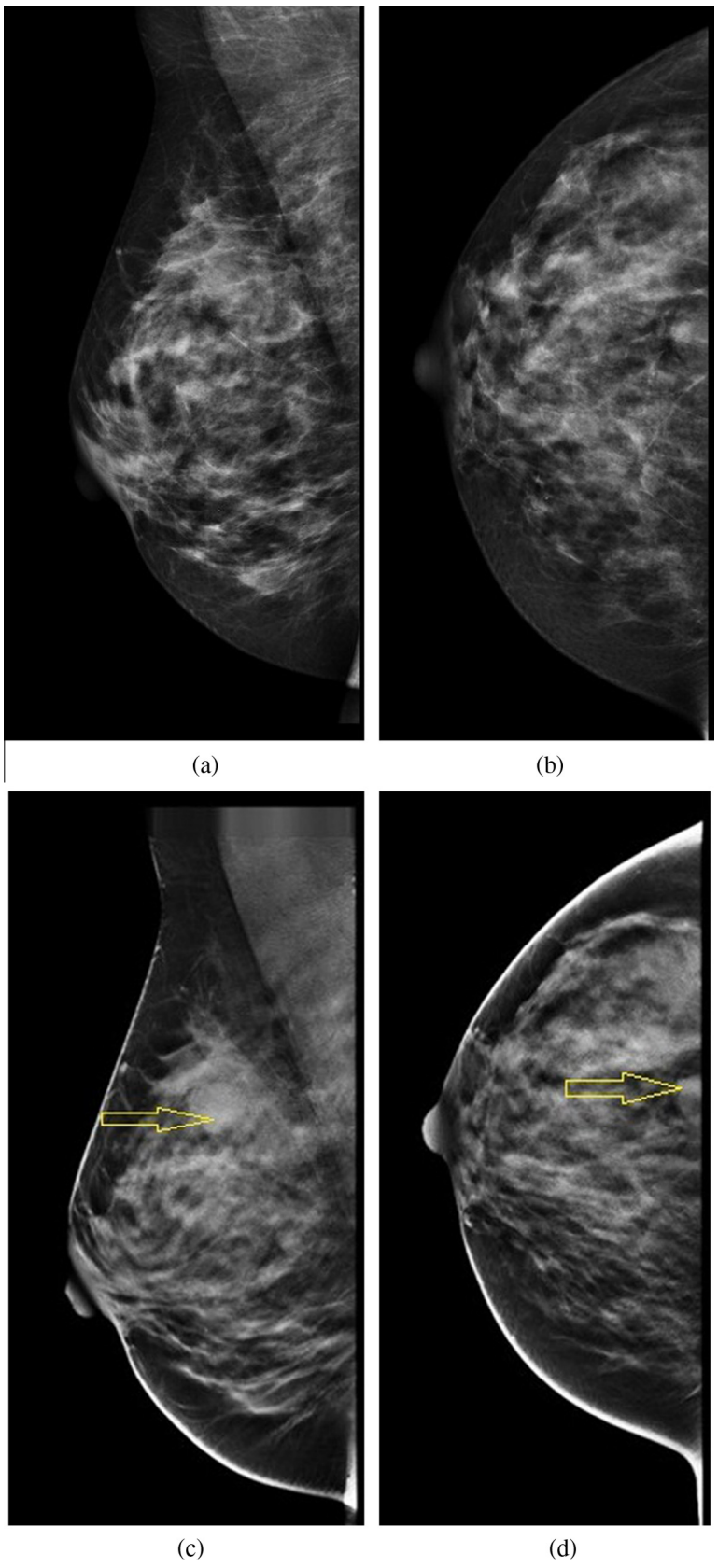


Fig. 7 FFDM CC view (a) revealed partially obscured nodule in lower half of right breast (white line) that suspecting malignancy while Tomosynthesis CC view (b) showed the previously mentioned nodule be well defined (yellow arrow) and revealed another well-defined nodule at retro-areolar region (red arrow). Final diagnosis: Fibroadenomata.

5. Conclusion

Breast tomosynthesis is a promising technology that offers improved diagnostic and screening accuracy, fewer recalls as well as 3D lesion localization. Lesion conspicuity is improved using DBT compared with FFDM with a more confidence in making clinical decisions.

Conflict of interest

There is no conflict of interest.

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