Fat Grafting in Breast Reconstruction

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Abstract

Keywords

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The past two decades have witnessed a growing application of autologous fat grafting in the setting of breast reconstruction after surgical treatment of breast cancer. While traditionally used to correct contour deformities during secondary revisions, fat grafting has since evolved to achieve desired breast shape and size both as a complementary adjunct to established reconstructive techniques as well as a stand-alone technique for whole breast reconstruction. In this article, we will review fat grafting as an adjunct to autologous and implant-breast based reconstruction, an option for primary breast reconstruction, and a treatment of postmastectomy pain.

In the century following the first reported case of fat transfer to the breast, fat grafting has assumed an increasingly prominent role in breast augmentation and reconstruction.^{1–4} However, in 1987, the American Society of Plastic Surgeons cautioned the use of autologous fat grafting due to its suspected interference with cancer surveillance and oncogenic potential for breast cancer.⁵ This statement was later retracted following the work by Coleman and Saboeiro describing benign postoperative findings on mammogram following autologous fat grafting.^{6,7} Additional studies have since described the safety and efficacy of autologous fat grafting to the breast, mitigating initial concerns regarding the oncogenic potential of fat grafts and their interference with tumor surveillance.^{8–11}

Refinement of techniques and establishment of clear standards for the process of fat grafting to the breast have allowed surgeons to successfully use fat grafting for various applications.^{12–14} The use of fat grafting can result in a breast with both a natural appearance and a supple feel, and the technique continues to gain popularity as a reconstructive option for eligible patients.¹² Autologous fat grafting offers tremendous versatility in its extensive potential applications in breast reconstruction. While smaller volumes of fat injection are suitable for correction of minor contour irregularities, higher injection quantities offer powerful alternatives to conventional means of whole breast reconstruction.¹⁵ This

article aims to review fat grafting techniques and discuss the different roles of fat grafting for breast reconstruction, including as a primary reconstructive technique and as a secondary adjunct to implant-based, autologous tissue, and partial breast reconstruction.

Fat Grafting in Implant-Based Breast Reconstruction

Two-stage implant-based reconstruction (IBR) remains the most common method of breast reconstruction, and this technique benefits in a variety of manners from adjunctive fat grafting.^{16,17} Fat has historically been used to treat step-off deformities caused by a marked delineation between the native chest wall and the implant.¹² Most commonly, fat grafting is initiated during implant placement after tissue expansion (→ Fig. 1). In this manner, delayed fat grafting with injection into the subcutaneous plane superficial to the implant capsule carries multiple advantages. In reconstructions using a bioprosthetic, delayed fat grafting allows time for maximal vascularization of the matrix.^{18–22} Delay also facilitates the maturation of contour irregularities, revealing areas of skin thinning and rippling to be targeted during fat grafting, especially in thin women who have limited available donor material. Fat grafting may also be performed over the

Fig. 1 (A,B) A 45-year-old female 3 months after bilateral nipple-sparing mastectomy and prepectoral tissue expander placement. (C,D) Six months after expander-to-implant exchange and concurrent fat grafting to skin envelope.

tissue expander as an interim procedure prior to final implant exchange. Proponents of this algorithm advocate the regenerative potential of fat in patients who have previously undergone radiation therapy or who otherwise have thin mastectomy flaps that may lead to compromised soft tissue envelope integrity.^{23–25} It is believed that fat grafting not only improves chest wall healing but also reverses damage to the soft tissue by stabilizing it during tissue expansion.²⁶

Submuscular Breast Reconstruction

Traditionally, implants were most commonly placed in the subpectoral pocket for breast reconstruction.^{16,27} Submuscular expanders or implants may be inserted with total muscular coverage or may be suspended at the inferior pole with bio-prosthetic or synthetic materials.²⁷ In two-staged expander-implant reconstruction, fat grafting at the time of implant exchange targets the upper poles of the breast, the upper edge of the implant, and the midline plane to reduce implant visibility, camouflage rippling, and achieve a more natural anatomic upper pole slope.²⁸ Fat grafting can also be localized to the pectoral muscle to augment volume.¹¹ Favorable patient satisfaction outcomes have been proposed with the adjunctive use of autologous fat grafting in patients who undergo IBR after mastectomy.^{29,30} In 2017, Qureshi et al conducted a prospective cohort study to evaluate patient-report satisfaction with aesthetic outcomes in patients who underwent direct

implant (DTI) placement versus implant placement after tissue expansion (TE/I). The authors found that patients within the TE/I patient cohort who underwent fat grafting reported higher BREAST-Q scores compared with those undergoing TE/I reconstruction without fat grafting (87 ± 17 vs. 66 ± 12 ; $p = 0.02$). This comparison was not assessed in the DTI group as these patients completed the BREAST-Q prior to their scheduled fat grafting sessions. The additional use of fat grafting to the traditional method of implant placement has favorable aesthetic outcomes from both the surgeon's and patient's perspective.^{29,30}

Prepectoral Breast Reconstruction

In recent years, prepectoral implants have reemerged as a valuable option for IBR.^{21,31} Prepectoral implant procedures were previously abandoned due to high associated rates of capsular contracture, mastectomy flap necrosis, and implant migration requiring explantation.³² With refinement of surgical skills, establishment of fat grafting principles, and performance of intraoperative flap perfusion analysis, prepectoral implants were revisited and appreciated for their relative decreases in the patient's pain and muscular impairment.^{20–22,31,33} Perhaps, to an even greater extent than in submuscular IBR, fat grafting represents a powerful adjunctive tool for prepectoral breast reconstruction, which relies on a more diminutive soft tissue envelope for implant coverage and support. Fat grafting to the upper pole can be

used to minimize the clear “step-off” or “rippling” deformity often found in patients with prepectoral implants and a thin skin envelope.^{21,31} Fat grafting can also be applied to the plane between the acellular dermal matrix (ADM) and the overlying skin flap—a method first proposed in 2015 by Hammond et al. The authors outlined a new technique that would restore flap thickness, enhance overall breast volume, and mask deformities.¹⁸ Initial stages involved tissue expander placement in the submuscular pocket with an ADM placed over the pectoralis major muscle. Following tissue expander removal and implant placement, the ADM had achieved sufficient vascularization, and fat was injected between the ADM and the overlying skin flap to achieve increased volume and mask implant irregularities. The complications matched those of IBR without fat grafting and included capsular contracture, oil cysts, fat necrosis, and minor incision breakdown.

Implant-to-Fat Conversion

In instances of implant failure, conversion with fat grafting has been proposed as the next best option for patients who cannot tolerate prolonged tissue flap procedures or who have experienced recurrent prosthetic-associated infections. Panetti et al, for example, reported the achievement of optimal aesthetic outcomes of fat grafting after implant

failure in a patient unable to undergo general anesthesia due to comorbidities.³⁴ Achieving desired aesthetic outcomes relies heavily on proper timing of conversion; Khouri et al recommend that fat grafting be performed immediately after implant removal due to maximum tissue laxity and compliance that is lost over time.¹⁵ As described by Khouri et al, fat grafting begins in the immediate subdermal plane surrounding the implant. The implant is then removed through a lateral thoracic incision, after which the subcapsular plane is fat grafted. Depending on the surgical method, implant-to-fat conversion may result in a smaller or similar sized breast, but the overall result may be a more natural-appearing breast compared with that of IBR.^{15,28,35}

Fat Grafting in Autologous Breast Reconstruction

Delayed fat grafting likewise has multiple applications in autologous reconstruction. Fat may be used to improve volume in autologous-based breast reconstructions in thin patients desiring larger reconstruction without the use of prosthetic devices (►Fig. 2).^{28,29} Fat grafting is also useful to ease the contour of the transition between tissue flaps and the native chest wall.²⁸ Exposure of the internal mammary vessels at the third or fourth interspace, which typically

Fig. 2 (A,B) A 44-year-old female 3 months after bilateral nipple-sparing mastectomy and deep inferior epigastric perforator flap reconstruction. (C,D) One month after bilateral fat grafting for volume.

requires excision of the costochondral cartilage at the sternal junction, may exacerbate upper pole concavities that are amenable to correction with secondary fat grafting.

Fat grafting can also expand the profile of eligible patients for specific reconstructive techniques. For example, most patients with a thin body habitus and medium- to large-sized breasts may not be ideal for autologous reconstruction due to inadequate donor-site volume.²¹ Laporta et al reported their outcomes using deep inferior epigastric perforator flaps in this specific subset of patients over a 4-year period. By augmenting flaps with large volume fat grafts, they were able to yield high levels of both patient and surgeon satisfaction without additional take-backs or prolonged total treatment periods compared with autologous reconstruction without fat grafting.³⁶

While fat grafting in the setting of autologous reconstruction is typically performed in the secondary, delayed setting, immediate fat injection at the time of pedicled flap transposition has also been proposed.¹¹ Niddam et al showed that when fat grafts are placed in the latissimus dorsi and the pectoralis major during the reconstructive procedure, surgeons may be able to forego expansion and implant augmentation.³⁷

Beyond contour correction and volume amplification, fat grafting has also been used to address fat necrosis, an adverse outcome that leads to abnormal palpable and/or visible densities within reconstruction flaps. Injection of fat is thought to mechanically break down areas of fibrosis, facilitate tissue regeneration and remodeling, and improve locoregional vascularity.^{10,15}

Fat Grafting for Whole Breast Reconstruction

While fat grafting is most commonly performed as an adjunctive procedure in breast reconstruction to complement autologous tissue flaps and implants, recent studies have shown success with primary reconstruction using fat grafting alone.²⁹ External expansion is crucial to primary breast reconstruction with fat grafting, with timelines ranging from 6 to 12 hours daily for up to 2 months.^{10,29,38} Adipocyte maturation typically takes between 2 to 3 months.³⁹ Therefore, following expansion, fat grafting sessions occur in 3- to 6-month intervals, with the end goal of a breast of natural proportion and supple feel. As described by Stark et al, primary fat grafting following nipple-sparing mastectomy typically requires at least two sessions to restore the soft tissue deficiency, with an estimated 60% of volume maintenance per session.²⁹ The first stage begins with injection of fat into the pectoralis major muscle, the lateral thoracic fascia, and the base of the mastectomy flaps following principles similar to that of injection of breast tissue. Desired aesthetic outcomes are typically achieved in five or six sessions.¹⁰ Khouri et al also had favorable outcomes using an average of 225 mL per fat grafting session every 8 to 14 weeks until completion, with each session resulting in a 27 to 52% retention volume.¹⁰ They described expansion and fat grafting as a safe, cost-effective, and minimally invasive technique alternative to autologous reconstruction.¹⁰

Fat Grafting in Breast Conservation Therapy

Similar to its use in other methods of breast reconstruction, fat grafting may be used following breast conservation therapy to increase volume, achieve breast symmetry, and reduce scarring.^{40,41} In a prospectively maintained database of patients undergoing fat grafting after radiation therapy and breast-conserving surgery, van Turnhout et al found that fat grafting led to significant improvement in volume, shape, symmetry, and scarring over a 6-month postoperative period.⁴⁰ Despite the positive aesthetic outcomes associated with this method, fat grafting following breast-conserving surgery remains controversial given the inconclusive literature on its oncological safety.⁴¹ Regarding tumor surveillance, Juhl et al have noted that fat grafting in breast conservation patients causes immediate radiological changes such as the presence of oil cysts, which should be discernable from neoplastic changes with the use of ultrasound and mammography.⁴² However, the authors conclude that despite the ability to make clear radiological distinctions, more studies are necessary to conclusively rule out possible recurrences in the presence of these fat grafting changes.⁴²

Older reports of tumor recurrence in patients undergoing fat grafting after breast-conserving therapy were largely incidental and were the result of weaker study designs that lacked independent control groups. In response, Mestak et al performed a prospective study of 77 breast conservation patients over a 2-year period to assess recurrence rates between patients who underwent fat grafting after breast-conserving surgery and those who did not.⁴³ The authors found that 6.25% of patients who had undergone fat grafting following breast-conserving surgery had cancer recurrence and 4.88% who only underwent breast-conserving surgery had cancer recurrence with no significant difference in recurrence rates between the two groups ($p = 0.593$).⁴³ In a more recent literature review of studies to date on the oncological safety of fat grafting following breast-conserving surgery, Cohen et al appraised 19 studies according to seven safety criteria. These criteria included (1) a description of the interval between cancer resection and lipofilling, (2) a minimum follow-up period of 6 years after primary cancer resection, (3) a minimum follow-up period of 3 years after lipofilling, (4) an analysis of breast cancer subgroups specifically focusing on ER/PR/Her2, (5) a defined cohort comparison group, (6) controls matched for receptor status, and (7) adequate powering.⁴¹ The authors concluded that while some described this practice safe according to their own standards, none of the included studies met all seven criteria, mainly due to insufficient power. Study designs included were retrospective case series, prospective case series, retrospective case-control studies, and prospective case-control studies. Cohen et al concluded that to determine the safety of fat grafting following breast-conserving surgery, a multicentered, high-powered, prospective study would be necessary.⁴¹ Overall, while fat grafting improves aesthetic outcomes in breast conservation patients, the literature is inconclusive when it comes to its oncological safety and tumor surveillance in this patient population.

Therapeutic Indications of Fat Grafting

Uses for autologous fat grafting in the setting of breast reconstruction extend beyond recreation or remodeling of the breast mound. Proposed therapeutic applications include treatment of postmastectomy pain syndrome, capsular contracture pain, and irradiated tissue fibrosis.^{26,44–46} Postmastectomy pain syndrome is characterized by chronic pain that is neuropathic in character, located in the axilla, shoulder, or chest wall ipsilateral to the patient's operation, and occurs continuously or intermittently beyond the normal healing period of 3 months.^{29,44} Medical treatment options include the use of tricyclic antidepressants, anticonvulsants, or topical lidocaine patches, but long-term use of pharmacological agents is poorly tolerated.⁴⁴ Multiple studies have reported that autologous fat grafting is an effective treatment for postmastectomy pain syndrome due to scar remodeling by the adipose tissue.^{45,47,48} Fat grafting to the scarred area is proposed to prevent nerve entrapment that leads to persistent pain experienced by patients.^{44,49,50} This method has also been found to have minimal morbidity that is similar to that of liposuction procedures.⁴⁴

Pain associated with capsular contracture may also be relieved by fat grafting. Capsular contracture affects up to 30% of patients who have undergone both breast augmentation and IBR.⁴⁶ It has been suggested that fat grafting not only relieves pain associated with capsular contracture but also improves skin quality and sensation of the breast.⁴⁶ Papadopoulos et al found that fat grafting can provide pain relief and reduce the grade of capsular contracture from grade 4 to grade 3.⁴⁶ Treatment typically occurs over a prolonged period of time, requiring multiple sessions of fat grafting. The authors attributed pain relief to tissue differentiation and softening that decreased nerve entrapment.⁴⁶

Fat grafting may also improve healing in patients that have undergone radiation therapy. Effects of radiation include fibroblast injury, excessive scarring, and decreased microcirculation in targeted areas.²⁶ These injuries have been linked to poor aesthetic outcomes and increased risk for capsular contracture. The pluripotent stem cells in grafted fat are postulated to improve angiogenesis through paracrine signaling and endothelial cell recruitment.¹⁵ Another consideration is the timing and the number of sessions needed to achieve optimal aesthetic outcomes. While a nonirradiated, minimally scarred recipient site may only require two sessions, irradiated surgical fields have decreased compliance requiring at least four total sessions to overcome radiation effects.^{15,28,51} Additionally, while most fat grafting for postradiation patients occurs between 3 and 6 months following the conclusion of radiation therapy, there has been evidence to support the use of fat grafts at earlier time points prior to severe tissue fibrosis and decreased perfusion.^{52,53}

Oncological Safety

Initial arguments against fat grafting were focused on its perceived oncogenic potential and interference with tumor surveillance.⁴ Numerous studies have since shown compara-

ble rates of local, regional, and distant recurrence rates compared with nonfat grafting breast reconstruction.^{8,11,12,54} Additionally, technological advances permit radiologists to properly identify the differences between post fat grafting necrosis and neoplastic calcification, ameliorating previous worries about impaired tumor surveillance.^{55–58} The overall consensus among authors is that fat grafting alone does not increase rates of cancer recurrence or reduce the ability to identify recurrence on imaging.^{59,60}

Complications

Rates of fat grafting complications are relatively low during breast reconstruction and include fat necrosis, oil cysts, and infection.²⁹ Detection of these complications is achieved by ultrasound and mammography to differentiate cysts from masses and to definitively detect recurrence, respectively.¹² Recurrence will appear similar to the initial imaging of the cancerous lesion, with irregular masses and pleomorphic calcifications seen on mammography, whereas fat necrosis and oil cysts have very distinct characteristics on imaging, such as coarse calcifications that rarely need to be biopsied. Additionally, breast cancer will demonstrate rapid uptake of contrast, whereas fibrosis and fat necrosis typically will not at all, with rare cases demonstrating gradual uptake.

Rates of complications depend heavily on the recipient site for fat grafting and reflect the degree of compliance in these sites. While overall major complication rates in breast reconstruction are low, these rates are higher in patients who have undergone radiation therapy following modified radical mastectomy and skin-sparing mastectomy.¹⁴ Due to increased fibrosis and decreased compliance of the recipient sites in irradiated breasts, these patients require an increased number fat grafting sessions.^{14,15} In patients without irradiated breasts, increased volume does not increase the recipient site's capacity even with maximum compliance.¹² Therefore, surgeons seeking to overcorrect greater than 10% with larger volumes of fat grafts will have higher rate of oil cysts and subsequent calcifications.¹² Common treatments for complications include the use of local anesthesia to drain cysts, liposuction or needle band release for fat necrosis, and fat grafting for any residual defects of these procedures.²⁸

Limitations

Though surgeons continue to integrate fat grafting into breast reconstruction, there are still limitations to its use, largely centered on treatment timelines. There are numerous proposed rules to optimize oncological, aesthetic, and reconstructive outcomes; however, many are constrained by the patient's specific course of treatment including need for adjuvant therapies, as well as patient amenability to undergo staged procedures. Successful graft integration requires a suitable bed for revascularization, and an upper limit exists for feasible injection volumes during each single treatment. If a substantial size increase is desired, serial procedures and adequate donor-site options are requisite.

Conclusion

The role of fat grafting has transformed since its inception and continues to gain new applications within the field of breast reconstruction. Initially limited to the correction of contour deformities following breast reconstruction, fat grafting currently has utility in various stages of the reconstructive process. Fat injection serves not only as an adjunct to implant-based and autologous breast reconstruction but also as a primary reconstructive option in eligible patients. Fat grafting achieves the look and feel of a naturally supple breast while mitigating some of the negative effects associated with mastectomies. As surgeons perfect their personal approach, fat grafting will continue to evolve within the realm of breast reconstruction.

Conflicts of Interest

None of the authors has a financial interest in any of the products, devices, or drugs mentioned in this manuscript.

References

- Czerny V. Plastischer Ersatz der Brustdrüse durch ein Lipom. *Zentralbl Chir* 1895;27:72–75
- Bircoll M, Novack BH. Autologous fat transplantation employing liposuction techniques. *Ann Plast Surg* 1987;18(04):327–329
- Illouz YG. Body contouring by lipolysis: a 5-year experience with over 3000 cases. *Plast Reconstr Surg* 1983;72(05):591–597
- Abu-Ghname A, Perdanasari AT, Reece EM. Principles and applications of fat grafting in plastic surgery. *Semin Plast Surg* 2019;33(03):147–154
- Report on autologous fat transplantation. ASPRS Ad-Hoc Committee on New Procedures, September 30, 1987. *Plast Surg Nurs* 1987;7(04):140–141
- Coleman SR, Saboeiro AP. Fat grafting to the breast revisited: safety and efficacy. *Plast Reconstr Surg* 2007;119(03):775–785, discussion 786–787
- Gutowski KA; ASPS Fat Graft Task Force. Current applications and safety of autologous fat grafts: a report of the ASPS fat graft task force. *Plast Reconstr Surg* 2009;124(01):272–280
- Krastev TK, Jonasse Y, Kon M. Oncological safety of autologous lipoaspirate grafting in breast cancer patients: a systematic review. *Ann Surg Oncol* 2013;20(01):111–119
- Spear SL, Coles CN, Leung BK, Gitlin M, Parekh M, Macarios D. The safety, effectiveness, and efficiency of autologous fat grafting in breast surgery. *Plast Reconstr Surg Glob Open* 2016;4(08):e827
- Khoury RK, Rigotti G, Khouri RK Jr, et al. Tissue-engineered breast reconstruction with Brava-assisted fat grafting: a 7-year, 488-patient, multicenter experience. *Plast Reconstr Surg* 2015;135(03):643–658
- Groen JW, Negenborn VL, Twisk DJWR, et al. Autologous fat grafting in onco-plastic breast reconstruction: a systematic review on oncological and radiological safety, complications, volume retention and patient/surgeon satisfaction. *J Plast Reconstr Aesthet Surg* 2016;69(06):742–764
- Kanchwala SK, Glatt BS, Conant EF, Bucky LP. Autologous fat grafting to the reconstructed breast: the management of acquired contour deformities. *Plast Reconstr Surg* 2009;124(02):409–418
- Illouz YG, Sterodimas A. Autologous fat transplantation to the breast: a personal technique with 25 years of experience. *Aesthetic Plast Surg* 2009;33(05):706–715
- Herly M, Ørholm M, Larsen A, et al. Efficacy of breast reconstruction with fat grafting: a systematic review and meta-analysis. *J Plast Reconstr Aesthet Surg* 2018;71(12):1740–1750
- Khoury RK Jr, Khouri RK. Current clinical applications of fat grafting. *Plast Reconstr Surg* 2017;140(03):466e–486e
- Albornoz CR, Bach PB, Mehrara BJ, et al. A paradigm shift in U.S. breast reconstruction: increasing implant rates. *Plast Reconstr Surg* 2013;131(01):15–23
- Cemal Y, Albornoz CR, Disa JJ, et al. A paradigm shift in U.S. breast reconstruction: part 2. The influence of changing mastectomy patterns on reconstructive rate and method. *Plast Reconstr Surg* 2013;131(03):320e–326e
- Hammond DC, O'Connor EA, Scheer JR. Total envelope fat grafting: a novel approach in breast reconstruction. *Plast Reconstr Surg* 2015;135(03):691–694
- Jones G, Yoo A, King V, et al. Prepectoral immediate direct-to-implant breast reconstruction with anterior AlloDerm coverage. *Plast Reconstr Surg* 2017;140(6S Prepectoral Breast Reconstruction):31S–38S
- Darrach H, Kraenzlin F, Khavanin N, Chopra K, Sacks JM. The role of fat grafting in prepectoral breast reconstruction. *Gland Surg* 2019;8(01):61–66
- Elswick SM, Harless CA, Bishop SN, et al. Prepectoral implant-based breast reconstruction with postmastectomy radiation therapy. *Plast Reconstr Surg* 2018;142(01):1–12
- Sigalove S, Maxwell GP, Sigalove NM, et al. Prepectoral implant-based breast reconstruction: rationale, indications, and preliminary results. *Plast Reconstr Surg* 2017;139(02):287–294
- Kolasinski J. Total breast reconstruction with fat grafting combined with internal tissue expansion. *Plast Reconstr Surg Glob Open* 2019;7(04):e2009
- Serra-Renom JM, Muñoz-Olmo JL, Serra-Mestre JM. Fat grafting in postmastectomy breast reconstruction with expanders and prostheses in patients who have received radiotherapy: formation of new subcutaneous tissue. *Plast Reconstr Surg* 2010;125(01):12–18
- Borrelli MR, Patel RA, Sokol J, et al. Fat chance: the rejuvenation of irradiated skin. *Plast Reconstr Surg Glob Open* 2019;7(02):e2092
- Komorowska-Timek E, Turfe Z, Davis AT. Outcomes of prosthetic reconstruction of irradiated and nonirradiated breasts with fat grafting. *Plast Reconstr Surg* 2017;139(01):1e–9e
- Frey JD, Salibian AA, Karp NS, Choi M. Implant-based breast reconstruction: hot topics, controversies, and new directions. *Plast Reconstr Surg* 2019;143(02):404e–416e
- Katzel EB, Bucky LP. Fat grafting to the breast: clinical applications and outcomes for reconstructive surgery. *Plast Reconstr Surg* 2017;140(5S Advances in Breast Reconstruction):69S–76S
- Stark RY, Mirzabeigi MN, Vonderhaar RJ, Bucky LP. Utilizing large volume fat grafting in breast reconstruction after nipple sparing mastectomies. *Gland Surg* 2018;7(03):337–346
- Qureshi AA, Odom EB, Parikh RP, Myckatyn TM, Tenenbaum MM. Patient-reported outcomes of aesthetics and satisfaction in immediate breast reconstruction after nipple-sparing mastectomy with implants and fat grafting. *Aesthet Surg J* 2017;37(09):999–1008
- Highton L, Johnson R, Kirwan C, Murphy J. Prepectoral implant-based breast reconstruction. *Plast Reconstr Surg Glob Open* 2017;5(09):e1488
- Gruber RP, Kahn RA, Lash H, Maser MR, Apfelberg DB, Laub DR. Breast reconstruction following mastectomy: a comparison of submuscular and subcutaneous techniques. *Plast Reconstr Surg* 1981;67(03):312–317
- Sbitany H, Piper M, Lentz R. Prepectoral breast reconstruction: a safe alternative to submuscular prosthetic reconstruction following nipple-sparing mastectomy. *Plast Reconstr Surg* 2017;140(03):432–443
- Panetti P, Accorsi D, Marchetti L, Sgrò F, Sbarbati A. Large-breast reconstruction using fat graft only after prosthetic reconstruction failure. *Aesthetic Plast Surg* 2011;35(05):703–708
- Del Vecchio DA. “SIEF”–simultaneous implant exchange with fat: a new option in revision breast implant surgery. *Plast Reconstr Surg* 2012;130(06):1187–1196

- 36 Laporta R, Longo B, Sorotos M, Pagnoni M, Santanelli di Pompeo F. Breast reconstruction with delayed fat-graft-augmented DIEP flap in patients with insufficient donor-site volume. *Aesthetic Plast Surg* 2015;39(03):339–349
- 37 Niddam J, Vidal L, Hersant B, Meningaud JP. Primary fat grafting to the pectoralis muscle during latissimus dorsi breast reconstruction. *Plast Reconstr Surg Glob Open* 2016;4(11):e1059
- 38 Mestak O, Mestak J, Bohac M, Edriss A, Sukop A. Breast reconstruction after a bilateral mastectomy using the Brava expansion system and fat grafting. *Plast Reconstr Surg Glob Open* 2013;1(08):e71
- 39 Kato H, Mineda K, Eto H, et al. Degeneration, regeneration, and cicatrization after fat grafting: dynamic total tissue remodeling during the first 3 months. *Plast Reconstr Surg* 2014;133(03):303e–313e
- 40 van Turnhout AA, Fuchs S, Lisabeth-Broné K, Vriens-Nieuwenhuis EJC, van der Sluis WB. Surgical outcome and cosmetic results of autologous fat grafting after breast conserving surgery and radiotherapy for breast cancer: a retrospective cohort study of 222 fat grafting sessions in 109 patients. *Aesthetic Plast Surg* 2017;41(06):1334–1341
- 41 Cohen S, Sekigami Y, Schwartz T, Losken A, Margenthaler J, Chatterjee A. Lipofilling after breast conserving surgery: a comprehensive literature review investigating its oncologic safety. *Gland Surg* 2019;8(05):569–580
- 42 Juhl AA, Redsted S, Engberg Damsgaard T. Autologous fat grafting after breast conserving surgery: breast imaging changes and patient-reported outcome. *J Plast Reconstr Aesthet Surg* 2018;71(11):1570–1576
- 43 Mestak O, Hromadkova V, Fajfrova M, Molitor M, Mestak J. Evaluation of oncological safety of fat grafting after breast-conserving therapy: a prospective study. *Ann Surg Oncol* 2016;23(03):776–781
- 44 Caviggioli F, Maione L, Forcellini D, Klinger F, Klinger M. Autologous fat graft in postmastectomy pain syndrome. *Plast Reconstr Surg* 2011;128(02):349–352
- 45 Huang SH, Wu SH, Chang KP, et al. Alleviation of neuropathic scar pain using autologous fat grafting. *Ann Plast Surg* 2015;74 (Suppl 2):S99–S104
- 46 Papadopoulos S, Vidovic G, Neid M, Abdallah A. Using fat grafting to treat breast implant capsular contracture. *Plast Reconstr Surg Glob Open* 2018;6(11):e1969
- 47 Salgarello M, Visconti G, Barone-Adesi L. Fat grafting and breast reconstruction with implant: another option for irradiated breast cancer patients. *Plast Reconstr Surg* 2012;129(02):317–329
- 48 Maione L, Vinci V, Caviggioli F, et al. Autologous fat graft in postmastectomy pain syndrome following breast conservative surgery and radiotherapy. *Aesthetic Plast Surg* 2014;38(03):528–532
- 49 Juhl AA, Karlsson P, Damsgaard TE. Fat grafting for alleviating persistent pain after breast cancer treatment: a randomized controlled trial. *J Plast Reconstr Aesthet Surg* 2016;69(09):1192–1202
- 50 Zuk PA, Zhu M, Ashjian P, et al. Human adipose tissue is a source of multipotent stem cells. *Mol Biol Cell* 2002;13(12):4279–4295
- 51 Del Vecchio D, Rohrich RJ. A classification of clinical fat grafting: different problems, different solutions. *Plast Reconstr Surg* 2012;130(03):511–522
- 52 Thanik VD, Chang CC, Zoumalan RA, et al. A novel mouse model of cutaneous radiation injury. *Plast Reconstr Surg* 2011;127(02):560–568
- 53 Gabriel A, Champaneria MC, Maxwell GP. Fat grafting and breast reconstruction: tips for ensuring predictability. *Gland Surg* 2015;4(03):232–243
- 54 Silva MMA, Kokai LE, Donnenberg VS, et al. Oncologic safety of fat grafting for autologous breast reconstruction in an animal model of residual breast cancer. *Plast Reconstr Surg* 2019;143(01):103–112
- 55 Leibman AJ, Styblo TM, Bostwick J III. Mammography of the postreconstruction breast. *Plast Reconstr Surg* 1997;99(03):698–704
- 56 Kneeshaw PJ, Lowry M, Manton D, Hubbard A, Drew PJ, Turnbull LW. Differentiation of benign from malignant breast disease associated with screening detected microcalcifications using dynamic contrast enhanced magnetic resonance imaging. *Breast* 2006;15(01):29–38
- 57 Yunus M, Ahmed N, Masroor I, Yaqoob J. Mammographic criteria for determining the diagnostic value of microcalcifications in the detection of early breast cancer. *J Pak Med Assoc* 2004;54(01):24–29
- 58 Chala LF, de Barros N, de Camargo Moraes P, et al. Fat necrosis of the breast: mammographic, sonographic, computed tomography, and magnetic resonance imaging findings. *Curr Probl Diagn Radiol* 2004;33(03):106–126
- 59 Orbay H, Hinchcliff KM, Charvet HJ, Sahar DE. Fat graft safety after oncologic surgery: addressing the contradiction between in vitro and clinical studies. *Plast Reconstr Surg* 2018;142(06):1489–1499
- 60 Kronowitz SJ, Mandujano CC, Liu J, et al. Lipofilling of the breast does not increase the risk of recurrence of breast cancer: a matched controlled study. *Plast Reconstr Surg* 2016;137(02):385–393