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Original Article

A retrospective comparison of clinical outcomes between endoscopic and open nipple-sparing mastectomy with immediate implant reconstruction versus breast-conserving surgery

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Abstract: Objectives: To compare perioperative outcomes, complications, aesthetic results, and patient-reported satisfaction among breast-conserving surgery (BCS), endoscopic nipple-sparing (ENS) mastectomy with immediate implant-based reconstruction, and open nipple-sparing (ONS) mastectomy, and to identify factors independently associated with aesthetic outcome. Methods: This retrospective study included 160 early-stage breast cancer patients (BCS=100, ENS=30, ONS=30). Perioperative outcomes, complications classified according to the Clavien-Dindo system, oncologic safety, aesthetic scores, and BREAST-Q domains were analyzed. Multivariable regression analysis was performed to identify predictors of aesthetic outcomes. A 1:1 propensity score-matched sensitivity analysis (30 pairs) was conducted, which confirmed significantly reduced blood loss in the ENS group (P<0.001), and showed a numerical but non-significant difference in aesthetic scores (P=0.088). Results: The ENS group had the longest operative time (159.2 min), whereas the ONS group experienced the greatest intraoperative blood loss (72.5 ml). Patients in the BCS group had the shortest drainage and hospital stay (both P<0.001). The overall complication rates were 7.0% in BCS group, 20.0% in the ENS group, and 16.7% in the ONS group. Aesthetic scores were highest in the BCS group (84.9), followed by the ENS group (79.2) and the ONS group (75.8) (all P<0.001). BREAST-Q scores demonstrated a similar pattern. No significant differences were observed among groups regarding margin positivity or short-term recurrence. Multivariable analysis identified surgical approach, complications, and tumor location as independent predictors of aesthetic outcomes. Conclusion: BCS remains the preferred option for eligible patients with early-stage breast cancer. For patients unsuited to BCS, ENS is associated with significantly lower intraoperative blood loss than ONS. While aesthetic scores showed a favorable trend in the ENS group, this difference did not reach statistical significance in the propensity score-matched analysis.

Keywords: Breast cancer, nipple-areola-sparing mastectomy, immediate implant-based breast reconstruction, endoscopic-assisted surgery, aesthetic outcome, complications

Introduction

Breast cancer is the most common malignant tumor among women worldwide and one of the leading causes of cancer-related death in women [1]. With the popularization of breast cancer screening and advances in therapeutic methods, the detection rate of early-stage breast cancer has increased significantly, and patients' expectations regarding postoperative quality of life, especially breast appearance, have risen steadily [2]. Maximizing breast shape preservation, minimizing surgical trauma, and improving patient satisfaction while ensuring oncological safety have become a research hotspot in the field of breast surgery.

Breast-conserving surgery (BCS) combined with postoperative radiotherapy is a standard treatment for early-stage breast cancer, and its oncological safety has been confirmed in several large-scale randomized controlled trials [3]. BCS resects the tumor while preserving most of the normal breast tissue, resulting in favorable postoperative breast appearance and high patient satisfaction [4]. However,

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some patients are unsuited to BCS due to multicentric tumors, relatively large tumor size, or special tumor location, and thus require total mastectomy [5].

For patients ineligible for BCS, nipple-sparing mastectomy (NSM) combined with immediate prosthetic breast reconstruction provides a surgical option that balances oncological safety and aesthetic outcomes [6]. NSM excises the entire breast gland while preserving the nipple-areola complex, which significantly enhances the aesthetic appearance of the reconstructed breast and avoids psychological trauma caused by nipple loss [7]. Immediate prosthetic breast reconstruction allows breast reconstruction in a single-stage operation, avoiding the pain and financial burden associated with a second surgery [8].

With the development of minimally invasive surgical techniques, endoscopic-assisted technology has been gradually applied to NSM [9]. Endoscopic nipple-sparing mastectomy with immediate breast reconstruction (ENS) resects the breast gland under endoscopic assistance through small incisions, theoretically offering advantages such as reduced surgical trauma, less bleeding, concealed scars, and superior cosmetic outcomes [10, 11]. However, ENS is technically demanding with a long learning curve, and its clinical superiority over traditional open NSM with immediate breast reconstruction (ONS) remain controversial [12].

At present, there are few comparative studies on BCS, ENS, and ONS, and most focus on the two-procedure comparisons, lacking systematic evaluation of all three procedures in the same center [13]. In particular, the differences between ENS and ONS regarding perioperative outcomes, complication profiles, and aesthetic results, as well as whether ENS truly has minimally invasive and aesthetic advantages over ONS, still lack high-quality clinical evidence [14, 15]. In addition, the analysis of independent factors affecting postoperative aesthetic outcomes is of great significance for guiding clinical procedure selection and patient counseling.

Accordingly, this study retrospectively analyzed the clinical data from 160 patients with early-stage breast cancer who underwent BCS, ENS, or ONS at the First Affiliated Hospital of Anhui Medical University from January 2022 to June 2023. Baseline characteristics, perioperative outcomes, complications, oncological safety, and aesthetic outcomes were compared among the three groups. Multivariate regression analysis was performed to identify independent predictors of aesthetic outcomes. This study aims to provide clinical evidence for surgical procedure selection in early-stage breast cancer and to clarify the clinical value and potential applications of ENS.

Materials and methods

Study participants

This retrospective cohort study consecutively collected clinical data of female breast cancer patients who underwent surgical treatment at the First Affiliated Hospital of Anhui Medical University between January 2022 and June 2023. The study protocol was approved by the Ethics Committee of the First Affiliated Hospital of Anhui Medical University. All procedures performed in this study involving human participants were conducted in accordance with the Declaration of Helsinki (as revised in 2013).

Inclusion criteria: (1) pathologically confirmed primary breast cancer; (2) treatment with BCS, ENS, or ONS; (3) for the ENS and ONS groups, meeting the indications for nipple-areola complex preservation (tumor ≥2 cm from the nipple-areola margin and negative intraoperative frozen section of the nipple base); and (4) availability of complete clinicopathologic data. Exclusion criteria: (1) bilateral breast cancer or distant metastasis; (2) history of thoracic radiotherapy; (3) receipt of neoadjuvant therapy prior to surgery; or (4) concurrent malignancies. The patient selection process is illustrated in **Figure 1**. A total of 160 patients were included in the final analysis, comprising 100 in the BCS group, 30 in the ENS group, and 30 in the ONS group.

Surgical methods

Breast-conserving surgery (BCS Group): Patients were placed in the supine position under general anesthesia. Incision design was based

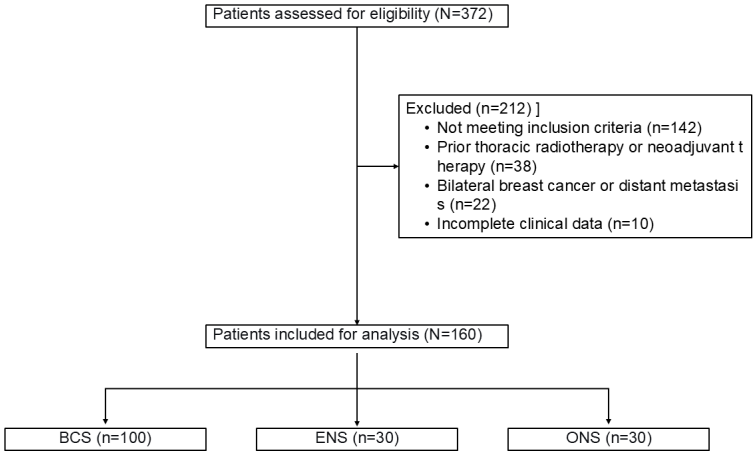

Figure 1. Patient selection flowchart.

on tumor location. The tumor and surrounding normal glandular tissue were excised to achieve negative margins. Sentinel lymph node biopsy or axillary lymph node dissection was performed as indicated. A drainage tube was routinely placed postoperatively.

Endoscopic nipple-sparing mastectomy with immediate breast reconstruction (ENS Group): Endoscopic-assisted NSM (ENS) was performed using a reverse-sequence technique under magnified endoscopic visualization, allowing for precise dissection of the gland from the subcutaneous plane while preserving the nipple-areola complex. The endoscope provided enhanced visualization of perforating vessels, facilitating hemostasis and minimizing tissue trauma. The prosthesis was preemptively wrapped and fixed with TiLoop® Mesh extracorporeally, and then implanted into the prepectoral plane through the axillary incision. Implant position was adjusted intraoperatively to ensure symmetry.

Open nipple-sparing mastectomy with immediate breast reconstruction (ONS Group): Patients were placed in the supine position under general anesthesia. An axillary incision was made, and skin flaps were dissected under direct vision. The mammary gland was completely excised while preserving the nipple-areola complex. The prosthesis was preemptively wrapped and fixed with TiLoop® Mesh extracorporeally, and then implanted into the prepectoral plane through the same axillary incision. Drainage tubes were placed before incision closure.

In this study, all patients in the ENS and ONS groups (30/30, 100%) received TiLoop® Mesh for implant wrapping and fixation. No mesh was used in the BCS group (0/100).

Observation indicators

The following data were collected from the hospital electronic medical record system:

Baseline characteristics: age, body mass index (BMI), tumor size, molecular subtype (Luminal A, Luminal B, HER2-positive, Triple-negative), tumor location (upper-outer, lower-outer, upper-inner, lower-inner, central), menopausal status (premenopausal/postmenopausal), T stage (T1 ≤2 cm, T2 2-5 cm, T3 >5 cm), N stage (N0, N1, N2), smoking history, history of diabetes, history of hypertension.

Perioperative indicators: operative time, intraoperative blood loss, total postoperative drainage volume, duration of drainage, and length of postoperative hospital stay.

Patient-reported outcome assessment

Patient-reported outcomes were evaluated using the BREAST-Q questionnaire (version 2.0) at 6 months postoperatively. Patients completed the appropriate module according to their surgical procedure: the Breast-Conserving Therapy (BCT) module for the BCS group, and the Reconstruction Module (post-mastectomy reconstruction) for the ENS and ONS groups. Six domains were assessed: satisfaction with breasts, psychosocial well-being, physical well-being (chest), sexual well-being, satisfaction with surgeon, and satisfaction with medical team. Raw scores were transformed to 0-100 scale scores using Rasch conversion models (Q-Score scoring software), with higher scores indicating better satisfaction or quality of life.

Postoperative photographs were independently scored by two breast surgeons on a scale of 0-100. If the difference between the two scores exceeded 10 points, a third senior surgeon

adjudicated the final score; otherwise, the average of the two scores was used.

The primary outcomes: (1) postoperative aesthetic score at 6 months, and (2) overall complication rate according to Clavien-Dindo classification.

Secondary outcomes: operative time, intraoperative blood loss, drain duration, length of hospital stay, BREAST-Q domain scores, positive surgical margin rate, reoperation rate, and short-term recurrence/metastasis.

Complication indicators

Postoperative complications occurring within 30 days after surgery or during hospitalization were recorded. Flap or nipple-areola complex necrosis requiring surgical intervention was classified as Grade IIIa or higher according to the Clavien-Dindo system. For patients in the reconstruction groups, nipple-areola complex necrosis was recorded (0 = no necrosis, 1 = partial necrosis, 2 = complete necrosis).

Oncologic safety indicators: Oncologic outcomes included positive surgical margin rate, reoperation rate, local recurrence rate, distant metastasis rate, and follow-up time.

Aesthetic outcome assessment: Aesthetic outcomes were evaluated 6 months postoperatively using aesthetic score and Harris Grading. Aesthetic score: postoperative photographs were independently assessed by two breast surgeons using a 0-100-point scale, with higher scores indicating better aesthetic outcomes. Harris Grading: Outcomes were classified into four grades: Excellent, Good, Fair, and Poor.

Statistical analysis

Statistical analyses were performed using Python 3.9. Continuous variables were expressed as mean ± standard deviation ($\bar{x}\pm s$), and categorical variables were expressed as frequency and percentage (n, %).

Comparisons of continuous variables among the three groups were performed using the Kruskal-Wallis H test, with the test statistic denoted as *H*. Comparisons of categorical variables among the three groups were performed using the chi-square test (χ^2 test) or Fisher's exact test (when more than 20% of cells had expected frequencies <5), with the test statistic reported as χ^2. Comparisons of continuous variables between two groups were performed using the independent-samples t-test or Mann-Whitney U test, as appropriate.

Kaplan-Meier curves were generated to analyze the duration of drainage tube placement among the three groups, and intergroup comparisons were performed using the log-rank test.

Univariate analysis was performed to identify risk factors associated with nipple-areola complex necrosis in the reconstruction groups. Continuous variables were analyzed using the independent samples t-test, whereas categorical variables were analyzed using Fisher's exact test. Odds ratios (OR) and 95% confidence intervals (CI) were calculated.

Multivariable linear regression analysis was conducted to identify independent predictors of aesthetic score. Variables were entered using the "Enter" method, and regression coefficients (β) with 95% CI were calculated. Furthermore, a high aesthetic score was defined as ≥80. Multiple logistic regression analysis was used to identify independent predictors of achieving a high aesthetic score, and ORs with 95% CIs were calculated. All statistical tests were two-sided. A *P*-value <0.05 was considered significant.

For multiple comparisons among the three groups, post-hoc tests with Bonferroni correction were performed when the overall group differences were statistically significant. Adjusted *P*-values were reported accordingly.

To address potential selection bias arising from baseline imbalances, a *post-hoc* sensitivity analysis using 1:1 propensity score matching (PSM) was performed between the ENS and ONS groups. Propensity scores were estimated using a multivariable logistic regression model, with treatment group (ENS vs. ONS) as the dependent variable and age, BMI, T stage, and tumor location as covariates. Matching was performed without replacement using a caliper width of 0.2 standard deviations of the logit of the propensity score. After matching, 30 patients were retained in each group. Baseline

characteristics were compared using standardized mean differences (SMDs), with values <0.1 indicating adequate balance. Primary and secondary outcomes were then compared in the matched cohort using the Wilcoxon signed-rank test for continuous variables and McNemar's test for categorical variables.

Results

Baseline characteristics

A total of 160 female patients were included (BCS, n=100; ENS, n=30; ONS, n=30). Age differed significantly among the three groups (BCS: 52.81±7.04 years; ENS: 47.50±6.33 years; ONS: 49.13±7.72 years; H=14.297, P<0.001), with ENS patients being the youngest. No other baseline characteristics differed significantly (all P>0.05). Post-mastectomy radiotherapy (PMRT) was more frequently administered in the BCS group (90.0%) than in the ENS (50.0%) and ONS (53.3%) groups (P<0.001, **Table 1**).

Perioperative key indicators

Operative time, intraoperative blood loss, and hospital stay are summarized in **Figure 2A-C**. Surgery duration (**Figure 2A**) was longest in ENS group (median 159.1 min, IQR 140.8-174.4 min) and shortest in the BCS group (median 95.2 min, IQR 76.3-109.0 min; Kruskal-Wallis P<0.001). Blood loss (**Figure 2B**) was highest in the ONS group (median 78.9 ml, IQR 53.2-91.2 ml), intermediate in the ENS group (median 39.8 ml, IQR 31.5-48.6 ml), and lowest in the BCS group (median 28.7 ml, IQR 19.0-38.3 ml; all pairwise P<0.001). Hospital stay (**Figure 2C**) was significantly shorter in the BCS group (median 3.5 days, IQR 2.7-4.3 days) than in the ENS (median 5.7 days, IQR 4.9-6.8 days) and ONS groups (median 6.1 days, IQR 4.9-6.6 days; both P<0.001), with no difference between ENS and ONS groups. Total postoperative drainage volume and drain duration were also significantly lower in BCS than in both reconstruction groups (both P<0.001; Supplementary Table 1).

Postoperative complications

The distribution of complications according to the Clavien-Dindo classification is presented in **Table 2**. In the BCS group, 93.0% of patients had no complications, 6.0% had Grade II, and 1.0% had Grade IIIa events. In the ENS group, four patients (13.3%) developed partial-thickness flap necrosis managed conservatively (Grade I-II), with no Grade IIIa events observed. In the ONS group, two patients (6.7%) experienced Grade IIIa complications requiring surgical intervention. The overall complication distribution differed significantly among the groups (χ^2=17.347, P=0.008).

Type-specific complication rates are detailed in **Table 3**. Flap necrosis occurred only in reconstruction groups (ENS 13.3%, ONS 6.7%; Fisher's exact P=0.001). Infection was most frequent in ONS (10.0%; P=0.049), whereas seroma rates were comparable across groups (P=0.576).

Among the 60 reconstruction patients (ENS, n=30; ONS, n=30), six (10.0%) developed nipple-areola complex necrosis; all cases were partial and managed conservatively. Clinical characteristics of these patients are summarized in **Table 4**. No formal statistical analysis was performed due to the small number of events.

Aesthetic and patient-reported outcomes

Postoperative aesthetic score at 6 months was highest in the BCS group (84.86±5.09), followed by ENS (79.23±6.97) and ONS (75.79±8.33) (H=35.687, P<0.001). Excellent/good Harris grading rates were 98.0% (BCS), 70.0% (ENS), and 53.3% (ONS) (all P<0.05, **Table 5**). BREAST-Q scores (**Table 6**) showed a consistent pattern, with BCS achieving the highest scores across all six domains, followed by ENS and then ONS (all P<0.001). For example, satisfaction with breast appearance was 84.55±6.72 (BCS), 72.60±7.68 (ENS), and 63.96±8.64 (ONS), respectively (H=73.308, P<0.001). The distribution of BREAST-Q scores across domains is visually depicted in the radar chart (**Figure 5**).

Oncologic outcomes

Follow-up duration, positive surgical margin rate, reoperation rate, local recurrence rate, and distant metastasis are summarized in **Table 7**. The mean follow-up duration was 23.7±7.5 months in the BCS group, 25.7±6.8 months in the ENS group, and 25.8±6.4 months

Table 1. Baseline characteristics

Variable	BCS (n=100)	ENS (n=30)	ONS (n=30)	H/χ^2	*P*-value
Age (years)	52.81±7.04	47.50±6.33	49.13±7.72	14.297	<0.001
BMI (kg/m^2)	23.53±3.21	23.45±2.16	23.09±2.76	0.528	0.768
Tumor size (cm)	1.96±0.78	2.04±0.85	2.03±0.85	0.381	0.827
Molecular Subtype				2.332	0.887
HER2+	12 (12.0%)	4 (13.3%)	5 (16.7%)		
Luminal A	45 (45.0%)	13 (43.3%)	9 (30.0%)		
Luminal B	28 (28.0%)	9 (30.0%)	11 (36.7%)		
TNBC	15 (15.0%)	4 (13.3%)	5 (16.7%)		
Tumor Location				6.325	0.611
Central	16 (16.0%)	5 (16.7%)	6 (20.0%)		
Upper-inner	19 (19.0%)	2 (6.7%)	7 (23.3%)		
Lower-inner	11 (11.0%)	6 (20.0%)	5 (16.7%)		
Upper-outer	39 (39.0%)	14 (46.7%)	9 (30.0%)		
Lower-outer	15 (15.0%)	3 (10.0%)	3 (10.0%)		
Menopause				*	0.007
Postmenopausal	65 (65.0%)	10 (33.3%)	15 (50.0%)		
Premenopausal	35 (35.0%)	20 (66.7%)	15 (50.0%)		
T_stage				*	0.548
T1 (≤2 cm)	55 (55.0%)	13 (43.3%)	17 (56.7%)		
T2 (2-5 cm)	45 (45.0%)	17 (56.7%)	13 (43.3%)		
N_stage				1.817	0.769
N0	71 (71.0%)	18 (60.0%)	22 (73.3%)		
N1	19 (19.0%)	8 (26.7%)	6 (20.0%)		
N2	10 (10.0%)	4 (13.3%)	2 (6.7%)		
Smoking				*	0.745
No	85 (85.0%)	24 (80.0%)	25 (83.3%)		
Yes	15 (15.0%)	6 (20.0%)	5 (16.7%)		
Diabetes				*	0.755
No	82 (82.0%)	24 (80.0%)	26 (86.7%)		
Yes	18 (18.0%)	6 (20.0%)	4 (13.3%)		
Hypertension				*	0.796
No	82 (82.0%)	24 (80.0%)	26 (86.7%)		
Yes	18 (18.0%)	6 (20.0%)	4 (13.3%)		
Positive Surgical Margin				*	0.514
No	94 (94.0%)	27 (90.0%)	27 (90.0%)		
Yes	6 (6.0%)	3 (10.0%)	3 (10.0%)		
Reoperation				*	0.342
No	94 (94.0%)	27 (90.0%)	26 (86.7%)		
Yes	6 (6.0%)	3 (10.0%)	4 (13.3%)		
Local Recurrence				*	0.139
No	97 (97.0%)	27 (90.0%)	28 (93.3%)		
Yes	3 (3.0%)	3 (10.0%)	2 (6.7%)		
PMRT				*	<0.001
No	10 (10.0%)	15 (50.0%)	14 (46.7%)		
Yes	90 (90.0%)	15 (50.0%)	16 (53.3%)		
Mesh use	0 (0.0%)	30 (100%)	30 (100%)		

Fisher's exact test was used for variables marked with an asterisk (*) due to small expected cell frequencies; only the *P*-value is shown. Abbreviation: BMI, Body mass index; HER2+, Human epidermal growth factor receptor 2 positive; TNBC, Triple-negative breast cancer; PMRT, Post-mastectomy radiotherapy; IQR, Interquartile range; H, Kruskal-Wallis H statistic; χ^2, Chi-square statistic; BCS, Breast-conserving surgery; ENS, Endoscopic nipple-sparing mastectomy; ONS, Open nipple-sparing mastectomy.

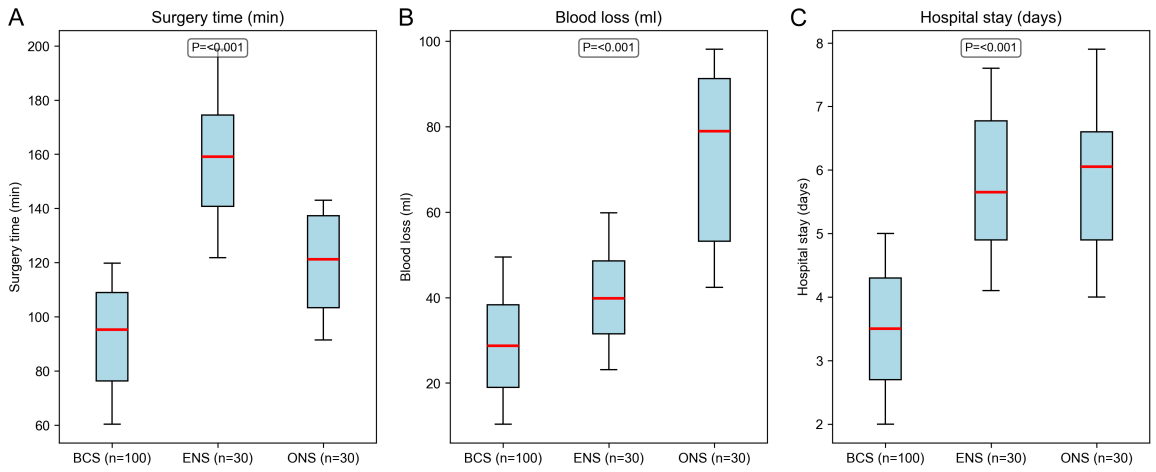

Figure 2. Boxplots of perioperative key indicators: surgery time, intraoperative blood loss, and hospital stay. (A) Surgery time (min), (B) intraoperative blood loss (ml), and (C) hospital stay (days). The box represents the interquartile range (IQR), the red line indicates the median, and the whiskers extend to the minimum and maximum values. The *P*-value from the Kruskal-Wallis test is shown above each panel. For surgery time and blood loss, all pairwise comparisons were significant (P<0.001). Hospital stay was significantly shorter in the BCS group than in both reconstruction groups (P<0.001), with no significant difference between ENS and ONS. Abbreviation: IQR, Interquartile range; P, Probability (*P*-value); BCS, Breast-conserving surgery; ENS, Endoscopic nipple-sparing mastectomy; ONS, Open nipple-sparing mastectomy.

Table 2. Clavien-Dindo classification of postoperative complications

Group	BCS (n=100)	ENS (n=30)	ONS (n=30)	χ^2	P
Grade I	0 (0.0%)	4 (13.3%)	2 (6.7%)	17.347	0.008
Grade II	6 (6.0%)	2 (6.7%)	1 (3.3%)		
Grade IIIa	1 (1.0%)	0 (0.0%)	2 (6.7%)		
Grade IIIb	0 (0.0%)	0 (0.0%)	0 (0.0%)		

Abbreviation: Clavien-Dindo, Clavien-Dindo classification of surgical complications; BCS, Breast-conserving surgery; ENS, Endoscopic nipple-sparing mastectomy; ONS, Open nipple-sparing mastectomy.

Table 3. Type-specific complication rates by group

Complication	BCS (n=100)	ENS (n=30)	ONS (n=30)	*P*-value (Fisher)
Flap necrosis	0 (0.0%)	4 (13.3%)	2 (6.7%)	0.001
Seroma	6 (6.0%)	2 (6.7%)	0 (0.0%)	0.576
Infection	1 (1.0%)	0 (0.0%)	3 (10.0%)	0.049

Abbreviation: BCS, Breast-conserving surgery; ENS, Endoscopic nipple-sparing mastectomy; ONS, Open nipple-sparing mastectomy.

in the ONS group, with no significant difference among the groups (P=0.226). Similarly, no significant differences were observed among groups in positive surgical margin rate (BCS: 6.0%, ENS: 10.0%, ONS: 10.0%; Fisher exact P=0.515), reoperation rate (6.0%, 10.0%, 13.3%; P=0.349), local recurrence rate (3.0%, 10.0%, 6.7%; P=0.153), or distant metastasis rate (2.0%, 0%, 0%; P=1.000).

Propensity score matching (PSM) sensitivity analysis

To address baseline age imbalance between the ENS and ONS groups, a 1:1 propensity score matching was performed using age, BMI, T stage, and tumor location. After matching, 30 patients remained in each group, and baseline characteristics were well-balanced (all P>0.05, Supplementary Table 1).

After matching, intraoperative blood loss remained significantly lower in the ENS group than in the ONS group (40.93±11.14 vs. 72.50±19.70 ml, P<0.001). Aesthetic scores were numerically higher in the ENS group, but the difference did not reach statistical significance (79.23±6.97 vs. 75.79±8.33, P=0.088; Supplementary Table 2). Complication rates were similar between the two groups (P>0.05).

Table 4. Clinical characteristics of nipple-areola complex necrosis cases in the reconstruction group (ENS + ONS)

Group	Age (years)	BMI (kg/m^2)	Tumor location	Clavien-Dindo	Nipple necrosis score	Management	Outcome
ONS	34	20.2	Lower-inner	None	Partial	Conservative	Resolved
ENS	60	23.78	Upper-outer	None	Partial	Conservative	Resolved
ENS	52	21.16	Lower-inner	None	Partial	Conservative	Resolved
ENS	56	23.16	Lower-inner	None	Partial	Conservative	Resolved
ONS	58	21.7	Upper-inner	None	Partial	Conservative	Resolved
ONS	50	24.09	Upper-outer	None	Partial	Conservative	Resolved

Abbreviation: BMI, Body mass index; Clavien-Dindo, Clavien-Dindo classification of surgical complications; ENS, Endoscopic nipple-sparing mastectomy; ONS, Open nipple-sparing mastectomy.

Table 5. Aesthetic outcomes (aesthetic score and Harris grading)

Variable	BCS (n=100)	ENS (n=30)	ONS (n=30)	H/χ^2	*P*-value
Aesthetic Score (0-100)	84.86±5.09	79.23±6.97	75.79±8.33	35.687	<0.001
Harris Grade - Poor	0 (0.0%)	0 (0.0%)	1 (3.3%)	Fisher exact	0.367
Harris Grade - Fair	2 (2.0%)	9 (30.0%)	13 (43.3%)	Fisher exact	<0.001
Harris Grade - Good	81 (81.0%)	20 (66.7%)	15 (50.0%)	Fisher exact	0.005
Harris Grade - Excellent	17 (17.0%)	1 (3.3%)	1 (3.3%)	Fisher exact	0.049

Abbreviation: Harris, Harris grading of aesthetic outcomes; H, Kruskal-Wallis H statistic; BCS, Breast-conserving surgery; ENS, Endoscopic nipple-sparing mastectomy; ONS, Open nipple-sparing mastectomy.

Table 6. BREAST-Q domain scores by group

Variable	BCS (n=100)	ENS (n=30)	ONS (n=30)	H	*P*-value
Satisfaction with breasts	84.55±6.72	72.60±7.68	63.96±8.64	73.308	<0.001
Psychosocial well-being	78.92±4.99	70.59±5.83	65.73±5.91	84.992	<0.001
Physical well-being (chest)	85.00±5.80	74.99±6.89	70.52±6.27	80.103	<0.001
Sexual well-being	69.74±7.52	60.52±8.64	54.15±8.36	62.114	<0.001
Satisfaction with surgeon	87.60±4.01	85.69±4.27	80.71±3.68	61.858	<0.001
Satisfaction with medical team	86.22±4.43	83.97±4.54	81.61±4.38	13.048	<0.001

Abbreviation: BREAST-Q, Breast Reconstruction Satisfaction Questionnaire; H, Kruskal-Wallis H statistic; BCS, Breast-conserving surgery; ENS, Endoscopic nipple-sparing mastectomy; ONS, Open nipple-sparing mastectomy.

Drain removal time

Kaplan-Meier curves for drain removal time are shown in **Figure 3**. The median drain removal time was 1.1 days in the BCS group, 5.2 days in the ENS group, and 4.8 days in the ONS group. Log-rank tests demonstrated significant differences between the BCS and ENS groups (P<0.001) and between the BCS and ONS groups (P<0.001), but no significant difference was observed between the ENS and ONS groups (P=0.655).

Independent factors associated with aesthetic outcomes

Multivariable logistic regression identified several independent predictors of achieving a high aesthetic score (≥80). As illustrated in the forest plot (**Figure 4**), compared to BCS, both ENS (OR=0.290, 95% CI 0.096-0.874, P=0.028) and ONS (OR=0.089, 95% CI 0.029-0.273, P<0.001) were independently associated with lower odds of achieving a high aesthetic score. Postoperative complications were also independently associated with reduced odds (OR=0.215, 95% CI 0.065-0.711, P=0.012). In contrast, tumors in the upper-outer quadrant (vs. central) were associated with a greater likelihood of achieving a high aesthetic score (OR=4.720, 95% CI 1.438-15.494, P=0.011). Age, BMI, PMRT, and other tumor locations were not significantly associated with aesthetic outcomes.

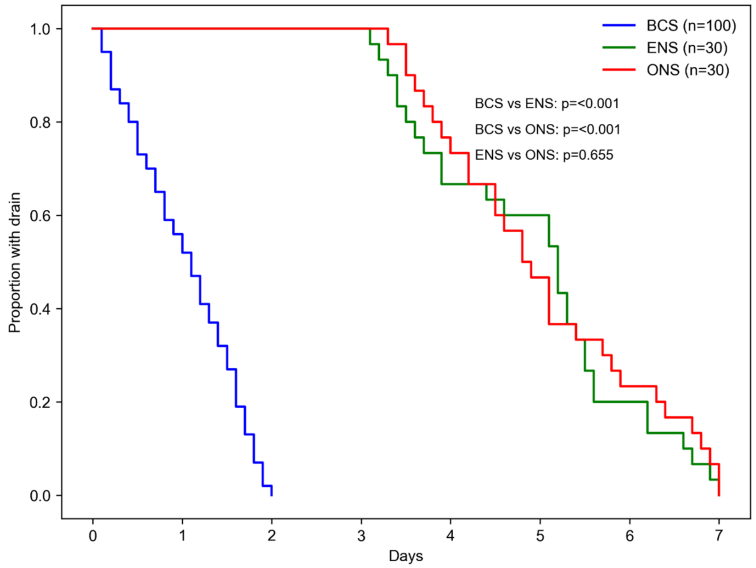

Figure 3. Kaplan-Meier curves for drain removal time. Abbreviation: BCS, Breast-conserving surgery; ENS, Endoscopic nipple-sparing mastectomy; ONS, Open nipple-sparing mastectomy.

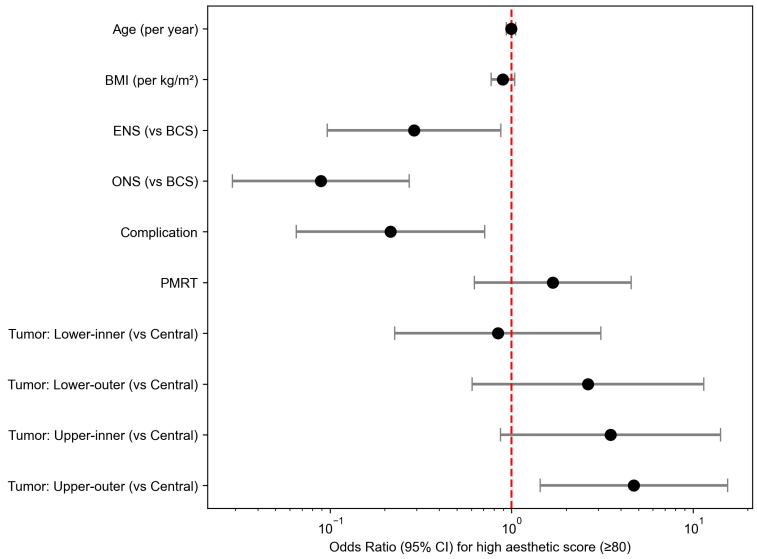

Figure 4. Forest plot of multivariable logistic regression for high aesthetic score (≥80). Abbreviation: OR, Odds ratio; CI, Confidence interval; vs, Versus; BCS, Breast-conserving surgery; ENS, Endoscopic nipple-sparing mastectomy; ONS, Open nipple-sparing mastectomy; PMRT, Post-mastectomy radiotherapy.

Discussion

This retrospective study compared perioperative indicators, complications, oncological safety, and aesthetic outcomes among patients with early-stage breast cancer undergoing BCS, ENS, and ONS. The results showed that although ENS was associated with a longer operative time, it was associated with less blood loss and a relatively lower flap necrosis rate, with aesthetic outcomes superior to ONS and close to BCS. In contrast, ONS was associated with more blood loss, higher risks of infection and severe complications, and less favorable aesthetic outcomes. BCS remained the first-choice option for early-stage breast cancer, while ENS may represent an alternative reconstructive option for patients unsuitable for breast-conserving surgery. In addition, multivariate regression analysis in this study identified surgical procedure, postoperative complications, and tumor location as independent factors associated with postoperative aesthetic outcomes.

This study found that the ENS group had the longest operative time, with a mean of 159.19 minutes, significantly longer than that in the ONS group (119.81 minutes) and BCS group (92.87 minutes). This is consistent with previous studies [16]. ENS requires the creation of subcutaneous tunnels, endoscopic insertion, and endoscopic-assisted flap dissection, all of which are relatively complex procedures associated with a long learning curve, thus leading to prolonged operative time. Nevertheless, intraoperative blood loss in the ENS group (40.93 ml) was significantly lower than that in the ONS group (72.51 ml), suggesting that endoscopic-assisted technique facilitates more precise dissection and hemostasis, possibly related to the magnified operative field and enhanced visualization provided by the endoscope [17].

The BCS group demonstrated significantly lower postoperative drainage volume, shorter

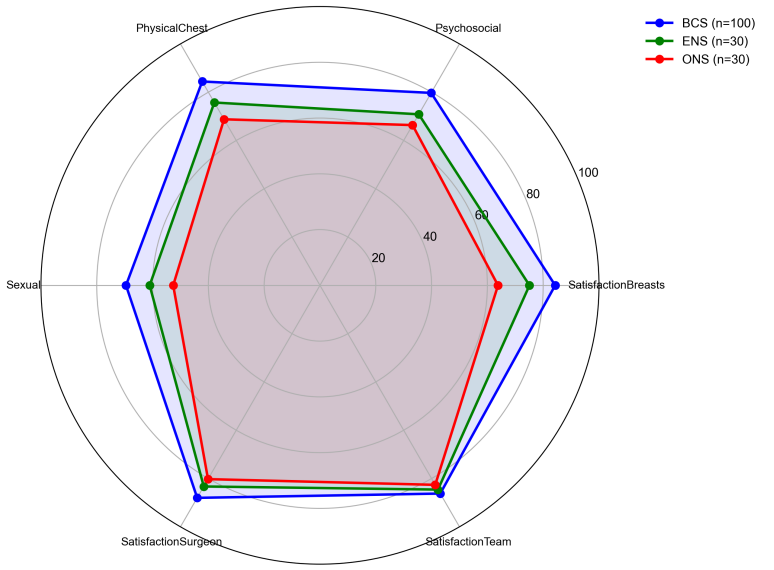

Figure 5. Radar chart of BREAST-Q domain scores by group. Abbreviation: BREAST-Q, Breast Reconstruction Satisfaction Questionnaire (validated patient-reported outcome measure); BCS, Breast-conserving surgery; ENS, Endoscopic nipple-sparing mastectomy; ONS, Open nipple-sparing mastectomy.

drain duration, and shorter hospital stay than both reconstruction groups. BCS involves limited tissue resection while preserving most normal breast tissue, resulting in less postoperative exudation and faster recovery. In contrast, NSM requires complete resection of breast glandular tissue, creating a large surgical field, which leads to more postoperative drainage, longer drainage tube indwelling, and correspondingly longer hospital stay [18]. No significant differences were observed between the ENS and ONS groups in postoperative drainage volume, drain duration, or hospital stay, indicating that the minimally invasive advantage of the endoscopic approach may primarily be reflected in reduced blood loss rather than improvements in postoperative recovery measurements.

In this study, the severity distribution of complication differed significantly among the three groups (P=0.008). The BCS group exhibited the lowest overall complication rate (7.0%), dominated by seroma (6.0%), consistent with reports on breast-conserving surgery [19]. The overall complication rate in the ENS group was 20.0%, mainly flap necrosis (13.3%). The complication rate in the ONS group was 16.7%, dominated by infection (10.0%) and severe complications (Grade IIIa 6.7%).

The higher flap necrosis rate in the ENS group than in the ONS group may be related to the effect of endoscopic manipulation on flap blood supply. Electrocoagulation and thermal injury during endoscopic-assisted flap dissection may damage the subcutaneous vascular network, increasing the risk of flap ischemia and necrosis [20]. However, flap necrosis in the ENS group was generally limited in extent and was successfully managed with conservative treatment. In contrast, the ONS group had 2 cases (6.7%) of Grade IIIa severe complications requiring interventional management. These findings suggest that although ENS has a slightly higher incidence of flap necrosis, the severity is milder, and the risk of severe complications is lower than that of ONS.

The superior aesthetic outcomes in the BCS group were corroborated by the patient-reported BREAST-Q scores, which showed significantly higher satisfaction across all domains compared to the reconstruction groups. Notably, ENS achieved significantly better BREAST-Q scores than ONS in satisfaction with breasts and sexual well-being, highlighting the benefits of the endoscopic approach in preserving patient-reported quality of life. These findings align with previous studies demonstrating that minimally invasive techniques yield higher patient satisfaction due to concealed scars.

The infection rate in the ONS group (10.0%) was significantly higher than that in the ENS group (0) and BCS group (1.0%), which may be related to the longer incision, longer exposure time, and greater tissue damage associated with open surgery [21]. Although both ONS and ENS utilized axillary incisions, open dissection under direct vision may result in greater tissue trauma and increased bacterial contamination risk compared to the precise endoscopic technique.

The incidence of nipple-areola complex necrosis in the reconstruction groups was 10.0%

Table 7. Oncologic outcomes including follow-up, surgical margin status, reoperation rate, recurrence rate, and metastasis rate

Variable	BCS (n=100)	ENS (n=30)	ONS (n=30)	H/χ^2	*P*-value
Follow-up (months)	23.68±7.52	25.69±6.81	25.82±6.36	2.971	0.226
PositiveMargin_Yes	6 (6.0%)	3 (10.0%)	3 (10.0%)	Fisher exact	0.515
Reoperation_Yes	6 (6.0%)	3 (10.0%)	4 (13.3%)	Fisher exact	0.349
LocalRecurrence_Yes	3 (3.0%)	3 (10.0%)	2 (6.7%)	Fisher exact	0.153
DistantMetastasis_Yes	2 (2.0%)	0 (0.0%)	0 (0.0%)	Fisher exact	1.000

Abbreviation: H, Kruskal-Wallis H statistic (for follow-up); BCS, Breast-conserving surgery; ENS, Endoscopic nipple-sparing mastectomy; ONS, Open nipple-sparing mastectomy.

(6/60), similar to the 5%-15% reported in the literature [22-25]. Univariate analysis revealed no significant association of age, BMI, surgical approach, or tumor location with nipple necrosis, which may be attributed to the small sample size and limited number of events. Previous studies have shown that smoking, diabetes, and tumor-to-nipple distance are risk factors for nipple necrosis [26]. Although smoking history and diabetes history were collected as baseline variables in the present study, the limited number of necrosis events precluded a robust evaluation of their potential effects, representing an important limitation of this analysis.

Aesthetic outcome is a key indicator for evaluating the success of breast reconstruction surgery. In this study, the BCS group achieved the highest aesthetic score (84.86 points), followed by the ENS group (79.23 points), and the ONS group (75.79 points), with significant differences among the three groups (P<0.001). The Harris classification distribution showed a similar trend: the excellent and good rate was 98.0% in the BCS group, 70.0% in the ENS group, and 53.3% in the ONS group. These results suggest that the aesthetic outcome of ENS is significantly better than that of ONS and close to BCS, which has important clinical significance. All implant reconstructions in this study utilized TiLoop® Mesh to provide additional coverage and reduce visible rippling. While mesh may improve lower-pole projection and inframammary fold definition, it can also increase the risk of seroma and infection. The absence of mesh in the BCS group represents a fundamental difference in surgical technique. Therefore, the superior aesthetics observed in the BCS group cannot be solely attributed to the absence of mesh. Future studies comparing different mesh types or mesh-free techniques are needed.

The superior aesthetic outcome of ENS compared to ONS may be related to its concealed incision, small scar, and intact preservation of the nipple-areola complex. ENS is performed through a small axillary incision, resulting in a hidden scar and a more natural postoperative breast appearance [27]. In contrast, although ONS also uses an axillary incision, open dissection involves more extensive subcutaneous disruption, potentially affecting breast contour and symmetry. Endoscopic magnification in ENS allows precise preservation of perforating vessels and subcutaneous architecture, which may improve flap viability and cosmetic outcomes. In addition, endoscopic assistance in ENS facilitates more careful preservation of the subcutaneous vascular network, enhancing flap blood supply and supporting postoperative recovery and aesthetic preservation [28].

Multivariate linear regression analysis identified BMI as an independent negative predictor of aesthetic score (β=-0.332, P=0.026), indicating that higher BMI was associated with lower aesthetic scores. This can be explained by thicker subcutaneous fat, impaired flap blood supply, increased risk of postoperative complications, and challenges in achieving optimal breast shaping in obese patients [29]. Compared to the BCS group, aesthetic scores were significantly lower in the ENS group (β=-4.900, P<0.001) and ONS group (β=-8.410, P<0.001), with a stronger negative effect observed in the ONS group, further confirming the aesthetic advantage of ENS over ONS. Patients who developed complications had significantly lower aesthetic scores (β=-3.559, P=0.010), suggesting that complication pre-

vention is crucial for guaranteeing aesthetic outcomes.

Regarding tumor location, compared to central tumors, upper-outer (β=8.010), upper-inner (β=6.159), lower-outer (β=5.956), and lower-inner (β=3.419) tumors were all associated with higher aesthetic scores. This may be explained by easier surgical access, better concealment of incisions, and minimal impact on overall breast contour in the upper-outer quadrant [30]. Central tumors are close to the nipple-areola complex and requires a wide excision scope, which can significantly compromise breast appearance.

Logistic regression results were consistent with the linear regression analysis. ENS (OR=0.249), ONS (OR=0.075), and complications (OR=0.229) were associated with a lower likelihood of achieving a high aesthetic score, whereas upper-outer tumor location (OR=4.475) increased this probability. These findings provide clinically relevant information for clinical decision-making and patient counseling.

In this study, there were no significant differences among the three groups in positive surgical margin rate (P=0.649), reoperation rate (P=0.399), local recurrence rate (P=0.273), or distant metastasis rate (P=0.545), suggesting that NSM with immediate reconstruction can achieve oncological outcomes comparable to those of BCS. In both the ENS and ONS group, eligibility criteria included a tumor-to-nipple distance ≥2 cm and a negative intraoperative frozen-section examination of the nipple base, ensuring the oncological safety of the nipple-areola complex [31].

Short-term follow-up results showed that the local recurrence rate in the ENS group was 10.0% (3/30), slightly higher than that in the BCS group (3.0%) and ONS group (6.7%). This trend may be related to selection bias in the ENS group and needs to be verified with longer follow-up and a larger sample size. Previous studies have reported a 5-year local recurrence rate of 2%-5% after NSM, which are comparable to those observed after BCS [32], and the results of the present study are within an acceptable range.

Among the three cases of local recurrences in the ENS group, two occurred during the surgeon's initial 15 ENS procedures, corresponding to the early learning-curve period. Both cases presented as subcutaneous recurrences rather than deep chest-wall recurrences, suggesting possible residual glandular tissue rather than aggressive tumor behavior. The molecular subtypes of these two patients were triple-negative (case 1) and HER2-positive with Ki-67 >30% (case 2). The third recurrence occurred in a patient with Luminal B cancer who had a positive deep surgical margin requiring re-excision. All three patients had negative final margins after reoperation, and none received post-mastectomy radiotherapy. Although the recurrence rate was not significantly different from that observed in the BCS (3.0%) or ONS (6.7%) groups, these findings underscore the importance of maintaining adequate flap thickness and achieving complete glandular resection during endoscopic dissection, particularly during the learning phase. Further studies with longer follow-up and larger cohorts are needed to confirm the long-term oncologic safety of ENS.

Based on the results of this study, several clinical recommendations are proposed for surgical decision-making in patients with early-stage breast cancer. (1) For patients who meet the indications for breast-conserving treatment, BCS should remain the preferred surgical option, as it demonstrates significant advantages in perioperative recovery, complication profile, and aesthetic outcomes. (2) For patients who are not suitable candidates for BCS but desire preservation of breast morphology, ENS can be prioritized as a reconstruction option, as it was associated with significantly lower intraoperative blood loss, favorable aesthetic outcomes, and lower risk of severe complications. However, the potential aesthetic advantage of ENS over ONS should be interpreted cautiously, as this difference did not remain statistically significant in the propensity score-matched analysis. (3) For medical centers lacking endoscopic equipment or where endoscopic techniques are not yet mature, ONS remains a feasible reconstruction option, but attention should be paid to minimizing postoperative infection and severe complications.

This study has several limitations: First, the retrospective study design is subject to selection and information bias. Although baseline char-

acteristics of the three groups were comparable, the influence of confounding factors could not be completely excluded. Second, the sample size was relatively small, particularly in the ENS and ONS groups (n=30 each), limiting the statistical power for subgroup analysis. Some differences may not have reached statistical significance due to insufficient sample size. Third, the follow-up period was relatively short (approximately 2 years on average), precluding assessment of long-term oncologic safety and aesthetic outcomes. Fourth, this was a single-center study, which limited the generalizability of the results. Fifth, certain known risk factors for nipple-areola complex necrosis, such as smoking and diabetes, were not included in the analysis, which reduced its comprehensiveness. Finally, although aesthetic evaluation adopted a dual-independent-rater scoring system, some degree of subjectivity remains.

Future research should focus on conducting multi-center, large-sample, prospective cohort studies or randomized controlled trials to further validate the conclusions of this study. Extending the follow-up time to observe 5-year and 10-year local recurrence rates, disease-free survival, and overall survival will provide more robust evidence of long-term oncologic safety. Cost-effectiveness analyses of ENS and investigation of molecular biological markers associated with flap and nipple necrosis may further optimize surgical planning and complication prevention.

Conclusion

ENS was associated with the longest operative time but significantly less intraoperative blood loss than ONS, demonstrating the minimally invasive advantages of endoscopic technology. BCS exhibited the fastest postoperative recovery, with significantly lower drainage volume, shorter duration of drainage, and shorter hospital stay compared to the reconstruction groups. Regarding complications, ENS was primarily associated with minor flap necrosis and no severe complications, whereas ONS had higher rates of infection and Grade IIIa complications, indicating poorer safety; BCS had the lowest complication rate. In terms of aesthetic outcomes, BCS achieved the highest excellent/good rate (98.0%), followed by ENS (70.0%) and ONS (53.3%), with ENS demonstrating a clear advantage over ONS. There were no significant differences in oncologic safety among the three groups, and short-term follow-up confirmed the reliable oncologic safety of NSM with reconstruction. Multivariate analysis showed that surgical approach, complications, and tumor location were independent factors influencing aesthetic outcomes.

In summary, BCS remains the preferred option for patients eligible for breast conservation. For patients unsuitable for BCS, ENS may be considered a reconstructive alternative, as it offers significantly lower blood loss, fewer severe complications, and a favorable trend in aesthetic outcomes compared to ONS. Although the aesthetic advantage of ENS did not reach statistical significance, its combined perioperative and safety benefits support its clinical value as a minimally invasive reconstruction option.

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Disclosure of conflict of interest

None.

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Supplementary Table 1. Baseline characteristics after propensity score matching (ENS vs. ONS)

Variable	ENS	ONS	*P*-value
Age	47.50±6.33	49.13±7.72	0.374
BMI	23.45±2.16	23.09±2.76	0.582
Tumor Size_cm	2.04±0.85	2.03±0.85	0.987
Tumor location			–
Central	5	6	
Lower-inner	6	5	
Lower-outer	3	3	
Upper-inner	2	7	
Upper-outer	14	9	

Abbreviation: ENS, Endoscopic nipple-sparing mastectomy; ONS, Open nipple-sparing mastectomy; BMI, Body mass index.

Supplementary Table 2. Perioperative and aesthetic outcomes after propensity score matching (ENS vs. ONS)

Outcome	ENS	ONS	*P*-value
Blood Loss_ml	40.93±11.14	72.50±19.70	<0.001
Aesthetic Score	79.23±6.97	75.79±8.33	0.088
Complication	6/30 (20.0%)	5/30 (16.7%)	1.000
Flap Necrosis	4/30 (13.3%)	2/30 (6.7%)	0.671

P-values were calculated using the paired Wilcoxon signed-rank test. Aesthetic scores did not differ significantly between the matched ENS and ONS groups (P=0.088). Abbreviation: ENS, Endoscopic nipple-sparing mastectomy; ONS, Open nipple-sparing mastectomy.