The use of soft tissue fillers to treat volume and contour defects is among the fastest growing, minimally invasive cosmetic procedures in the United States. In particular, the application of autologous adipose tissue as soft tissue filler is gaining popularity; more than 71,000 procedures were performed in 2012. Fat is an attractive filler because it is biocompatible, abundantly available, and easily harvested. Adipose tissue for fat grafting has been used for various indications, including facial rejuvenation, facial lipodystrophy, hand rejuvenation, lower limb augmentation/atrophy, buttock aesthetic augmentation, and aesthetic or reconstructive breast surgery. Despite its
popularity and clinical applications, fat grafting is not without problems. This procedure’s highly variable outcomes present a significant concern. Poor fat graft retention affects clinical outcomes, sometimes requiring additional grafting procedures to achieve optimal results. At present, fat graft viability and retention cannot be reliably predicted, and reasons for the variability are not fully understood; however, fat processing methodology has been implicated as a possible cause.

Various fat-processing techniques range from simple decantation to centrifugation, washing with physiologic solutions, and filtration with a dense cloth or a common strainer. However, centrifugation is generally considered the standard fat-processing method. Recently, a new fat-processing system, Revolve (LifeCell, Bridgewater, New Jersey), has been developed. Revolve incorporates the harvesting, filtering, and washing steps into a single unit, thus simplifying fat processing. The purpose of this study was to compare quantity and quality of processed fat obtained via the Revolve system with samples from decantation and centrifugation methods.

METHODS

Study Subjects

Ten subjects voluntarily consented to elective abdominal liposuction surgery. Individuals who were smokers or who had a body mass index (BMI) > 35 kg/m², history of bleeding disorder, human immunodeficiency virus (HIV), diabetes, or lipoatrophy disorders were excluded from the study. The local Institutional Review Board at Renew in San Antonio, Texas, approved this study under protocol number LCELL_120328. Figure 1 displays the study design.

Autologous Fat Harvesting

Liposuction was performed by a single surgeon (J.R.G.) using a standard procedure. The liposuction site was prepared with 1% xylocaine with 1:100 000 epinephrine solution. A standard tumescent fluid was used that included Lactated Ringer’s solution, 50 mg of 1% lidocaine, and 1 mL of 1:1000 epinephrine. The VentX aspiration system (Solta, Hayward, California) was applied with a 3.2-mm cannula, with approximately ½ atmosphere of negative pressure. Lipoaspirate was obtained from contralateral sides of the abdomen; half was collected directly into the Revolve system and the other half into a sterile canister for processing by decantation and centrifugation methods. Lipoaspirate from each patient was processed by each of the 3 methods: decantation, centrifugation, and the Revolve system.

Decantation Method

In total, 500 mL of lipoaspirate collected into the decantation container (Fluid Management System; Medela, McHenry, Illinois) was allowed to settle for 10 minutes, resulting in lipoaspirate separation into an aqueous phase, a fat phase, and a free oil phase. The aqueous phase was drained from the bottom and discarded. The retained fat sample represented the decantation arm of the study.

Centrifugation Method

A portion of the fat phase obtained from the decantation method was transferred into 20-mL syringes and centrifuged at 1200 g for 3 minutes (Thermo Scientific Medilite centrifuge; Thermo Fisher Scientific, Waltham, Massachusetts). The resulting lower aqueous phase was expressed, the upper oil phase was wicked away, and the middle fat phase was retained. This retained fat sample represented the centrifugation arm of the study.

Revolve System

Revolve is an inline fat-processing system in which lipoaspirate is harvested directly into the device (Figure 2). The Revolve device consists of an outer canister and an inner filter basket (200-µm pores) that allows fat to be separated from the tumescent fluid immediately. Once at least 300 mL of fat was collected in the inner filter, 400 mL of Lactated Ringer’s solution at 37°C was added, and the fat was washed for 15 ± 5 seconds. The Revolve device contains rotating paddles within the filter basket, which gently agitated the tissue and ensured the fat was thoroughly washed. The fluid was then vacuum-aspirated for 60 ± 5 seconds. The wash was repeated a total of 3 times. Following the final wash, the fat sample was aspirated through the collection port into syringes for in vitro and in vivo analyses. Total processing time for the Revolve system was approximately 10 minutes. The fat sample collected in syringes represented the Revolve arm of the study.
In Vitro Assessments

Approximately 30 mL of processed fat from each method was reserved for in vitro assessments. For the animal studies, twelve 3-mL syringes were loaded with 1 mL fat from each processing method for implantation into nude mice. Immediately after processing, composition and physiological quality of fat from the 3 methods were assessed. For quantitative assessments of the fat graft’s composition, samples were centrifuged at 5000 g for 5 minutes to separate the aqueous, fat, and free oil phases. A centrifugation speed of 5000 g was chosen to separate the fat graft phases for in vitro assessment only, not for grafting. The volume of the 3 phases was measured, and composition of fat from the 3 processing methods was compared. The aqueous phase was retained for pH, osmolality, and hematocrit assays.

The pH was determined using a standard pH meter; pH test strips were used when insufficient aqueous phase was available. Osmolality was measured in triplicate from the aqueous phase of the fat samples with a Wescor osmometer (Vapro 5520; ELitech Group, Princeton, New Jersey).

Hematocrit was measured in triplicate by enzyme-linked immunosorbent assay according to manufacturer instructions (Bethyl E80-135; Bethyl Laboratories, Montgomery, Texas).

In Vivo Assessments

All animal procedures were performed in compliance with Institutional Animal Care and Use Committee protocols at the University of Texas at San Antonio. Nude mice (5-6 weeks old) were implanted with 1-mL fat grafts as a single bolus. The fat bolus was injected subcutaneously into the flanks using a 14-gauge angiocatheter and a 3-mL syringe, as described previously. The nude mouse model was developed to model fat graft retention and health but is not intended to model clinical fat grafting techniques. In this study, percent retention of fat grafts was calculated from the weight of each graft at injection and at explant. The weight of each fat graft injected was determined by weighing syringes on a scale, pre- and postinjection, and subtracting the difference. Each tissue donor (cohort) was paired across the 3 processing methods. Fat from each processing arm was implanted into 8 animals for a total of 24 animals per cohort. Thus, the 10-subject study scheme yielded a total of 240 mice. A prior power analysis performed on pilot data using a power of 80% and an α of 0.1% determined that a sample size of 8 mice per group per patient was the minimal sample size necessary to detect a 5% difference across groups.

Mice were euthanized at 28 days postimplantation, and the fat grafts were excised and weighed. Percent fat retention was calculated by comparing the weight of implanted fat grafts. Gross observations were made on both intact and bisected fat grafts.

Histology samples of fat grafts were taken of both preimplanted fat and 28 days after implantation. Samples were processed via standard histological procedures and stained with hematoxylin and eosin. Histological samples were evaluated by 3 experts (M.C.M. and 2 external histopathologists associated with CRO [InCell, San Antonio, Texas]), with slides randomized, blinded, and rated according to the relative presence or absence of cysts/vacuoles, fibrosis, and inflammation as evidenced by infiltration of lymphocytes and macrophages. After initial grading, slides were sorted into experimental groups (group identity was blinded), and the experts made a subjective determination of the fat quality of each group.

Statistical Analysis

The average and standard deviation was calculated for all quantitative measures. Relative standard deviation of percent fat retention was calculated (mean/standard deviation) to assess predictability in all test arms. A 1-way analysis of variance (ANOVA) test across groups was conducted with α set at 0.05.

RESULTS

Subjects

Nine women and 1 man, all between ages 30 and 55 years (mean, 40.7 ± 8.9 years) and with a BMI of 21 to 33 kg/m²,
participated in this study. While 11 patients consented to participate, 1 was excluded due to a scheduling conflict. Individuals who were smokers or who had a BMI > 35 kg/m², history of bleeding disorder, human immunodeficiency virus (HIV), diabetes, or lipoatrophy disorders were excluded from the study. Patients were not tracked for any outcomes related to this study but received standard follow-up care.

**In Vitro Assessments**

**Gross Observations**

Fat processed by the 3 methods was examined grossly prior to implantation to determine the tissue’s overall quality. Figure 3 displays representative fat tissue processed by the 3 methods. Compared with the decantation and centrifugation processing methods, fat obtained via the Revolve system was visibly whiter and more compact. Quantitative assessment of fat tissue components demonstrated statistically significant different amounts among the 3 methods (Figure 4). Fat from the Revolve system contained little free oils (0 ± 1%), while fat from the decantation and centrifugation methods had statistically higher (P < .05) amounts of free oils (8% ± 5% and 20% ± 4%, respectively). Furthermore, fat from the Revolve system had statistically higher (P < .05) adipose tissue content (79% ± 7% vs 59% ± 8% for decantation and 72% ± 4% for centrifugation). In contrast, fat from centrifugation had statistically lower (P < .05) aqueous content (8% ± 3% vs 33 ± 7% for decantation and 21 ± 7% for the Revolve system).

**Aqueous Phase Characterization**

The aqueous phase from the preimplant fat samples was collected and measured for markers of physiological quality—specifically, pH, osmolality, and hematocrit. Fat obtained from the Revolve system had a statistically lower (P < .05) pH compared with fat from decantation and centrifugation. Fat pH from the Revolve system was 6.9, while that from the other 2 processing methods was 7.3. It should be noted that the Lactate Ringer’s wash solution has a pH of 6.8. Fat obtained from the Revolve system had a statistically lower (P < .05) hematocrit compared with decantation and centrifugation. The hematocrit of fat from the Revolve system was 0.02% ± 0.01%, while that from the decantation and centrifugation methods was 0.47% ± 0.38% and 0.42% ± 0.31, respectively. The 3 methods showed no difference in fat osmolality. Osmalalities of 242 ± 31, 249 ± 23, and 259 ± 18 mmol/kg for the Revolve, centrifugation, and decantation methods, respectively, are all considered iso-osmotic and represent physiologic

![Figure 3](https://example.com/figure3.png)

**Figure 3.** Representative samples of fat tissue processed by each of the 3 methods: (A) Revolve method, (B) centrifugation method, and (C) decantation method. After processing, the grafts were placed into 3-mL syringes for implantation into nude mice.

![Figure 4](https://example.com/figure4.png)

**Figure 4.** Composition of processed fat tissue. The lipoaspirated fat tissue was processed by all 3 methods; afterward, as described in the Methods section, the percent volume fraction of major fat components was measured (red = aqueous phase; blue = adipose phase; yellow = oil phase; n = 9 for all groups). *P < .05.
In Vivo Assessment

Gross Observations

Two mice were euthanized early due to complications unrelated to the study. All other animals tolerated the procedure and remained healthy postimplantation up to euthanization at day 28. At the time of fat excision, fat boluses from both the Revolve system and centrifugation method were observed to be yellow and of normal appearance with visible surface vascularization; there was no gross evidence of encapsulation or adverse immunological response. Excised fat boluses from the decanted group displayed similar gross observations, but on bisection of the fat grafts, large oil cysts were observed as pooled free oil (Figure 5).

Fat Retention

Percent fat retention following the 28-day implantation was calculated from the pre- and postinjection fat weights. Percent fat retention with the Revolve system was not statistically different from centrifugation, at 73.2% ± 14.7% (n = 79) and 67.7% ± 16.9% (n = 80), respectively (Figure 6). In contrast, fat retention was statistically lower (P < .05) with the decantation method at 37.5% ± 13.3% (n = 77) compared with both other methods. The relative standard deviation of percent fat retention was similar between the Revolve system (20%) and the centrifugation method (25%) but higher with the decantation method (35%). Although relative standard deviation cannot be compared statistically across groups, the difference indicates that both the Revolve system and centrifugation method provide more reliable and reproducible fat graft retention compared with the decantation method.

Histological Assessment

Explanted fat graft histology was reviewed by 3 experts in fat physiology (M.C.M. and 2 external histopathologists associated with CRO [InCell]) and scored for attributes critical for fat tissue viability. Figure 7 displays representative images from the 3 processing systems. Overall, the 3 methods yielded histologically similar fat grafts; a comparison of histological scoring values from the 3 systems yielded no major difference in histological characteristics (data not shown). Histologically, fat grafts from all samples demonstrated areas of healthy vascularized fat tissue, along with some areas of mild fibrosis and inflammation.

DISCUSSION

Autologous fat grafting for soft tissue augmentation is a common procedure in plastic surgery. A major obstacle reducing this procedure’s clinical efficacy is loss of graft volume over time. Volume loss arises as a result of fat necrosis and resorption; causes include donor site variability, aspiration technique, fat-processing method, and injection techniques. Currently, the 2 most common fat-processing methods are decantation and centrifugation. The literature shows that in the clinic, these methods yield fat retention rates ranging from 20% to 90%. This study compares fat graft quality (pre- and postinjection) and volume retention in 3 fat processing methods—decantation, centrifugation, and the Revolve system—in an established preclinical model.

Our study demonstrated that the Revolve system yields clean adipose tissue with a higher preimplant fat content than the standard of care centrifugation method. Several features make the Revolve system unique from other fat-processing methods. First, the internal filter basket collects contaminants—such as tumescent fluid, blood, cell fragments, and free oil—and to retain viable adipocytes. Contaminants in grafts are believed to induce an inflammatory response, leading to diminished fat retention. Keeping adipocytes in a physiologic state and away from contaminants is thought to contribute to the fat graft’s health. The Revolve system maintains physiologic conditions for adipocytes by immediately removing unwanted components (tumescent fluid, cell debris, blood, free oils) during liposuction. The significantly reduced hematocrit serves as a

Table 1. Biochemical Characterization of Processed Fat Tissue

<table>
<thead>
<tr>
<th>Processing Method</th>
<th>pH</th>
<th>Osmolality</th>
<th>Hematocrit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Revolve</td>
<td>6.9 ± 0.1a</td>
<td>242 ± 31</td>
<td>0.02 ± 0.01a</td>
</tr>
<tr>
<td>Centrifugation</td>
<td>7.3 ± 0.2</td>
<td>249 ± 23</td>
<td>0.42 ± 0.31</td>
</tr>
<tr>
<td>Decantation</td>
<td>7.3 ± 0.2</td>
<td>259 ± 18</td>
<td>0.47 ± 0.38</td>
</tr>
</tbody>
</table>

Fat tissue samples were obtained immediately postprocessing by the 3 methods. As described in the Methods section, samples were analyzed for retention of aqueous phase physiological properties, as well as presence of red cell debris (n = 10 for each arm).

*p < .05.
Figure 5. Representative samples of explanted fat grafts. Following 28 days of subcutaneous implantation in nude mice, fat grafts from the 3 processing methods were explanted and photographs were taken for gross assessment: (A, B) Revolve method, intact and bisected explant, respectively; (C, D) decantation method, intact and bisected explant, respectively; and (E, F) centrifugation method, intact and bisected explant, respectively.
The implanted fat was measured. Methods were explanted and the percentage retention of implantation in nude mice, fat grafts from the 3 processing methods showed similar results at 1 month postimplant in the nude mouse model. This indicates that retained fat tissue evaluated in this model at 28 days was relatively healthy. Note that in this model, fat grafts were injected in a single large bolus, whereas fat grafts are injected clinically in small droplets or strings. Blood supply to a single large bolus is limited and therefore stresses the fat graft’s health more than may be expected in clinical fat grafting. This additional stress is an intentional factor in the single-bolus, small-animal model used in this study. A benefit to this animal model is that the intentional stress on the graft allows inherent differences seen at 28 days would be similar to differences at early and late time points. We chose the 28-day end point in this study because any initial apoptosis or graft necrosis was resolved and only revascularized, healthy graft remained. Previous studies have demonstrated that retention differences were consistent at early and late time points. While 28 days is not representative of a long-term outcome, the large sample size and paired study design presented in the current study, in conjunction with previous results, lend confidence that differences seen at 28 days would be similar to differences at
Figure 7. Representative micrographs of explanted fat grafts. As described in the Methods section, after 28 days of subcutaneous implantation in nude mice, fat grafts from the 3 processing methods were explanted and processed for histology. Histology slides were reviewed to determine the quality of each fat graft: (A, B) Revolve method, display magnification 40× and 100×, respectively; (C, D) decantation method, display magnification 40× and 100×, respectively; (E, F) centrifugation method, display magnification 40× and 100×, respectively.
later time points. Future clinical studies should be conducted to determine volume retention from standard grafting techniques in humans. Moreover, in the clinical setting, where larger volumes of fat undergo processing, the ability to remove blood and oil from adipose tissue may more profoundly affect grafting outcomes.

**CONCLUSIONS**

Compared with the decantation and centrifugation methods of fat processing, the Revolve system produced preinjection fat grafts of higher quality; this was demonstrated by significantly higher percentages of adipose tissue and significantly less blood cell debris and free oil. The volume retention of fat grafts from the Revolve system in an animal model was similar to centrifugation and significantly greater than fat grafts from the decantation method. The Revolve system presents a fat-processing option that is less time-consuming, easier to use, and more efficient than standard centrifugation or decantation methods.

**Acknowledgment**

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**Disclosures**

Dr Ansorge, Dr Leamy, Ms Roesch, Mr Aaron Barere, and Dr Connor are employees of LifeCell Corporation, the manufacturer of the products discussed in this study. Mr McCormack is a paid consultant to LifeCell Corporation and received compensation for preclinical method development activities and for providing expert analysis of histology related to the study. Dr Garza is a speaker and consultant for LifeCell, in addition to being a consultant for Allergan. Dr Garza holds no stocks in any company in the aesthetic industry.

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