RESEARCH ARTICLE

Correlation of intra operative specimen imaging with final histopathology in breast conserving surgery for breast cancer

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Abstract

Objective: To determine the effectiveness of specimen mammography in breast conserving surgery cases with respect to reduction in margin positivity rate, and to see whether the rate of secondary surgeries is decreased by intra-operative excision based on specimen mammography evaluation.

Method: The retrospective study was conducted at the Shaukat Khanum Memorial Cancer Hospital and Research Centre, Lahore, Pakistan, and comprised data from January 2018 to December 2019 related to all female breast cancer patients who underwent mastectomy or breast conserving surgery with the involvement of specimen mammography. Sensitivity, specificity, positive predictive value and negative predictive value of specimen mammography were calculated. Data was analysed using SPSS 20.

Results: Of the 226 patients initially assessed, 65(28.7%) were excluded, and the final sample comprised 161(71.2%) women with mean age 46.71±10.47 years. The sensitivity, specificity, positive predictive value and negative predictive value of specimen mammography for the sample were 65.8%, 80.8%, 54% and 87.3%, respectively. Performing specimen mammography for intra-operative margin assessment in 12 patients was likely to spare one patient from re-excision.

Conclusion: Intra-operative specimen mammography was found to be a reliable tool for assessing margin status.

Key Words: Breast cancer, Specimen mammography, Breast conservation surgery, Margin positivity.

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Introduction

From the key clinical trials that established the equality of breast conservation surgery (BCS) with mastectomy in terms of survival decades ago, to the recent cohort studies showing even BCS supremacy, the paradigm shift from mastectomy to BCS in early-stage breast cancer has the force of literature behind it[1-5]. Although less invasive, BCS is associated with the risk of positive surgical margins, which, in turn, leads to an increased risk of local recurrence as well as repeat surgery and subsequent waste of healthcare resources along with patient dissatisfaction[6]. Since one of the most important prerequisites for BCS is adequacy of margin excision, the need of intra-operative margin assessment cannot be denied[6,7]. Different radiological and pathological intra-operative margin evaluation tools are being used worldwide to avoid the need of secondary surgery, the more common among them being specimen mammography (SMG), magnetic resonance imaging (MRI), ultrasound (US), and frozen section and touch cytology[8-10]. The definition of an optimum negative margin width for both invasive as well as in situ cancer had remained a matter of considerable debate since long till the publication of consensus guidelines on margins by the Society of Surgical Oncology (SSO) and the American Society of Radiation Oncology (ASTRO) in 2014 and 2016[11, 12].

The current study was planned to determine the effectiveness of SMG in BCS cases with respect to reduction in margin positivity rate, and to see whether the rate of secondary surgeries is decreased by intra-operative excision based on SMG evaluation.

Materials and Methods

The retrospective study was conducted at the Shaukat Khanum Memorial Cancer Hospital and Research Centre (SKMCH&RC), Lahore, Pakistan, and comprised data from January 2018 to December 2019 related to all female patients with breast cancer, both invasive and in situ, who underwent mastectomy or BCS, either upfront and post-neoadjuvant chemotherapy (NACT), with the involvement of SMG. Data of those who underwent mastectomy or BCS without SMG was excluded. After approval from the institutional ethics review board, the

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data was retrieved using the Hospital Information System (HIS).

In patients planned for BCS following NACT, metallic clips were placed prior to NACT. After completion of NACT, wire-localisation of non-palpable lesions / micro calcifications was done with a hooked wire under US or mammographic guidance. Wire-localisation was also done in patients with impalpable lesions who were scheduled for upfront surgery. If the lesion was detectable by US and was superficial, direct skin marking of the lesion was done instead of wire-localisation. BCS was performed with at least 1cm gross margin around the tumour or wire in case of occult lesions. Direction-oriented specimens were sent to the mammography unit where specimen radiograph was obtained. If mass, calcification, wire or clip was found close to the margin on visual analysis of specimen X-ray by the surgical team, further resection was performed. The final mammogram report was based on analysis by two radiologists. On histopathology, "no tumour on ink" was taken as negative margin, tumour on ink as positive margin, and within 1mm from the inked margin as close margin for both invasive and in situ cancer. SMG evaluation done by two surgeons was compared independently with the radiologist's and final histopathology reports.

Data was analysed using SPSS 20. Mean ± standard deviation were used to express quantitative data, whereas frequencies and percentages were used for qualitative data. The association of explanatory variables in relation to true negative (TN), false negative (FN), true positive (TP) and false positive (FP) status was determined using chi-square test or fisher's exact test. Sensitivity, specificity, positive predictive value (PPV) and negative predictive value (NPV) of SMG were calculated using 2x2 tables generated though chi-square or fisher's exact test. P≤0.05 was considered significant.

Results

Of the 226 patients initially assessed, 65(28.7%) were excluded, and the final sample comprised 161(71.2%) women with mean age 46.71±10.47 years. Clinic and pathological tumour characteristics of all the cases included were noted (Table 1).

Table-1: Demographic and clinic-pathological data.

Characteristics	Frequency (n)	Percentages
Age (years)		
Up to 40	42	26.1
Above 40	119	73.9
Focality		
Unifocal	129	80.1
Multifocal	32	19.9
IInitial tumour size (mm)		
T1	41	25.5
T2	114	70.8
T3	01	0.6
Tis	04	2.5
Tx	01	0.6
Nodal status		
Positive	76	47.2
Negative	80	49.7
Not applicable	05	3.1
ER status		
Positive	125	77.6
Negative	36	22.4
PR status		
Positive	101	62.7
Negative	60	37.3
HER2 neu status		
Positive	35	21.8
Negative	126	78.2
Histopathology		
IDC	71	44.1
IDC+DCIS	69	42.9
ILC	14	8.7
DCIS	07	4.3
Grade		
I	02	1.2
II	109	67.7
III	43	26.7
Not applicable	07	4.3
Chemotherapy		
Adjuvant	33	20.5
Neo adjuvant	128	79.5
Pre-operative tumour localization method		
Ultrasound marking	06	3.7
Ultrasound guided wire localization	90	55.9
Stereotactic wire localization	65	40.4
Margin status on histopathology		
R0	126	78.3
R0 (close)	18	11.2
R1	17	10.6
Re-excision		
Yes	14	8.6%
No	3	
Per-operative extra margin excision		
Yes	32	19.9
No	129	80.1
Per-operative extra margin histopathology (n=32)		
Tumour present	09	28.1
No tumour	23	71.9

T1: Tumour 20mm or less, T2; Tumour 21-50mm, T3: Tumour >50mm, Tis: Tumour in situ, Tx: Tumour size undetermined, ER: Oestrogen receptor, PR: Progesterone receptor, HER 2 neu: Human epidermal growth factor receptor 2, IDC: Invasive ductal carcinoma, ILC: Invasive lobular carcinoma, DCIS: Ductal carcinoma in situ, R0: Margin not involved micro/macroscopically, R0 (close): Margin close within 1mm of inked margin, R1: Margin involved microscopically.

Table-2: Comparison of specimen mammography (SMG) findings with final histopathology in relation to tumour characteristics.

Variables	Categories	True Negative n (%)	False Negative n (%)	True Positive n (%)	False Positive n (%)	Total n (%)	*p*-value
Whole group		97 (60.2%)	14 (8.7%)	27 (16.8%)	23 (14.3%)	161 (100%)	
Age (years)	Above 40	73 (61.3%)	13 (10.9%)	18 (15.1%)	15 (12.7%)	119 (100%)	0.185
	Up to 40	24 (57.1%)	01 (2.3%)	09 (21.4%)	08 (19%)	42 (100%)	
Tumour Size (mm)	T1	27 (65.8%)	03 (7.3%)	04 (9.8%)	07 (17.1%)	41 (100%)	0.189
	T2	68 (59.6%)	10 (8.8%)	22 (19.3%)	14 (12.2%)	114 (100%)	
Nodal Status	Positive	45 (59.2%)	08 (10.5%)	13 (17.1%)	10 (13.2%)	76 (100%)	0.133
	Negative	51 (63.7%)	05 (6.2%)	13 (16.3%)	11 (13.8%)	80 (100%)	
Focality	Multifocal	14 (43.8%)	02 (6.2%)	11 (34.4%)	05 (15.6%)	32 (100%)	1.00
	Unifocal	83 (64.3%)	12 (9.3%)	16 (12.4%)	18 (14%)	129 (100%)	
Chemotherapy	Adjuvant	17 (51.6%)	02 (06%)	07 (21.2%)	07 (21.2%)	33 (100%)	0.557
	Neo adjuvant	80 (62.5%)	12 (9.4%)	20 (15.6%)	16 (12.5%)	128 (100%)	
Histopathology	IDC	51 (71.9%)	06 (8.5%)	07 (9.8%)	07 (9.8%)	71 (100%)	0.273
	ILC	06 (42.8%)	02 (14.2%)	02 (14.2%)	04 (28.6%)	14 (100%)	
	IDC +DCIS	38 (55.1%)	05 (7.2%)	15 (21.8%)	11 (15.9%)	69 (100%)	
	DCIS	02 (28.6%)	01 (14.2%)	03 (42.9%)	01 (14.2%)	07 (100%)	
Grade	I/II	72 (64.8%)	09 (8.2%)	15 (13.5%)	15 (13.5%)	111 (100%)	0.143
	III	23 (53.4%)	04 (9.4%)	09 (20.9%)	07 (16.3%)	43 (100%)	
Pre op localization method	Ultrasound guided wire localization / ultrasound marking	68 (70.8%)	07 (7.3%)	10 (10.4%)	11 (11.5%)	96 (100%)	0.329
	Stereotactic wire localization	29 (44.7%)	07 (10.7%)	17 (26.2%)	12 (18.4%)	65 (100%)	

T1: Tumour 20mm or less, T2; Tumour 21-50mm, IDC: Invasive ductal carcinoma, ILC: Invasive lobular carcinoma, DCIS: Ductal carcinoma in situ.

The false negative rate (FNR) of SMG for the entire sample was 14(8.7%). FNR was highest for invasive lobular carcinoma (ILC) 02(14.2%) and ductal carcinoma in situ (DCIS) 1(14.2%) cases (Table 2).

The sensitivity, specificity, PPV and NPV of SMG for the entire sample were 65.8%, 80.8%, 54% and 87.3%, respectively. The specificity was highest for invasive ductal carcinoma (IDC) (87.9%), and lowest for ILC (60%), while the NPV was lowest for patients with DCIS (66.6%) (Table 3) (Figure 1).

A total of 32(19.9%) patients underwent per-operative extra margin excision; 24(75%) based on SMG findings and 8(25%) based on surgeon's suspicion without any margin involvement on SMG. Out of 24(75%) subjects who had margin involvement on SMG, 12(50%) had either close/involved margin on final histopathology, or evidence of cancer in the extra margin, and were thus spared from a re-excision surgery. Therefore, the number needed to treat (NNT) was 12, meaning that SMG for intra-operative margin assessment in 12 patients was enough to spare 1 patient

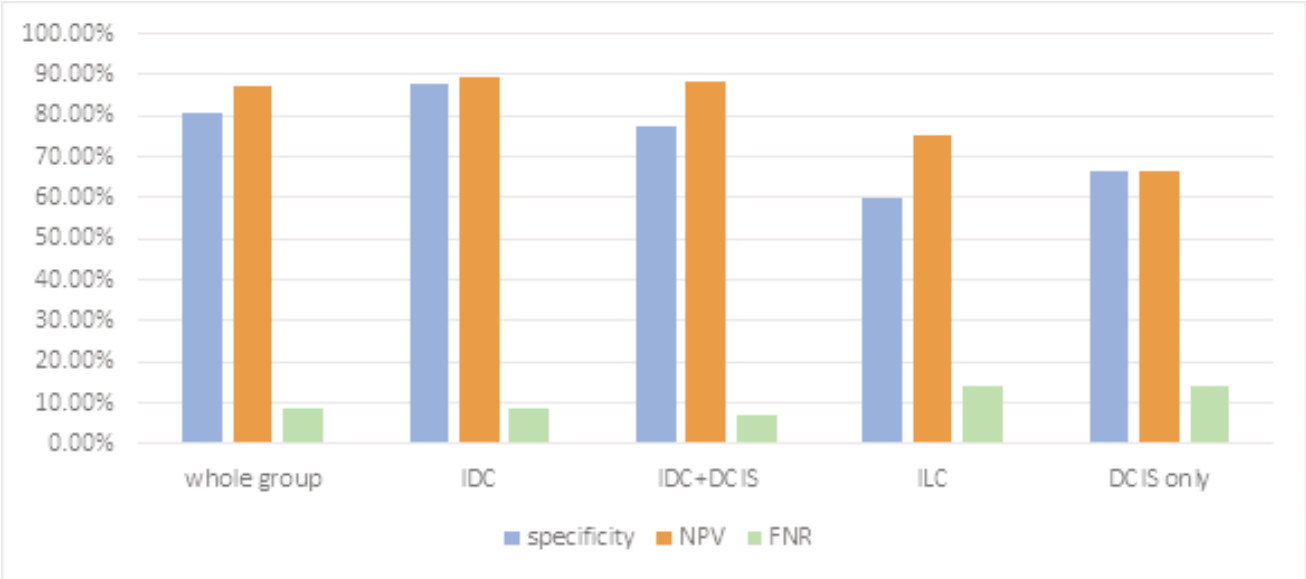

Figure: Specificity, negative predictive value (NPV) and false negative rate (FNR) of specimen mammography (SMG) with respect to histopathology.

Table-3: Comparison of performance characteristics of specimen mammography (SMG) in relation to tumour characteristics.

Study	Sensitivity % (CI)	Specificity % (CI)	PPV % (CI)	NPV % (CI)
Whole group	65.8(64.5-66.9)	80.8(79.3-81.7)	54 (53.6-54.9)	87.3(86.5-88.2)
Age:				
Above 40 year	58 (57.5-59.3)	82.9 (82.8-83.7)	54.5 (54.5-55.3)	84.8 (84.7-85.8)
Up to 40 year	90 (89.9-91.5)	75 (74.7-76.3)	52.9 (52.7-54.9)	96 (95.6-96.5)
Nodal Status:				
Positive	61.9 (61.7-63.3)	81.8 (81.8-82.5)	56.5 (55.7-57.4)	84.9 (84.8-85.7)
Negative	72.2 (71.7-73.8)	82.2 (81.8-83.6)	54.1 (53.7-55.8)	91 (90.8-91.7)
Focality:				
Unifocal	57.1 (56.2-57.9)	82.1 (81.3-83.9)	47 (46.2-47.3)	87.3 (87.2-88.7)
Multifocal	84.6 (83.9-85.2)	73.6 (73.8-74.2)	68.7 (68.3-69.7)	87.5 (86.8-88.3)
Chemotherapy:				
Upfront	77.7 (76.2-79.8)	70.8 (70.8-72.9)	50 (49.2-51.8)	89.4 (89.8-90.2)
Post-NAC	62.5 (61.8-63.7)	83.3 (83.2-84.8)	55.5 (55.8-56.2)	86.9 (86.9-87.8)
Histopathology:				
DCIS	75 (73.2-76.8)	66.6 (64.7-68.9)	75 (73.2-76.8)	66.6 (64-68.3)
IDC	53.8 (52.3-54.8)	87.9 (87.3-88.7)	50 (49.3-51.7)	89.4 (89.2-90.8)
IDC +DCIS	75 (74.3-76.7)	77.5 (77.3-78.8)	57.6 (57.7-58.3)	88.3 (88.8-89.2)
ILC	50 (48.2-52.8)	60 (59.3-60.7)	33.3 (32.2-34.8)	75 (74.8-75.3)
Tumour Size:				
T1	57.1 (55.8-58.8)	79.4 (78.7-80.9)	36.3 (35.3-37.8)	90 (89.8-90.2)
T2	68.7 (68.2-69.7)	82.9 (82.8-83.3)	61.1 (60.7-62.8)	87.1 (86.7-87.2)

CI: Confidence interval, PPV: Positive predictive value, NPV: Negative predictive value, NAC: Neoadjuvant chemotherapy, IDC: Invasive ductal carcinoma, ILC: Invasive lobular carcinoma, DCIS: Ductal carcinoma in situ, T1: Tumour size 20mm or less, T2; Tumour 21-50mm.

Table-4: Calculation of number needed to treat (NNT).

Re-excision rate with SMG-guided per-operative excision.	14 (16.1%)
Re-excision rate without SMG.	14 + 12 = 26 (8.6%)
Absolute risk with SMG (ART).	14/161 = 0.08
Absolute risk without SMG (ARC).	26/161 = 0.16
Absolute risk reduction (ARR).	ARC-ART = 0.16-0.08 = 0.08
NNT	1/ARR = 1/0.08 =12

SMG: Specimen mammography.

Table-5: Comparison of margin status on specimen mammography (SMG) with final histopathology.

No. of patients	Margin on specimen mammography	Margin on histopathology	Extra margin histopathology
03	Close/ involved	Close	No cancer
04	Close/ involved	Not involved	Cancer detected
05	Close/ involved	Close/ involved	Cancer detected
12	Close/ involved	Not involved	No cancer
08	Not involved (extra margin taken per-operatively on surgeons choice)	Not involved	No cancer
13	Close/involved	Close/involved margin taken	No extra
15	Close/involved	Not involved	No extra margin taken

from re-excision (Table 4). In contrast, none of the 8(25%) patients with normal SMG showed tumour involvement on final histopathology.

There were overall 28(17.4%) patients with close/involved margin on SMG, but no extra margin was taken per-operatively. Of them, 13(46.4%) showed close/involved margin on final histopathology (Table 5).

Discussion

Various studies support the use of intra-operative SMG in BCS for reducing margin positivity, and, thus, the rate of second surgeries[13,14]. On the contrary, Gray et al. discouraged SMG as a margin assessment tool[15] Likewise, Versteegden et al. did not recommend the routine use of SMG in patients with pure DCIS or in situ component in invasive cancer, reporting a wide range in the performance characteristics of SMG in their systematic review[16]. Similar diversity has also been observed in literature, including the current study, with a general trend of low sensitivity and PPV, but an acceptable specificity and NPV of SMG[9,17-19] (Table 6).

It has been postulated that lumpectomy margins are usually distorted by SMG owing to the so-called "pancake phenomenon", leading to false margin assessment[20,21]. The FNR of SMG is directly proportional to the re-excision rate, whereas the false positive rate (FPR) depicts the number of unnecessary per-operative excisions resulting in poor aesthetic outcomes. The FNR of 8.7% in the current study is quite concordant with the results of Schaefgen et al. and Funk et al. However, Schaefgen et al. demonstrated a higher FPR compared to the current study[17, 18]. The difference might be attributable to the diversity in the inclusion criteria and lack of standardisation in radiological margin assessment between the studies.

According to the current study, SMG based intra-operative margin excision reduced the rate of secondary surgeries by 7.4%, from 16.1% to 8.6% with an NNT of 12. This is comparable with the results of Schaefgen et al. in the subgroup of patients with partial response to NACT,

Table-6: Comparison of SMG performance characteristics with literature.

Study	Sample size	Sensitivity %	Specificity %	PPV %	NPV %
Schaefgen et al. (2022)[17]	174	19.2	89.2	7.7	95.9
Funk et al. (2020) [18]	470	36.8	86.8	25.6	91.8
Lin et al. (2020) [19]	205	64.8	94.0	70.5	92.3
Pop et al. (2018) [9]	83	45.4	85.2	-	-
Current study	161	65.8	80.8	54	87.3

SMG: Specimen mammography.

showing NNT of 15[17]. Funk et al. reported a 12.7% decrease in the secondary procedure rate by using SMG, with an NNT of 30[18]

There exists a lot of diversity in literature regarding the performance characteristics of SMG and their effect on re-excision rate, with respect to final histopathology. Where Versteegden et al. and Laws et al. refuted the efficacy of SMG in reducing re-re-excision rate in cases of DCIS, Hisada et al. and Koopmansch et al. claimed improved margin clearance with SMG in DCIS, owing to its high sensitivity and specificity compared to invasive cancer[16,22-24]. However, Lin et al. reported lower sensitivity of SMG in margin assessment for DCIS, but comparable specificity to invasive cancer, indicating SMG as an important margin assessment tool for DCIS[19]. This is in contrast to the current study, which showed low specificity and high FNR of SMG for DCIS, indicating increased rate of missed lesions and subsequently high re-excision rate. On the other hand, SMG was found to be have high sensitivity in detecting DCIS.

Regarding ILC, the current results were concordant with those of Lin et al.[19], revealing very low sensitivity, specificity and a high FNR of SMG owing to subtle imaging findings and high intrinsic margin positivity rate of ILC[22]. With respect to timing of chemotherapy, the current study, in line with Schaefgen et al.[17], noted lower sensitivity but higher specificity of SMG in post-NACT cases than the upfront surgery group. This is in contrast to Lin et al. who showed 100% sensitivity of SMG for post-NACT patients[19].

The current study has limitations owing to its retrospective nature, small sample size and single-centre data. Nevertheless, the current study is among a few studies using NNT to prove the efficacy of SMG as a tool to reduce re-excision rate. Moreover, comparison of the performance characteristics of SMG between different histopathological subtypes has also added to the strength of the study. Multi-centre prospective studies with larger sample size are recommended that may also measure the distance of tumour on final specimen / mammogram.

Conclusion

Intra-operative SMG was found to be a reliable tool for assessing margin status with a high specificity and NPV. SMG was quite effective in preventing secondary surgeries for positive margins. Performing SMG for intra-operative margin assessment in 12 patients was likely to spare 1 patient from re-excision. However, reliability of SMG as a margin assessment tool was questionable in cases of DCIS or ILC

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References

1. Fisher B, Redmond C, Poisson R, Margolese R, Wolmark N, Wickerham L, et al. Eight-year results of a randomized clinical trial comparing total mastectomy and lumpectomy with or without irradiation in the treatment of breast cancer. N Engl J Med. 1989; 320:822-8.
2. Veronesi U, Cascinelli N, Mariani L, Greco M, Saccozzi R, Luini A, et al. Twenty-year follow-up of a randomized study comparing breast-conserving surgery with radical mastectomy for early breast cancer. N Engl J Med.2002; 347:1227-32. DOI:10.1056/NEJMoa020989
3. Wang J, Deng JP, Sun JY, Dong Y, Zhang WW, He ZY, et al. Noninferior outcome after Breast-Conserving Treatment compared to Mastectomy in Breast Cancer patients with four or more positive lymph nodes. Front Oncol.2019; 9:143. DOI:10.3389/fonc.2019.00143
4. de Boniface J, Szulkin R, Johansson ALV. Survival after Breast Conservation vs Mastectomy adjusted for comorbidity and socioeconomic status: A Swedish National 6-year follow-up of 48 986 women. JAMA.2021; 156:628-37. DOI:10.1001/jamasurg.2021.1438
5. de Boniface J, Frisell J, Bergkvist L, Andersson Y. Breast-conserving surgery followed by whole-breast irradiation offers survival benefits over mastectomy without irradiation. BJS. 2018; 105:1607-14. DOI:10.1002/bjs.10889
6. Lombardi A, Pastore E, Maggi S, Stanzani G, Vitale V, Romano C, et al. Positive margins (R1) risk factors in breast cancer conservative surgery. Breast Cancer (Dove Med Press). 2019; 11:243-8. DOI: 10.2147/BCTT.S210788.
7. Hotsinpiller WJ, Everett AS, Richman JS, Parker C , DHB. Rates of margin positive resection with breast conservation for invasive breast cancer using the NCDB. Breast. 2021; 60:86-9. DOI:10.1016/j.breast.2021.08.012.
8. Maloney BW, McClatchy DM, Pogue BW, Paulsen KD, Wells WA, Barth RJ. Review of methods for intraoperative margin detection for breast conserving surgery. J Biomed Opt. 2018; 23:1-19. DOI:10.1117/1.JBO.23.10.100901
9. Pop MM, Cristian S, Hanko-Bauer O, Ghiga DV, Georgescu R. Obtaining adequate surgical margin status in breast-conservation therapy: intraoperative ultrasound-guided resection versus specimen mammography. Clujul Med. 2018; 91:197-202. DOI:10.15386/cjmed-891
10. Povoski SP, Jimenez RE, Wang WP, Xu RX. Standardized and reproducible methodology for the comprehensive and systematic assessment of surgical resection margins during breast-conserving surgery for invasive breast cancer. BMC Cancer. 2009; 9:254. DOI:10.1186/1471-2407-9-254
11. Moran MS, Schnitt SJ, Giuliano AE, Harris JR, Khan SA, Horton J, et al. Society of Surgical Oncology-American Society for Radiation Oncology consensus guideline on margins for breast-conserving surgery with whole-breast irradiation in stages I and II invasive breast cancer. Ann Surg Oncol.2014; 21:704-16. DOI: 10.1245/s10434-014-3481-4.
12. Morrow M, Van Zee KJ, Solin LJ, Houssami N, Chavez-MacGregor M, Harris JR, et al. Society of Surgical Oncology-American Society for Radiation Oncology-American Society of Clinical Oncology Consensus Guideline on Margins for Breast-Conserving Surgery with Whole-Breast Irradiation in Ductal Carcinoma in Situ. Ann Surg Oncol. 2016; 23:3801-10. DOI:10.1245/s10434-016-5449-z

13. Jin M, Kim JY, Kim TH, Kang DK, Han SH, Jung Y. Intraoperative specimen mammography for margin assessment in Breast-Conserving Surgery. J Breast Cancer. 2019; 22:635-40. DOI: 10.4048/jbc.2019.22.e58.
14. Larson KE, Jadeja P, Marko A, Jadeja V, Pratt D. Radiographically guided shave margins may reduce lumpectomy re-excision rates. Breast J. 2018; 24:820-2. DOI:10.1111/tbj.13050
15. Gray RJ, Pockaj BA, Garvey E, Blair S. Intraoperative margin management in Breast-Conserving Surgery: A systematic review of the literature. Ann Surg Oncol. 2018; 25:18-27. DOI:10.1245/s10434-016-5756-4
16. Versteegden DPA, Keizer LGG, Schlooz-Vries MS, Duijm LEM, Wauters CAP, Strobbe LJA. Performance characteristics of specimen radiography for margin assessment for ductal carcinoma in situ: A systematic review. Breast Cancer Res Treat. 2017; 166:669-79. DOI:10.1007/s10549-017-4475-2
17. Schaefgen B, Funk A, Sinn HP, Bruckner T, Gomez C, Harcos A, et al. Does conventional specimen radiography after neoadjuvant chemotherapy of breast cancer help to reduce the rate of second surgeries? Breast Cancer Res Treat. 2022; 191:589-98. DOI: 10.1007/s10549-021-06466-3.
18. Funk A, Heil J, Harcos A, Gomez C, Stieber A, Junkermann H, et al. Efficacy of intraoperative specimen radiography as margin assessment tool in breast conserving surgery. Breast Cancer Res Treat. 2020; 179:425-33. DOI: 10.1007/s10549-019-05476-6.
19. Lin C, Wang KY, Xu F, Liu Y, Li JF, Pan C, et al. The application of intraoperative specimen mammography for margin status assessment in breast-conserving surgery: A single-center retrospective study. Breast J. 2020; 26:1871-3. DOI: 10.1111/tbj.13835.
20. Ota K, Rivera C, Martin M. Specimen mammography distorts margin status in patients undergoing breast conserving surgery for early-stage breast cancer. Breast J. 2017; 23:760-761. DOI:10.1111/tbj.12920
21. Graham RA, Homer MJ, Katz J, Rothschild J, Safaii H, Supran S. The pancake phenomenon contributes to the inaccuracy of margin assessment in patients with breast cancer. Am J Surg. 2002; 184:89-93. DOI:10.1016/s0002-9610(02)00902-9
22. Koopmansch C, Noël JC, Maris C, Simon P, Sy M, Catteau X. Intraoperative evaluation of resection margins in Breast-Conserving Surgery for In Situ and Invasive Breast Carcinoma. Breast Cancer (Auckl). 2021; 15:1178223421993459. DOI:10.1177/1178223421993459
23. Laws A, Brar MS, Bouchard-Fortier A, Leong B, Quan ML. Does intra-operative margin assessment improve margin status and re-excision rates? A population-based analysis of outcomes in breast-conserving surgery for ductal carcinoma in situ. J Surg Oncol. 2018; 118:1205-11. DOI:10.1002/jso.25248
24. Hisada T, Sawaki M, Ishiguro J, Adachi Y, Kotani H, Yoshimura A, et al. Impact of intraoperative specimen mammography on margins in breast-conserving surgery. Mol Clin Oncol. 2016; 5:269-72. DOI: 10.3892/mco.2016.948.

Author's Contributions

NJ: Conception, data collection, interpretation, drafting and submission of manuscript.
SA: Drafting, synopsis, data collection and interpretation.
MAP: Study design, interpretation of data, critical review.
BR: Data collection, analysis and interpretation of data, drafting, critical review.
IBK: Conception of study, approval of synopsis, data collection and interpretation, referencing.