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Breast

A Comparison of Fat Graft Processing Techniques: Outcomes in 1,158 Procedures in Prosthetic Breast Reconstructions

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Background: As fat grafting in breast reconstruction evolves, questions of technique and outcomes persist. We compared 2 common fat processing techniques—decantation (DEC) versus closed wash and filtration (CWF)—with regard to outcomes and efficacy.

Methods: Chart review of a single surgeon experience with breast fat grafting was performed. Data extracted included demographics, technique, complications, graft volume, and revision rates. Secondarily, the timeline of complication profiles was analyzed. Lastly, subgroup analysis of radiated versus nonradiated breast outcomes was performed.

Results: One thousand one hundred fifty-eight fat grafting procedures were performed on 775 breasts (654 DEC, 504 CWF). Time-to-event analysis for all complications showed no difference between groups. Independent risk factors for fat necrosis included DEC technique, body mass index >30 kg/m^2, and fat injection >75 mL. The majority of cases of fat necrosis, cyst/nodule formation, ultrasounds, and biopsies occurred more than 6 months after grafting. Average graft volume was lower in DEC compared with CWF breasts (50.6 versus 105.0 mL, $P < 0.01$), and more DEC breasts required repeat fat grafting procedures (39.9% versus 29.6%, $P < 0.01$). Radiated breasts received larger fat graft volume (89.9 versus 72.4 mL, $P < 0.01$) and required more fat graft procedures (average 1.62 versus 1.47, $P < 0.01$).

Conclusions: This study represents the largest series of breast reconstruction fat grafting to date. DEC harvest technique may be a risk factor for fat necrosis, which results in less fat injection and greater need for repeat procedures. Similarly, radiated breasts require larger graft volume and more repeat procedures. *(Plast Reconstr Surg Glob Open 2019;7:e2276; doi: 10.1097/GOX.0000000000002; Published online 8 November 2019.)*

INTRODUCTION

Autologous fat grafting (AFG) is a widely accepted technique for improving esthetic outcomes through volume enhancement and correction of contour deformities following breast reconstruction surgery.[1–3] It provides the ability to shape and contour tissue through a minimally invasive approach and is associated with high patient satisfaction in numerous studies and systematic reviews.[1,4–7] AFG includes 4 steps: recipient site preparation, fat harvesting, processing, and injection. Fat processing is not a mandatory step of fat grafting; however, many surgeons process the harvested fat with the goal of purifying adipocytes to remove unwanted debris that could potentially affect cell viability.[8] Although previous studies have shown AFG to be a safe and effective technique to improve esthetic outcomes in breast reconstruction, the optimal fat processing technique remains elusive due to inconclusive evidence regarding relative efficacy.[9–15] Moreover, there is a paucity of data on longer-term nononcologic outcomes of fat grafting with respect to surgical complications and need for revision fat grafting.

Two commonly used methods of fat processing by the senior author include decantation (DEC), in which manually harvested fat is collected into a syringe and allowed to

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settle into separate layers, and closed wash and filtration (CWF), in which lipoaspirate is washed with saline and filtered with suction assistance. Although histologic studies have suggested advantages to CWF in terms of decreased cellular debris and greater fat retention, no studies have directly compared the risk of potential sequelae of fat impurities, such as oil cysts and fat necrosis, between these 2 techniques.[16,17]

Accordingly, this study's primary purpose is to compare these 2 common methods of fat harvest with respect to complications and efficacy. Second, we endeavor to provide the first granular detail on timelines of complications and risk factors for complications to better address surveillance issues following fat grafting. Third, we performed comparative subgroup analysis of radiated versus nonradiated breasts undergoing fat grafting.

METHODS

Patients and Data

A retrospective chart review with Institutional Review Board approval was performed on patients who underwent reconstruction followed by AFG spanning 9 years, from January 2008 to October 2017, by the senior author (JYSK). Patient charts reviewed included all patients who underwent consecutive fat grafting by the senior author in this time frame, including all types of reconstruction (implant and autologous based). Initial fat grafting was performed at the time of tissue expander to implant exchange or at the time of revisionary surgery for patients undergoing autologous-based reconstruction.

Variables of interest included demographics, intraoperative data, and postoperative outcomes. Primary outcome measures were postoperative complications or events (nodule/cyst, ultrasound, fat necrosis, biopsy, and cancer recurrence) and efficacy (measured by fat graft volume and number of revision procedures). Demographics included patient age, body mass index (BMI), smoking status, previous radiotherapy, and history of hypertension or diabetes. Data on each patient's fat grafting procedure included fat processing technique (DEC versus CWF), volume of fat injected and total number of fat grafting procedures. Outcomes included the following: nodule/cyst defined as palpable masses found in any office visits or incidentally noted on imaging, ultrasounds (performed for surveillance, nodule evaluation, or to rule out fluid collection), clinically relevant fat necrosis as identified on ultrasound reports, biopsy rate, and local cancer recurrence. In the senior surgeon's practice, breast reconstruction patients routinely follow up at 3- to 4-month intervals and the decision to fat graft is based on a combination of patient concern and surgeon judgment. These same patients are also followed by our breast surgeons who monitor for nodule formation, and thus ultrasound and biopsy rates are dependent on routine surveillance by both the breast and plastic surgeons. Follow-up period either went up to most recent plastic surgery clinic visit or the time of any revision fat grafting procedure if performed.

Fat Processing Technique

DEC

Before fat harvesting, patients' donor sites (typically abdomen, flank and/or thigh) were injected with tumescent solution (final concentration of 1:2 million epinephrine and 0.05% lidocaine in lactated ringer's solution). Using a Coleman Cannula and a 10-mL syringe, fat was harvested using manual aspiration. The harvested fat slurry was collected into a syringe and allowed to settle into separate layers for 5–10 minutes. The aqueous and free oil content were discarded before reinjection into recipient sites.

CWF

The CWF system used in this study was the Revolve system (LifeCell, Bridgewater, NJ). Donor sites were similarly injected with tumescent solution before harvesting. The CWF device was assembled and incorporated in-line with wall suction and power-assisted liposuction. Per standard procedure, fat was harvested via power-assisted liposuction and the harvested slurry deposited directly into the CWF canister. The canister contained a 200-μm filter allowing the aqueous component and other contaminants to pass through while under suction. After harvesting was complete, the filtrant containing adipose tissue was agitated with the built-in propeller device and washed with lactated Ringer's solution. The remaining fat isolate was drawn out in 10-mL syringes for injection. Figure 1 depicts the Revolve system.

Statistical Analysis

Descriptive statistical analysis including mean and SDs are reported for demographic and outcomes data. Statistically significant differences between DEC and CWF groups were tested by Student's t test, Chi-square tests, or binary regression analysis when appropriate. Kaplan–Meier curves were used to compare time-to-complication data between fat processing techniques, with statistical significance assessed by log-rank test. Logistic regression was performed to identify risk factors for complications. Statistical significance was defined at $P < 0.05$. Statistical tests were carried out in SPSS v23 (IBM, Armonk, NY).

RESULTS

Demographics

One thousand one hundred fifty-eight fat grafting procedures (654 DEC versus 504 CWF) were performed on 775 breasts. Mean follow-up time was 10.6 months (±12.1). Average age was 49.1 years (±10.0) and average BMI 25.9 kg/m^2 (±5.3) at time of first fat grafting procedure. There were no significant differences between DEC and CWF patients with respect to demographic or comorbid variables. Table 1 reports demographics.

Outcomes

Overall, there were 83 cases (7.2%) of nodule/cyst formation, 73 (6.3%) ultrasounds for surveillance/biopsy/palpable mass workup, 26 cases (2.3%) of clinically relevant

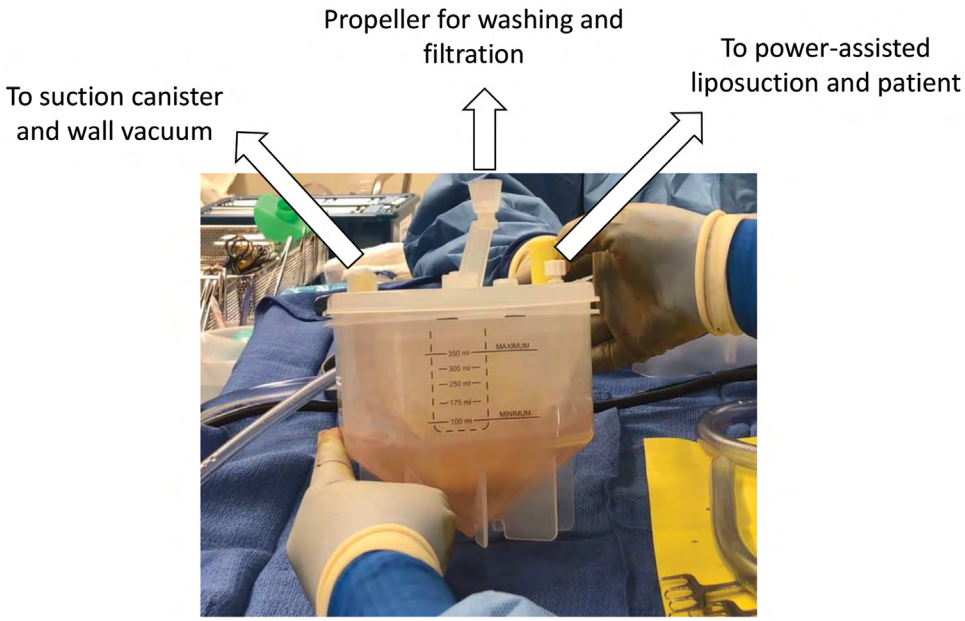

Fig. 1. Fat graft harvest and processing by the CWF technique. This is done by the Revolve system, as displayed. One end has a port for connection to power-assisted liposuction tubing whereas the other end has a port for connection to a wall vacuum. The handle in the center allows for gentle mixing and washing of fat content.

Table 1. Demographics

	Total	DEC	CWF
No. breasts	775	474	301
No. fat grafting procedures	1,158	654	504
Age, y	49.1 (SD 10.0)	49.5 (SD 10.1)	48.7 (SD 9.8)
BMI, kg/m^2	25.9 (SD 5.3)	25.2 (SD 5.0)	26.9 (SD 5.6)
Hypertension	104 (13.4%)	67 (14.1%)	37 (12.3%)
Diabetes	25 (3.2%)	17 (3.6%)	8 (2.7%)
Smoker	129 (16.7%)	81 (17.1%)	48 (16.0%)
Type of reconstruction			
Tissue expander/implant	698 (90.1%)	431 (90.5%)	267 (88.4%)
Direct to implant	14 (1.8%)	3 (0.6%)	11 (3.7%)
Latissimus flap ± implant	41 (5.3%)	27 (5.7%)	14 (4.7%)
Abdominal-based flap ± implant	18 (2.3%)	11 (2.3%)	7 (2.3%)
Fat grafting only	4 (0.5%)	2 (0.4%)	2 (0.7%)
Follow-up (mo)*	10.6 (SD 12.1)	13.2 (SD 12.2)	7.3 (SD 12.1)

*Statistical significance.

fat necrosis and 24 (2.1%) biopsies for nodules (Table 2). There were 6 (0.5%) local recurrences of breast cancer.

Comparing DEC versus CWF outcomes, there was a significantly higher rate of fat necrosis in the DEC group versus the CWF group (3.2% versus 1.0%, $P = 0.01$). No significant differences were noted for nodule/cyst, biopsy, or ultrasounds performed. Five of the 6 local cancer recurrences occurred in the DEC group (1.05%); however, this association was not significant ($P = 0.19$).

To correct for differences in follow-up (13.2 months in DEC versus 7.3 months in CWF, $P < 0.01$), time-to-event analysis was performed via Kaplan–Meier curves. On subsequent time-to-event analysis, there were no significant differences for any of the measured outcomes comparing DEC versus CWF (Fig. 2).

Looking at the timeline of complications, the cumulative event rate achieved a plateau 2–3 years after fat grafting (Fig. 3). The majority of cases of fat necrosis (76.9%) were not identified until after 6 months from time of fat grafting (Fig. 4). Similarly, nearly two-thirds of nodules/cysts were identified more than 6 months from time of fat grafting. Half of the cancer recurrences were identified within the first 2 years.

To identify risk factors for fat necrosis and biopsy, logistic regression analysis was performed. Independent risk factors for fat necrosis included DEC technique [odds ratio (OR) 5.90, 95% confidence interval (CI) 1.94–18.0], BMI > 30 kg/m^2 (OR 2.64, 95% CI 1.04–6.68), and fat graft volume >75 mL (OR 2.60, 95% CI 1.03–6.56) (Table 3). There were no independent risk factors identified for biopsy (Table 4).

Radiated versus Nonradiated Outcomes

There was a total of 206 (17.8%) fat grafting procedures in radiated breasts. When compared with the 952 nonirradiated

Table 2. Outcomes after Fat Grafting

	Total (N = 1,158)	DEC (n = 654)	CWF (n = 504)	*P*
Nodule/cyst	83 (7.2%)	53 (8.1%)	30 (6.0%)	0.16
Ultrasound	73 (6.3%)	48 (7.3%)	25 (5.0%)	0.10
Fat necrosis	26 (2.3%)	21 (3.2%)	5 (1.0%)	0.01*
Biopsy	24 (2.1%)	16 (2.5%)	8 (1.6%)	0.31

*Statistical significance.

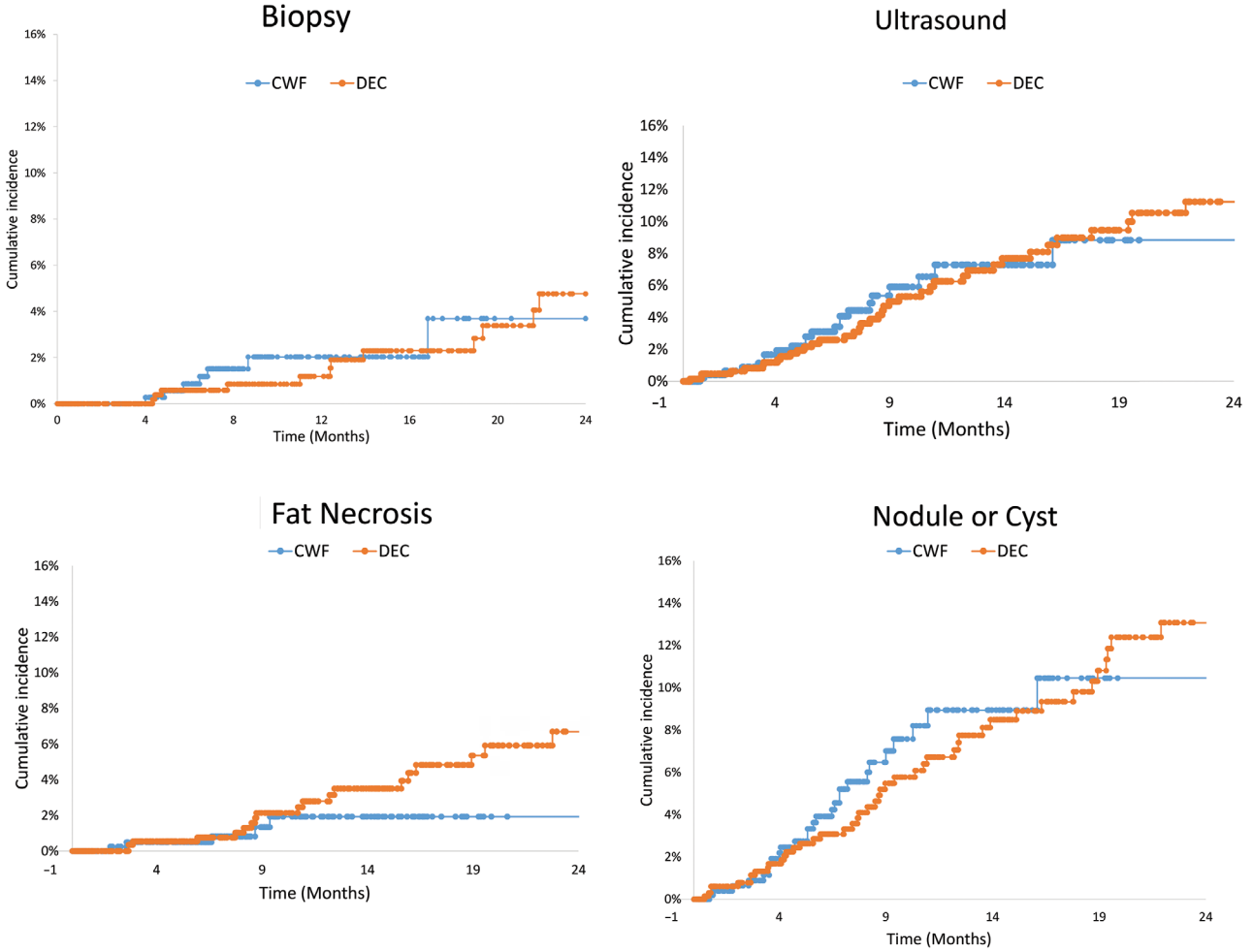

Fig. 2. Kaplan–Meier analysis of time to event for outcomes (biopsy, ultrasound, fat necrosis, nodules/cysts). There was no statistically significant difference in time to event for all outcomes compared between the DEC and CWF groups ($P = 0.47$, $P = 0.71$, $P = 0.29$ and $P = 0.47$, respectively).

fat grafting procedures, there were no differences with regard to fat necrosis (1.9 % versus 2.3%, $P = 0.75$), nodule/cyst (8.3 % versus 6.9%, $P = 0.52$), biopsy rate (1.9 % versus 2.1 %, $P = 0.88$), ultrasounds (6.8 % versus 6.2 %, $P = 0.75$), or overall complication rates (Table 5). There was also no difference in time to complication between groups (Fig. 5).

Efficacy

On average, 75.7-mL (±54.3) fat was injected to the breast per procedure. There was a lower volume in the DEC group than the CWF group (50.6 versus 105.0 mL, $P < 0.01$).

In total, 278 (35.9%) breasts required revision fat grafting, for an average of 1.49 fat graft procedures per breast. Patients in the DEC group underwent more revisions than those in the CWF group (mean 1.56 fat grafting procedures in DEC versus 1.38 in CWF, $P < 0.01$). This was driven by a significant difference in the proportion of patients requiring a second procedure (39.9% of DEC versus 29.6% of CWF, $P < 0.01$), as opposed to requiring a high number of procedures (3.6% in DEC requiring ≥4 procedures versus 2.0% in CWF, $P = 0.83$) (Fig. 6). There was no significant difference in the percent of patients requiring revision procedure after 1-year follow-up between the DEC and CWF groups (26.6% versus 22.9%, respectively, $P = 0.27$) or after 2 years of follow-up (33.5% versus 29.2%, $P = 0.24$) (Fig. 7).

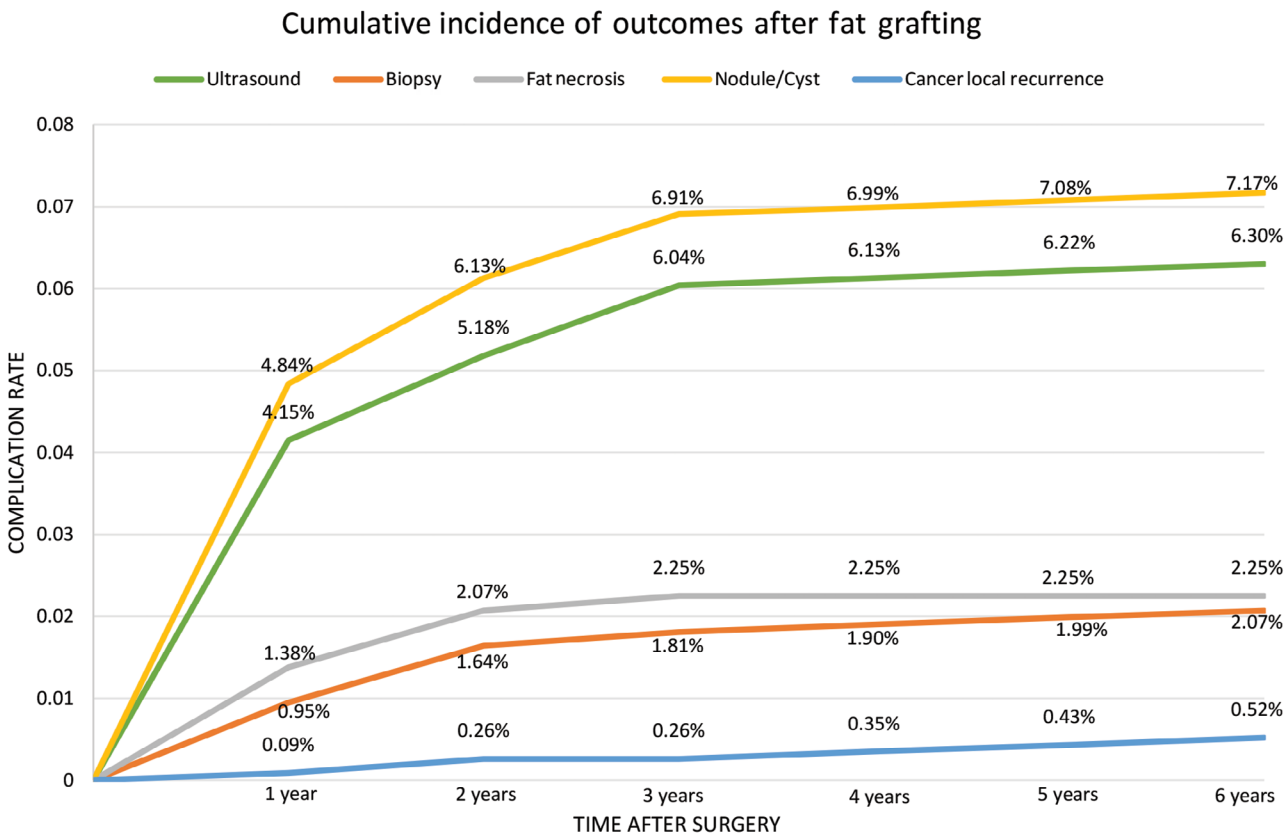

Fig. 3. Timeline demonstrating occurrence of postoperative outcomes. All outcomes examined reached a plateau between 2 and 3 years after fat grafting procedure.

Radiated versus Nonradiated Efficacy

Radiated breasts received a larger volume of fat graft compared with nonradiated breasts (89.9 versus 72.4 mL, respectively, $P < 0.01$). Radiated breasts also underwent a greater number of revision fat graft procedures than nonradiated breasts (mean 1.62 fat grafting procedures versus 1.47, respectively, $P = 0.04$). There was no difference in the proportion of radiated breasts requiring a revision procedure compared with nonradiated breasts (39.4% versus 35.2%, respectively, $P = 0.37$) or in the time to first revision fat grafting procedure (12.05 versus 11.52 months, respectively, $P = 0.37$) (Fig. 8).

DISCUSSION

By enabling the reconstructive surgeon to make fine adjustments to contour, AFG has become an essential and widespread tool for achieving a satisfactory esthetic outcome in breast reconstruction.[8,18,19] Recent censuses of the American Society of Plastic Surgeons have reported 30,516 fat grafting procedures for breast reconstruction performed in the United States annually,[20] with 62% of plastic surgeons using fat grafting in breast reconstruction.[10] However, there is little agreement as to which fat processing method is best. Among ASPS members, 45% reported using DEC, 34% filtration, 34% centrifuge, and 11% gauze.[10] Many options abound, but there is little objective evidence to guide these choices.

Clinical comparisons between fat grafting techniques have only recently been emerging.[21] Cleveland et al conducted a systematic review of fat processing methods, finding a paucity of data to support 1 method over another.[15] Other studies have shifted to focus on economic analysis of various fat processing methods. Gabriel et al reported on 98 patients receiving CWF and 96 patients receiving centrifuge for fat processing, concluding that CWF allowed for a larger volume of fat to be processed for injection and decreased operative time in these patients, translating to less expense per procedure when 22 mL or more fat was grafted.[7] Brzezienski and Jarrell published the first report comparing economics of DEC versus CWF and also suggested that using CWF for fat processing is economically beneficial in cases of planned fat transfer of 75 mL or more.[22,23] Other studies have found that processing method can impact viability and purity of grafted fat, but have not shown how this translates clinically.[12,14,24–27] In this study, we also compared DEC versus CWF but focused specifically on clinical outcomes. Correcting for follow-up period with Kaplan–Meier time-to-event analysis, our study demonstrated no difference in time to complication between the 2 groups. Overall, our complication rates were in-line with previous reports in the literature.[28–30]

We also identified several risk factors for fat necrosis in this study: DEC technique, BMI > 30 kg/m^2 , and graft volume > 75 mL. The larger graft volume is consistent with previous reports likewise noting higher rates of fat necrosis

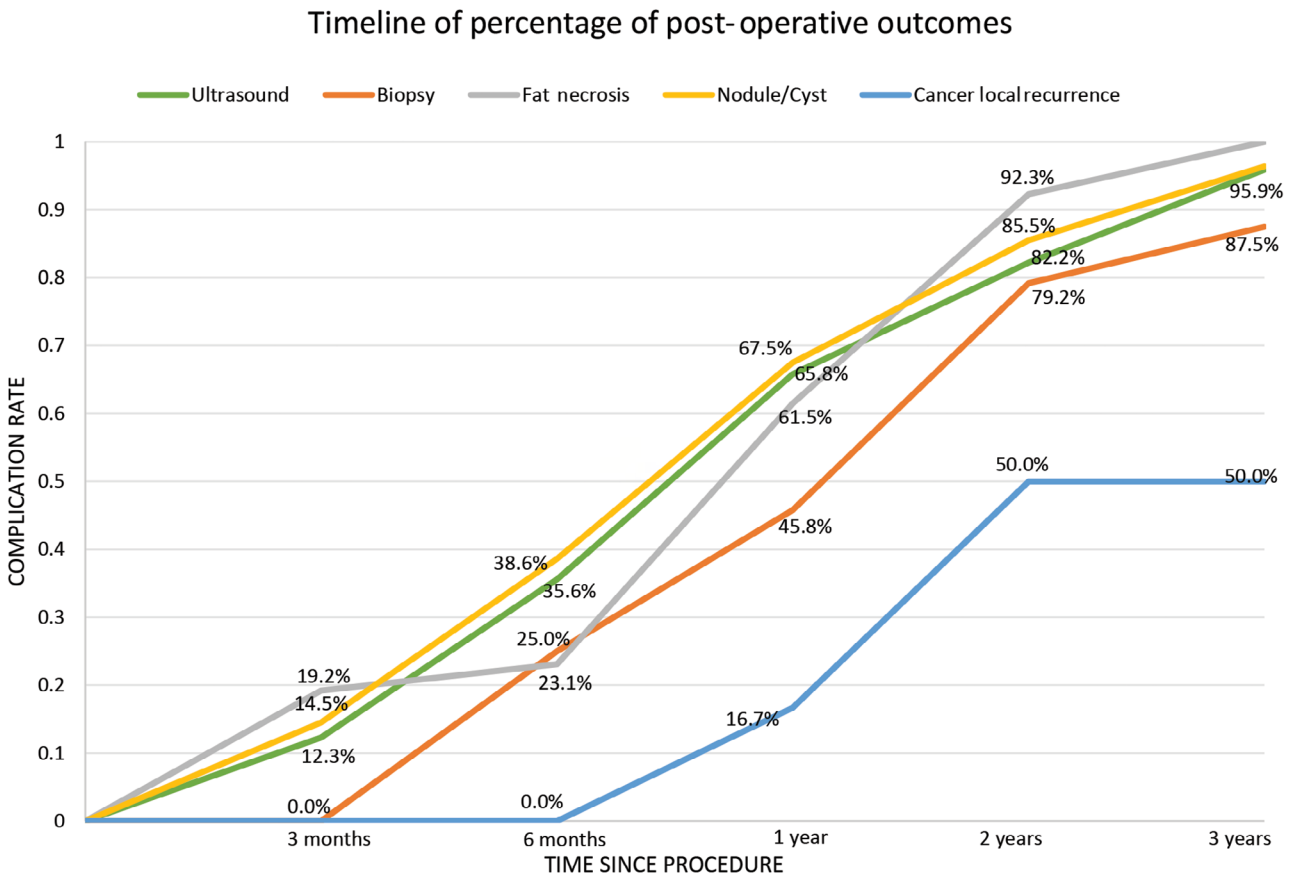

Fig. 4. Timeline demonstrating occurrence of postoperative outcomes, as a percentage of all outcomes. Note the majority of outcomes occurred more than 6 months after fat grafting procedure.

Table 3. Independent Risk Factor Associated with Fat Necrosis

Covariate	OR	95% CI		*P*
Age > 50 y	1.234	0.539	2.823	0.619
BMI > 30 kg/m^2	2.64	1.044	6.678	0.04*
Hypertension	0.695	0.206	2.349	0.558
Diabetes	1.99	0.425	9.321	0.382
History of smoking	0.772	0.257	2.322	0.645
Radiation	0.784	0.264	2.333	0.662
DEC versus CWF	5.903	1.937	17.99	0.002*
Amount of fat injection > 75 mL	2.599	1.029	6.564	0.043*

*Statistical significance.

Table 4. Independent Risk Factor Associated with Biopsy

Covariate	OR	95% CI		*P*
Age > 50 y	0.567	0.232	1.383	0.212
BMI > 30 kg/m^2	1.530	0.535	4.373	0.427
Hypertension	0.654	0.139	3.07	0.59
Diabetes	1.289	0.164	10.118	0.809
History of smoking	1.026	0.343	3.073	0.963
Radiation	1.003	0.334	3.013	0.995
DEC versus CWF	1.686	0.223	1.575	0.294
Amount of fat injection > 75 mL	0.978	0.341	2.807	0.967

Table 5. Outcomes after Fat Grafting by Radiation History

	Total (N = 1,158)	Radiotherapy (n = 206)	No Radiotherapy (n = 952)	*P*
Nodule/cyst	83 (7.2%)	17 (8.3%)	66 (6.9%)	0.51
Ultrasound	73 (6.3%)	14 (6.8%)	59 (6.2%)	0.75
Fat necrosis	26 (2.3%)	4 (1.9%)	22 (2.3%)	0.75
Biopsy	24 (2.1%)	4 (1.9%)	20 (2.1%)	0.88

when larger volumes were grafted.[31] Because there was no difference in time to complication between DEC and CWF techniques for fat necrosis, the finding of DEC technique as an independent risk factor may be related to the longer follow-up period of this cohort. Again, this replicates previous findings that fat necrosis rates are higher with longer follow-up periods[31] and reinforces our timeline analysis showing the majority of cases of fat necrosis are not identified until 6 months or more out from surgery. The association of obesity with fat necrosis is new, to our knowledge. A recent report found that obesity-prone rats produced greater amounts of inflammatory cytokines, including GM-CSF, when fed a high-fat diet.[32] Concomitant with this, fat graft take is known to be impaired under high levels of GM-CSF and other pro-inflammatory cytokines.[33] Thus, there may be a mechanistic explanation for this finding, although further studies should examine how BMI affects fat graft viability and retention.

Although complications seemed to be equivalent, we did find that CWF is associated with higher volumes of fat injection and fewer subsequent fat grafting procedures.

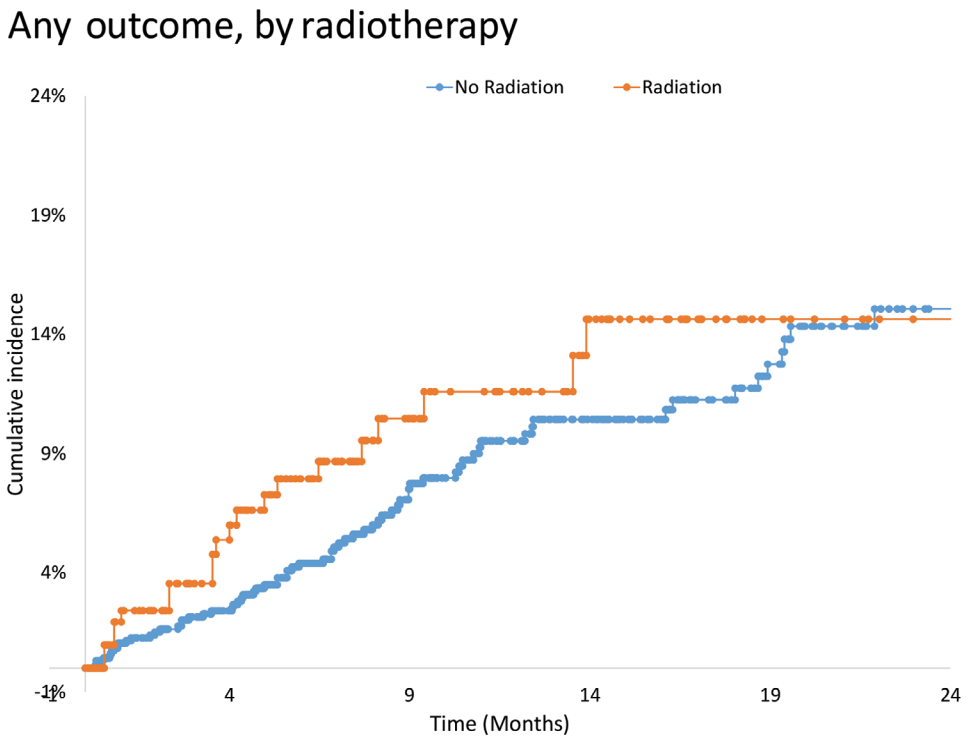

Fig. 5. Kaplan–Meier analysis of time to event for any complication between breasts with history of radiation compared with no radiation history. There was no statistically significant difference in time to complication between radiated and nonradiated breasts ($P = 0.58$).

This could be attributed in part to larger volumes of fat available for transfer by CWF (96.26 versus 47.65 mL in DEC, $P < 0.01$), which allows the surgeon to address more contour imperfections in a single procedure. CWF likely contributes to greater graft volume due to the use of power-assisted liposuction, unlike DEC which utilized manual aspiration. This supports Brzeneski's economic analysis showing cost–benefit superiority of CWF over DEC driven largely by increased fat volume injection per unit time period (4.69 mL/min with CWF versus 1.77 mL/min with

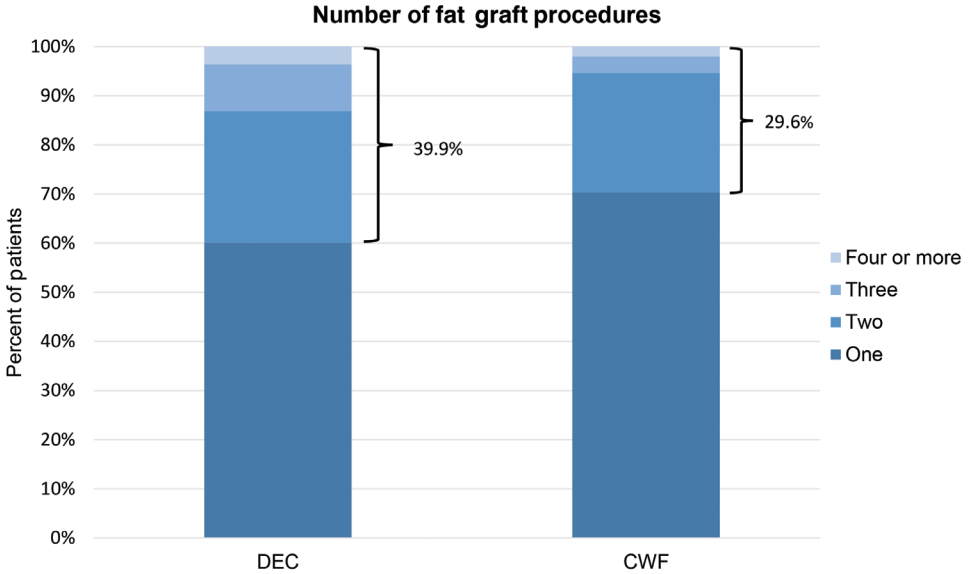

Fig. 6. Number of total fat graft procedures between the DEC and CWF groups. A greater percentage of DEC breasts required any revision procedure compared with CWF breasts (39.9% versus 29.6%, respectively, $P < 0.01$), but there was no difference between groups in patients requiring a large number (ie, 4 or more) procedures (3.6% versus 2.0%, respectively, $P = 0.83$).

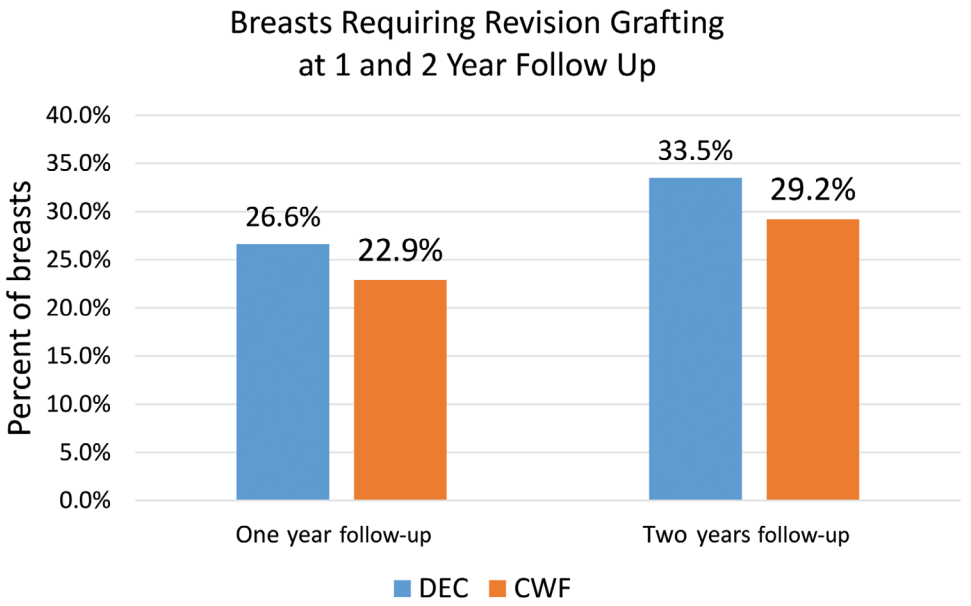

Fig. 7. Percentage of breasts requiring a revision procedure at 1- and 2-year follow-up time points. Although there was no difference in revision rates between DEC and CWF at 1- and 2-year time points ($P = 0.27$ and $P = 0.24$).

DEC). Furthermore, other studies have shown improved fat graft retention when processed via CWF, which may lead to fewer need for subsequent procedures.[34] Alternatively, this difference could also be due to longer follow-up time bias in the DEC cohort given no difference in revision rates at 1- and 2-year follow-up time points (Fig. 7).

The safety of AFG has been extensively researched.[35–38] Since 1987, there has been concern over the risk of fat

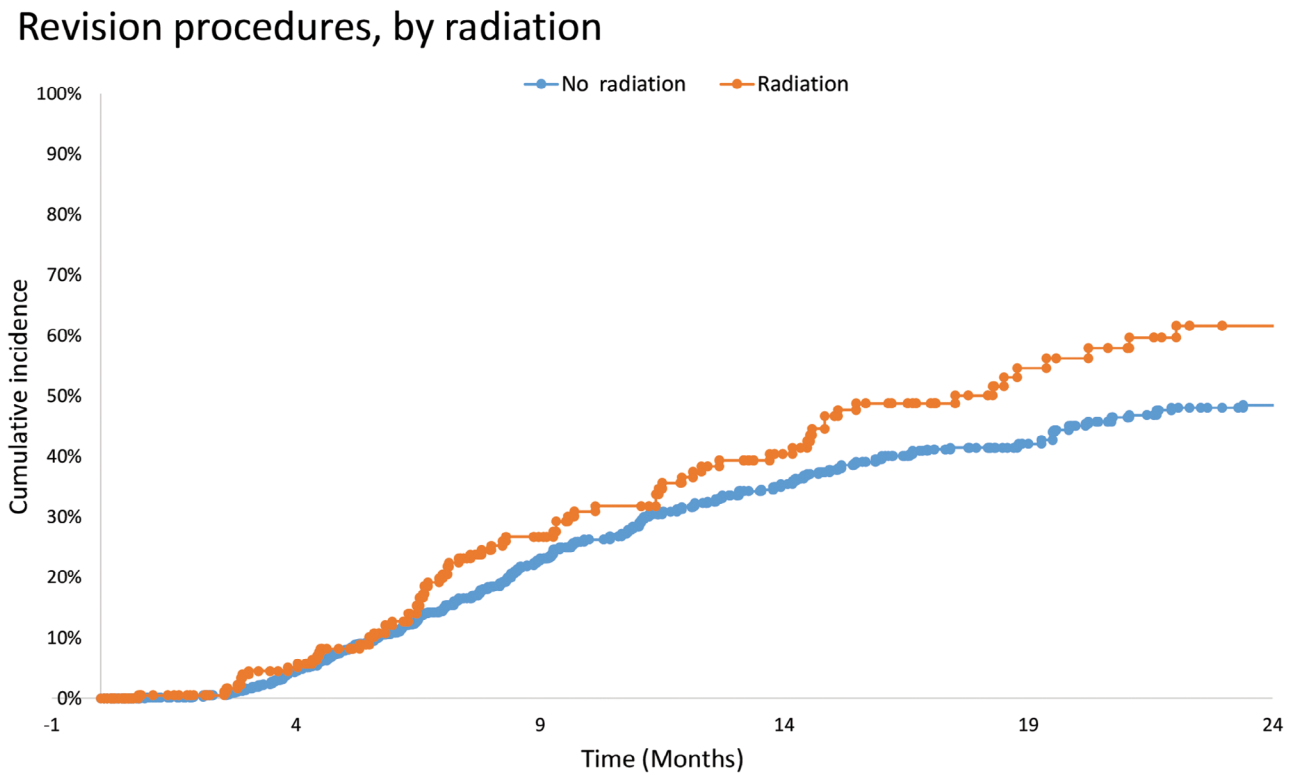

Fig. 8. Time-to-revision procedure by radiotherapy history. There was no difference in time-to-revision procedure between radiated and nonradiated breasts ($P = 0.37$).

necrosis and microcalcifications which may impede the detection of subsequent cancers (ASPRS "report on autologous fat transplantation"), but many studies have subsequently proven the safety of fat grafting.[28,29,39,40] This has been verified in multiple matched case–control studies between breast cancer patients who did and did not undergo fat grafting.[41–43] However, these studies have not found conclusive evidence supporting 1 fat processing technique over another. The ASPS Fat Grafting Task Force made general recommendations to isolate viable adipocytes via centrifugation of fat whereas they are still in the harvest syringe, but they did not discuss nuances between processing techniques.[28] We observed a very low rate of local cancer recurrence in our sample (0.33% CWF and 1.05% DEC, $P = 0.29$), lower than that observed in other large studies of AFG, and found no statistically significant difference in local recurrence between methods.[44]

Time-to-event analysis of all patients in aggregate revealed that most complications emerged within the first 2 years following fat injection, reaching a plateau thereafter. Looking at the finer detail of complication timelines, however, most complications did not occur until 6 months after surgery. Thus, we can anticipate that surveillance should be ongoing even after the initial postoperative period, but can reasonably expect that the majority of complications should manifest within 2 years.

Fibrosis has always been recognized as an important component of delayed radiation injury. The fibroatrophic model is supported by the cellular depletion and exuberant fibrosis that can be appreciated easily either clinically or with light microscopy of tissue samples taken from patients or experimental animals. Tissue fibrosis has always been recognized as an important component of delayed radiation injury. The fibroatrophic model is supported by the cellular depletion and exuberant fibrosis that can be appreciated easily either clinically or with light microscopy of tissue samples taken from patients or experimental animals.

A secondary goal of our study was to evaluate fat grafting in irradiated tissues, which tend to have worse vascularity and may be less hospitable to grafted tissue. Fat grafting can improve capsular contracture—one of the most frequent complications in irradiated patients reconstructed with implants.[45–47] It also improves postmastectomy pain syndrome and scar treatments in breast conservation surgery and radiation therapy.[48–50] There have also been various fat grafting protocols published with the goal of reducing radiotherapy-induced complications on implants.[51,52] However, actual complication rates of fat grafting in irradiated breasts have not been thoroughly addressed. In our study, we found no difference in complications due to fat grafting between radiated and nonirradiated breasts. These results are reminiscent of those found by Colwell et al and by Komorowska-Timek et al who found equivalence in overall complications between irradiated and nonirradiated fat grafting procedures in prosthetic breast reconstruction.[53,54]

This study, comprising 775 breasts and 1,158 fat grafting procedures, is the largest analysis of fat grafting to the breast to date. Limitations of this study include the absence of formal volume retention assessment by imaging, its retrospective nature, and follow-up time bias. Due to the retrospective nature, patients were not actively screened for the presence of fat necrosis or nodule formation, which limits the generalizability of our findings to only those patients who had imaging-relevant necrosis or clinically significant nodule formation. We endeavored to correct for differences in follow-up time by using time-to-event analysis via Kaplan–Meier curves. Volume retention analysis remains a challenge for these larger sample studies due to the logistic and cost challenge of prospectively assessing this variable with magnetic resonance imaging or other radiographic technique.

CONCLUSIONS

This study represents the largest series of fat grafting in breast reconstruction to date. Although comparison of 2 common harvest techniques such as DEC and CWF yields similar complication profiles, CWF facilitates larger graft volume, which may account for decreased revision procedures in this group. Risk factors for fat necrosis were identified, with a novel association between obesity and fat necrosis. Timeline analysis of complications showed that the majority of complications (fat necrosis, nodules, and cysts) occurred 6 months or more after surgery, thus surveillance should be ongoing. Lastly, there seems to be no difference in fat grafting complications between radiated and nonradiated breasts, but radiated breasts may require larger graft volume and more revisions. Overall, this long-term analysis of fat grafting technique and concomitant outcomes can help to better inform patient and surgeon expectations.

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