MEDWIN PUBLISHERS
Committed to Create Value for Researchers

International Journal of Transplantation & Plastic Surgery
ISSN: 2639-2127

Evaluating *In-Vitro* Viability of Fat Extracted in Liposuction: A Review of Proliferation Rate and Cell Yield

Valente DS[1]*, Steffen LP[1], Lazzaretti GS[1], Grando GF[2], Bins Ely MG[3], Zanella RK[3], Chem EM[4]

[1]Division of Surgical Clinics, Federal University of Medical Sciences of Porto Alegre, Brazil
[2]School of Medicine, Lutheran University of Brazil, Brazil
[3]School of Medicine, Pontifical University Catholic of Rio Grande do Sul, Brazil
[4]Division of Plastic Surgery, Santa Casa Hospital, Brazil

Research Article
Volume 8 Issue 1
Received Date: March 04, 2024
Published Date: April 19, 2024
DOI: 10.23880/ijtps-16000183

***Corresponding author:** Denis Souto Valente, Professor of Plastic Surgery, Surgical Clinics Division, Federal University of Medical Sciences of Porto Alegre, Rua Antonio Carlos Berta 475, 7th floor, Porto Alegre, Brazil, Zip: 91340-020, Tel: (55) 5130612484; Email: denis.valente@ufcspa.edu.br

Abstract

Liposuction is a commonly performed surgical technique used for body contouring, which entails the removal of excess adipose tissue. In recent times, there has been a growing interest in utilizing the harvested fat from liposuction procedures for various applications, such as regenerative medicine and tissue engineering. Assessing the in vitro viability of these fat cells can offer valuable insights into their functionality and potential for transplantation. The objective of this review article is to examine the in vitro viability of liposuction-derived fat by focusing on two crucial parameters: proliferation rate and cell yield. By conducting a comprehensive analysis of existing literature, we aim to shed light on the factors that influence fat cell viability and explore potential strategies to enhance their survival and functionality.

The evaluation of proliferation rate and cell yield serves as a fundamental approach to determine the viability of liposuction-derived fat cells in vitro. Proliferation rate refers to the ability of fat cells to divide and multiply, while cell yield indicates the total number of viable cells obtained from the liposuction procedure. These parameters are essential in assessing the potential of these cells for tissue regeneration and transplantation.

Several factors have been identified as influential in determining the in vitro viability of liposuction-derived fat cells. These factors include the donor characteristics, such as age, sex, and body mass index, as well as the technique used during the liposuction procedure. Furthermore, the processing and storage methods employed after fat extraction can also have a significant impact on cell viability.

In conclusion, understanding the in vitro viability of liposuction-derived fat cells is crucial for their successful utilization in regenerative medicine and tissue engineering.

Keywords: Liposuction; Transplantation; Regenerative; Adipose Tissue; *In Vitro Viability*

Introduction

Liposuction is a widely performed surgical procedure that involves the removal of excess adipose tissue from various areas of the body, such as the abdomen, thighs, and buttocks. The procedure aims to improve body contouring and achieve a more aesthetically pleasing appearance [1]. Traditionally, the primary goal of liposuction has been the

removal of fat cells. However, in recent years, there has been a growing interest in utilizing the fat obtained from liposuction procedures for purposes beyond simple fat reduction [2].

Liposuction-derived fat has emerged as a valuable resource for regenerative medicine and tissue engineering applications. Adipose tissue is rich in adipocytes as well as stromal vascular fraction cells, including mesenchymal stem cells and endothelial cells [3]. These cells possess unique regenerative and reparative properties, making them attractive for various therapeutic interventions [4,5].

Assessing the in vitro viability of liposuction-derived fat cells is crucial for determining their potential utility in these applications. In vitro viability refers to the ability of fat cells to survive and maintain their functionality outside the body in laboratory conditions. It involves evaluating parameters such as cell proliferation, cell yield, metabolic activity, and preservation of specific cell characteristics [6].

Understanding the viability of fat cells is essential because it directly influences their regenerative and therapeutic potential. It helps determine whether the extracted fat cells can survive and proliferate in a controlled laboratory environment, which is a prerequisite for their successful clinical translation [7]. Moreover, assessing the in vitro viability of liposuction-derived fat cells allows researchers to optimize culture conditions, develop strategies to enhance cell survival and function, and identify potential challenges and limitations associated with their use [8].

The objective of this review article is to evaluate the in vitro viability of fat extracted in liposuction by focusing on two key parameters: proliferation rate and cell yield. We will comprehensively analyze the existing literature, including studies conducted on both human and animal models. By synthesizing the available evidence, we aim to provide insights into the factors influencing fat cell viability and potential strategies to enhance their survival and functionality. This review will serve as a valuable resource for researchers, clinicians, and scientists in the field of regenerative medicine and tissue engineering, aiding in the development of effective approaches for the utilization of liposuction-derived fat cells in various applications.

Liposuction Techniques and Fat Processing

Overview of Liposuction Techniques

Liposuction techniques have evolved over the years, offering a range of options for fat extraction. Some commonly used techniques include suction-assisted liposuction (SAL), ultrasound-assisted liposuction (UAL), laser-assisted liposuction (LAL), and power-assisted liposuction (PAL). Each technique employs different mechanisms to disrupt and remove fat cells but follows a similar basic principle of suction-assisted fat removal [9].

SAL involves the injection of a large volume of tumescent fluid, consisting of a local anesthetic and vasoconstrictor, into the subcutaneous fat layer. This technique facilitates fat removal while minimizing bleeding and discomfort. UAL utilizes ultrasonic energy to liquefy fat cells, making them easier to remove. LAL employs laser energy to disrupt fat cell membranes and facilitate their removal. PAL involves the use of mechanical devices that vibrate or oscillate to aid in fat cell disruption and extraction [10].

Processing of Fat After Extraction

After liposuction, the extracted fat undergoes processing to separate the fat cells from other components such as blood, oil, and connective tissue. The processing steps typically involve centrifugation, washing, and filtration. Centrifugation separates fat cells from other debris, while washing helps remove residual blood and anesthetic solutions. Filtration further refines the fat by removing small particles and debris [11].

The processing techniques can vary depending on the specific protocol followed by the surgeon or research team. Different processing methods may have varying effects on fat cell viability and functionality. For example, prolonged or aggressive centrifugation can potentially damage fat cells, affecting their viability. Similarly, the use of harsh washing solutions or excessive filtration can lead to cell loss or damage [8].

Impact of Liposuction Techniques and Processing on Cell Viability

The choice of liposuction technique and the processing steps employed can significantly influence the viability and functionality of the extracted fat cells. Studies have indicated that different liposuction techniques can affect fat cell integrity and viability to varying degrees. For instance, UAL and LAL techniques, which involve the application of energy sources, may result in higher levels of fat cell damage compared to traditional tumescent liposuction. The energy used in these techniques can generate heat, which may cause thermal injury to the fat cells [10].

Moreover, the processing steps, particularly centrifugation, can also impact fat cell viability. Excessive centrifugation forces or prolonged spinning times can lead to cell damage or cell death. On the other hand, inadequate centrifugation may result in impurities and debris remaining in the processed fat, affecting its quality and viability [12].

Therefore, it is important to optimize liposuction techniques and processing protocols to minimize cell damage and maximize fat cell viability. Proper selection of liposuction techniques, as well as optimization of processing parameters such as centrifugation speed, duration, and washing solutions, can contribute to preserving the viability and functionality of the extracted fat cells.

Overall, the choice of liposuction technique and the processing steps employed should be carefully considered to ensure minimal cell damage and optimal viability of the extracted fat cells. This can pave the way for successful in vitro culture and utilization of liposuction-derived fat in various applications within regenerative medicine and tissue engineering fields.

Proliferation Rate as an Indicator of Viability

Definition and Measurement of Proliferation Rate

The proliferation rate of fat cells refers to their ability to undergo cell division and replicate, resulting in an increased number of cells. It is an essential indicator of cell viability and functionality. The measurement of proliferation rate can be assessed through various techniques, such as cell counting, DNA synthesis assays (e.g., bromodeoxyuridine incorporation or EdU labeling), and evaluation of cell cycle progression using flow cytometry [13].

Factors Influencing the Proliferation Rate of Fat Cells

Several factors can influence the proliferation rate of fat cells, both in vitro and in vivo. These factors include:

Donor Characteristics: The age, sex, and body mass index (BMI) of the donor can impact the proliferation rate of fat cells. Studies have shown that younger donors tend to have higher proliferation rates compared to older donors. Additionally, sex-related differences and variations in BMI can also affect fat cell proliferation [14].

Harvesting and Processing Techniques: The liposuction technique employed and the subsequent processing steps can influence the proliferation rate of fat cells. As discussed earlier, liposuction techniques that generate excessive mechanical or thermal energy may negatively impact cell viability and proliferation [10].

Isolation and Culture Conditions: The conditions under which fat cells are isolated and cultured play a crucial role in their proliferation rate. Factors such as the choice of culture medium, presence of growth factors and cytokines, oxygen tension, pH, and temperature can significantly influence cell proliferation. The use of specific supplements, such as fetal bovine serum (FBS) or platelet-rich plasma (PRP), can also affect fat cell proliferation [15].

Role of Growth Factors, Cytokines, and Culture Conditions

Growth factors and cytokines are key regulators of fat cell proliferation. Various growth factors, such as insulin-like growth factor-1 (IGF-1), fibroblast growth factor-2 (FGF-2), and epidermal growth factor (EGF), promote fat cell proliferation. These growth factors can activate signaling pathways involved in cell cycle progression and stimulate the replication of fat cells [16].

In addition to growth factors, the composition of the culture medium and the presence of specific nutrients are critical for supporting fat cell proliferation. Essential nutrients, such as glucose, amino acids, and lipids, provide the necessary energy and building blocks for cell division. The concentration and availability of these nutrients in the culture medium can influence the proliferation rate of fat cells [17].

Furthermore, the oxygen tension (hypoxia vs. normoxia) and pH level in the culture environment can affect cell proliferation. Hypoxic conditions have been shown to enhance the proliferation of fat cells, mimicking the low-oxygen environment present in adipose tissue in vivo.

Techniques to Enhance Proliferation Rate

To enhance the proliferation rate of fat cells in vitro, several strategies can be employed:

Optimization of Culture Medium: The composition of the culture medium, including the concentration and combination of growth factors, can be optimized to support fat cell proliferation. The addition of specific supplements, such as insulin, IGF-1, FGF-2, and EGF, has been shown to enhance fat cell proliferation in culture [18].

Co-Culture Systems: Co-culture of fat cells with other cell types, such as endothelial cells or mesenchymal stem cells, can promote cell-cell interactions and provide paracrine signals that stimulate fat cell proliferation. These co-culture systems can mimic the cellular microenvironment and enhance the proliferation and maintenance of fat cells [19].

Three-Dimensional (3D) Culture Techniques: Culturing fat cells in a 3D environment, such as scaffolds or hydrogels, can provide structural support and promote cell-cell interactions, leading to enhanced proliferation. These 3D culture systems can better mimic the native adipose tissue architecture and create a favorable microenvironment for fat cell proliferation [20].

Preconditioning Strategies: Preconditioning fat cells before or during culture can enhance their proliferation

rate. Preconditioning techniques may include exposure to specific growth factors, mechanical stimulation, or hypoxic conditions. These strategies aim to prime the fat cells and improve their proliferation capacity [21].

Genetic and Epigenetic Modifications: Genetic engineering approaches, such as overexpression of specific genes or knocking down inhibitory genes, can be employed to enhance fat cell proliferation. Additionally, epigenetic modifications, such as DNA methylation or histone modifications, can influence fat cell proliferation by regulating gene expression [22].

By employing these strategies, researchers can enhance the proliferation rate of fat cells in vitro, improving their potential for various applications in regenerative medicine and tissue engineering. However, it is essential to carefully balance the promotion of proliferation with maintaining cell functionality and avoiding aberrant cell growth.

Cell Yield as an Indicator of Viability

Definition and Measurement of Cell Yield

Cell yield refers to the total number of viable cells obtained from a given amount of tissue or sample. In the context of liposuction-derived fat cells, cell yield represents the quantity of viable fat cells obtained after the extraction and processing procedures. The measurement of cell yield typically involves counting the number of viable cells using methods such as manual counting with a hemocytometer or automated cell counting using specialized instruments [3].

Factors Influencing the Cell Yield of Fat Cells

Multiple Factors Can Influence the Cell Yield of Fat Cells Obtained from Liposuction Procedures:

Donor characteristics: Donor-specific factors, such as age, sex, BMI, and overall health, can impact the cell yield of liposuction-derived fat. Younger donors generally have a higher cell yield compared to older individuals. Additionally, donors with a higher BMI may have a greater adipose tissue volume, leading to a higher cell yield. However, it is important to note that the quality and functionality of the cells may not necessarily correlate with the cell yield [23].

Tissue Processing Techniques: The techniques used during tissue processing can significantly affect the cell yield. Factors such as the liposuction method employed, processing time, temperature, and mechanical forces applied during fat cell isolation and purification can influence the final cell yield. Aggressive processing techniques that result in excessive mechanical or thermal stress can lead to cell damage and lower cell yield [24].

Liposuction Site: The site from which fat is harvested can impact the cell yield. Different areas of the body have varying adipose tissue characteristics, including cell density and composition. For example, abdominal adipose tissue tends to have a higher cellular content compared to adipose tissue from the limbs. Therefore, the choice of liposuction site can affect the overall cell yield [25].

Impact of Donor Characteristics and Tissue Processing

Donor characteristics, such as age and BMI, can influence the cell yield of liposuction-derived fat cells. Younger donors generally have a higher number of viable fat cells due to the greater regenerative capacity of their adipose tissue. Similarly, donors with a higher BMI may have a larger adipose tissue volume, resulting in a higher cell yield. However, it is important to consider that the quality and functionality of the cells may not necessarily correlate with the cell yield [26].

Tissue processing techniques, including liposuction method and processing parameters, can also affect the cell yield. Aggressive liposuction techniques that result in extensive mechanical or thermal energy can lead to cell damage and reduce the cell yield. On the other hand, gentle processing techniques that prioritize cell preservation and minimize stress can yield a higher number of viable fat cells [27].

Strategies to Improve Cell Yield

Several strategies can be employed to enhance the cell yield of liposuction-derived fat cells.

Optimization of Processing Techniques: Fine-tuning the liposuction technique and processing parameters can improve the cell yield. Employing gentle liposuction techniques and minimizing processing time can help preserve cell viability and increase the overall cell yield [28].

Enhanced Tissue Disaggregation: Effective tissue disaggregation techniques, such as enzymatic digestion or mechanical disruption, can release a higher number of viable fat cells from the harvested tissue. Optimizing the concentration and duration of enzymatic digestion or employing mechanical methods, such as gentle agitation or shaking, can improve cell yield [29].

Cell Purification Methods: Additional purification steps, such as density gradient centrifugation or filtration, can be incorporated into the processing protocol to further enrich the cell yield. These methods help separate viable fat cells from debris, residual blood, and other non-cellular components [30].

Cryopreservation: Cryopreservation is a technique that involves freezing cells for long-term storage. By cryopreserving excess fat cells obtained during the processing steps, it is possible to preserve a larger pool of

cells for future use. Cryopreservation can help increase the available cell yield and provide a valuable resource for subsequent experiments or clinical applications [31].

Donor Selection: Careful donor selection based on factors such as age, BMI, and overall health can contribute to a higher cell yield. Younger donors with higher BMIs often yield a greater number of viable fat cells. However, it is important to consider the specific requirements of the intended applications and balance the cell yield with the desired cell characteristics [26].

By implementing these strategies, researchers can improve the cell yield of liposuction-derived fat cells, enhancing their potential for various applications in regenerative medicine, tissue engineering, and other fields that require a sufficient number of viable cells.

Methods to Enhance Viability and Functionality

Optimization of Culture Medium and Supplements

Nutrient Composition: The culture medium can be optimized by adjusting the nutrient composition to support the specific needs of the cells. This includes providing an appropriate balance of glucose, amino acids, lipids, vitamins, and minerals to meet the metabolic requirements of the cells and promote their viability and functionality [24].

Growth Factors and Cytokines: Addition of specific growth factors and cytokines to the culture medium can enhance cell viability and functionality. Growth factors such as insulin, IGF, FGF, and EGF can support cell survival, proliferation, and differentiation. Cytokines such as tumor necrosis factor-alpha (TNF-alpha) and interleukins can modulate cellular responses and promote cell viability [32].

Extracellular Matrix Components (ECM): Incorporating ECM components, such as collagen, fibrin, or Matrigel, into the culture system can provide a supportive microenvironment for cells. ECM components can enhance cell adhesion, migration, and signaling, thereby improving cell viability and functionality [33].

Co-Culture Systems and 3D Culture Techniques

Co-Culture Systems: Co-culturing cells with other cell types, such as fibroblasts, endothelial cells, or immune cells, can create a supportive microenvironment and enhance cell viability and functionality. The cross-talk between different cell types can provide reciprocal signaling and promote cellular interactions that are beneficial for cell survival and function [34].

3D Culture Techniques: Culturing cells in a 3D environment, such as hydrogels, scaffolds, or spheroids, can better mimic the in vivo conditions and enhance cell viability and functionality. 3D culture systems provide a more physiologically relevant architecture, nutrient diffusion, and cell-cell interactions, which can promote cell viability, differentiation, and tissue-specific functionality [35].

Preconditioning Strategies

Preconditioning strategies involve subjecting cells to specific stimuli or treatments before or during culture to enhance their viability and functionality. These strategies aim to activate cellular protective mechanisms and improve the cells' ability to withstand stress. Examples of preconditioning strategies include: [36]

Hypoxia Preconditioning: Exposing cells to low oxygen levels (hypoxia) for a short period can stimulate cellular responses, such as up-regulation of pro-survival factors and antioxidant enzymes, which enhance cell viability and resistance to subsequent stress [37].

Heat Shock Preconditioning: Brief exposure of cells to mild heat shock can induce the expression of heat shock proteins, which act as molecular chaperones and protect cells from subsequent stressors, thereby improving cell viability [33].

Chemical Preconditioning: Treatment with specific chemicals or pharmacological agents, such as antioxidants, growth factors, or small molecules, can activate cellular protective pathways and improve cell viability and functionality [38].

Genetic and Epigenetic Modifications

Genetic Modifications: Genetic engineering techniques, such as gene overexpression or knockdown, can be employed to enhance cell viability and functionality. For example, overexpression of anti-apoptotic genes or genes involved in cell survival pathways can promote cell viability and resistance to stress. Additionally, genetic modifications can be used to enhance specific cellular functions or improve tissue-specific functionality [39].

Epigenetic Modifications: Epigenetic modifications, such as DNA methylation or histone modifications, can regulate gene expression and affect cell viability and functionality. Modulating epigenetic marks through pharmacological or genetic approaches can enhance cell viability and functionality by altering gene expression patterns [40].

By employing these methods, researchers can enhance the viability and functionality of cells in various applications, including regenerative medicine, tissue engineering, and in vitro models. Optimizing culture conditions, utilizing co-culture systems and 3D culture techniques, implementing preconditioning strategies, and employing genetic and epigenetic modifications can collectively contribute to

improving the overall performance of cells for desired applications.

Challenges and Future Directions

One of the major challenges in the field is the lack of standardized protocols and assessment methods for evaluating cell viability and functionality. There is a need for consensus on best practices regarding cell isolation, culture conditions, and characterization techniques. Standardization would enable better comparison of results across different studies and facilitate the reproducibility of findings. Efforts are being made to develop guidelines and standardized protocols for various cell types to address this challenge [37].

Maintaining long-term viability and functionality of cells is crucial, particularly for applications that require extended culture periods or long-term storage. Cells can undergo changes in phenotype and function over time, and maintaining their viability and functionality over extended periods remains a challenge. Researchers are exploring strategies such as optimizing culture conditions, incorporating supportive matrices or scaffolds, and employing advanced preservation techniques like cryopreservation to enhance long-term viability and functionality [41].

While significant progress has been made in enhancing cell viability and functionality in research settings, the translation of these findings to clinical applications poses several challenges. The transition from laboratory-scale to large-scale production of viable and functional cells is complex and requires addressing issues such as scalability, cost-effectiveness, and regulatory requirements. Additionally, ensuring the safety, efficacy, and reproducibility of cell-based therapies or tissue-engineered constructs in clinical settings is a critical consideration [42].

To overcome these challenges and advance the field, several future directions can be explored:

Development of Standardized Protocols

Continued efforts should be made to establish standardized protocols for cell isolation, culture conditions, and assessment methods. Collaborative initiatives and consensus-building among researchers, clinicians, and regulatory agencies can help establish guidelines that promote reproducibility and facilitate translation [23].

Advances in Preservation Techniques

Further research is needed to improve long-term preservation methods for cells, such as cryopreservation and storage techniques. Developing novel cryoprotectants, optimizing freezing and thawing protocols, and exploring alternative preservation strategies, such as vitrification or lyophilization, can contribute to better long-term cell viability and functionality [43].

Understanding Cellular Mechanisms

Gaining a deeper understanding of the cellular mechanisms that influence viability and functionality is crucial for overcoming current limitations. Exploring the roles of cellular metabolism, stress response pathways, and epigenetic regulation can provide insights into strategies for enhancing cell viability and function [43].

Advanced Culture Systems

Developing advanced culture systems that better mimic the in vivo environment can enhance cell viability and functionality. This includes the use of bioreactors, microfluidic devices, and organ-on-a-chip technologies that provide more physiologically relevant conditions, including dynamic mechanical forces, gradients of nutrients, and oxygen tension [6].

Integration of Tissue Engineering Approaches

Combining cell-based approaches with tissue engineering strategies can enhance the viability and functionality of engineered tissues and organs. This involves incorporating cells into biomimetic scaffolds, optimizing the vascularization of engineered tissues, and promoting cellular organization to better recapitulate the native tissue architecture [44].

Regulatory Considerations

Addressing regulatory considerations early in the development process is crucial for successful translation. Collaboration with regulatory agencies, adherence to good manufacturing practices, and conducting rigorous preclinical and clinical studies are essential steps towards demonstrating safety, efficacy, and reproducibility of cell-based therapies or tissue-engineered constructs [16].

Overall, addressing the challenges related to standardization, long-term viability, and translation to clinical applications requires a multidisciplinary approach involving collaboration between scientists, clinicians, engineers, and regulatory bodies. By focusing on these challenges and future directions, researchers can make significant strides in enhancing cell viability and functionality, ultimately advancing the field of regenerative medicine and tissue engineering.

Conclusion

The viability and functionality of cells are critical factors in various fields, including regenerative medicine, tissue engineering, and in vitro models. This discussion has highlighted several methods to enhance these aspects, including optimizing culture medium and supplements, utilizing co-culture systems and 3D culture techniques, implementing preconditioning strategies, and employing genetic and epigenetic modifications. These approaches aim to create a supportive microenvironment, promote cell survival, and improve cellular functions.

However, several challenges need to be addressed for further advancements. Standardization of protocols and assessment methods is crucial for better comparability and reproducibility of research findings. Long-term viability and functionality remain a challenge, requiring advances in preservation techniques and a deeper understanding of cellular aging mechanisms. Additionally, translating research findings to clinical applications necessitates collaboration with regulatory agencies, adherence to GMP guidelines, and comprehensive preclinical and clinical studies to ensure safety, efficacy, and reproducibility.

Future research should focus on standardization efforts, exploring advanced culture systems, elucidating cellular mechanisms, and addressing the challenges associated with translation. By addressing these recommendations, researchers can contribute to the development of improved methods and strategies, ultimately advancing the field and benefiting patients in need of cell-based therapies and tissue-engineered constructs.

References

1. Valentine L, Alvarez AH, Weidman AA, Foppiani J, Hassell NE, et al. (2024) Liposuction Complications in the Outpatient Setting: A National Analysis of 246,119 Cases in Accredited Ambulatory Surgery Facilities. Aesthetic Surgery Journal Open Forum 6: 1-8.

2. Thamm OC, Eschborn J, Zimmermann L, Dekker C, Martin H, et al. (2023) Sublesional fat grafting leads to a temporary improvement of wound healing in chronic leg ulcers: A prospective, randomised clinical trial. Wound Repair Regen 31(5): 663-670.

3. Jovic D, Preradovic L, Kremenovic M, Jovic F, Antonic M, et al. (2023) Effect of Donor Site Selection for Fat Grafting on the Yield and Viability of the Stromal Vascular Fraction. Aesthetic Surgery Journal 43(9): NP704-NP712.

4. Pietramaggiori G, Ricci F, L'Erario S, Bassetto F, Scherer S (2024) Minimally invasive scar release by autologous adipose tissue transfer for post-traumatic neuropathic pain. Regenerative Therapy 25: 302-307.

5. Wang H, Liu Y, Li Y, Han F, Chen Q, et al. (2024) Autologous nanofat harvested from donor site of full-thickness skin or skin flap grafting for the treatment of early postburn scarring: a case series. Scars, Burns & Healing 10.

6. Li W, Yang Y, Lin Y, Mu D (2024) In Vitro Study of Thymosin Beta 4 Promoting Transplanted Fat Survival by Regulating Adipose-Derived Stem Cells. Aesthetic Plastic Surgery.

7. Felthaus O, Vedlin S, Eigenberger A, Klein SM, Prantl L (2024) Exosomes from Adipose-Tissue-Derived Stem Cells Induce Proapoptotic Gene Expression in Breast Tumor Cell Line. International Journal of Molecular Sciences 25(4): 1-12.

8. Gabriel A, Kabaria N, Fang CH, Lombardi JA, Stec E, et al. (2024) In Vitro Characterization of Fat Grafts Processed Using the REVOLVE ENVI System versus Decantation. Plastic and Reconstructive Surgery. Global Open, 12(2): e5615.

9. Beidas OE, Gusenoff JA (2021) Update on Liposuction: What All Plastic Surgeons Should Know. Plastic and Reconstructive Surgery 147(4): 658e-668e.

10. Urbonas T, Kievišas M, Petrikaitė V, Gibieža P, Baranauskas G, et al. (2023) Assessing Adipocyte Viability and Surgeons' Work Efficiency by Comparing Different Liposuction Methods. Plastic and Reconstructive Surgery. Global Open 11(8): e5190.

11. Chandrasekar S, Manas RK (2023) Closed-chamber Suction-assisted Fat Harvest: An Innovative Technique in Resource-limited Settings. Plastic and Reconstructive Surgery Global Open 11(7): e5136.

12. Guan J, He Y, Wang X, Yao Y, Li Y, et al. (2020) Identification of High-Quality Fat Based on Precision Centrifugation in Lipoaspirates Using Marker Floats. Plastic and Reconstructive Surgery 146(3): 541-550.

13. Yu Y, Zhang H, Sun Z, Wang S, Zhao X, et al. (2024) Exploring Preclinical Experiments with Different Fat Types for Autologous Fat Grafting. Aesth Plast Surg.

14. Mansour A, Steele A, Terrasse W, Butte Z, Kincaid H, et al. (2023) Incidence of Complications Associated With Lipectomy Techniques and Patient Body Mass Index: An Institutional and National Analysis Using the Tracking Operations and Outcomes for Plastic Surgeons. Annals of Plastic Surgery 90(5): S526-S532.

15. Tran VVT, Hong KY, Jin X, Chang H (2023) Histological

Comparison of Nanofat and Lipoconcentrate: Enhanced Effects of Lipoconcentrate on Adipogenesis and Angiogenesis. Aesth Plast Surg 48: 752-763.

16. Alharbi Z, Qari S, Bader M, Khamis S, Almarzouqi F, et al. (2023) The LipoDerm Method for Regeneration and Reconstruction in Plastic Surgery: A Technical Experimental Ex Vivo Note. Medical Sciences 11(1): 16.

17. Lai Z, Niu X, Chen X, Lu F, Zhang Y, et al. (2024) Composite Microparticles of Fat Graft and GFR Matrigel Improved Volume Retention by Promoting Cell Migration and Vessel Regeneration. Aesthetic Plastic Surgery.

18. Wang Y, Zhang H, Zhou M, Yi X, Duan P, et al. (2020) Autologous Fat Grafting Promotes Macrophage Infiltration to Increase Secretion of Growth Factors and Revascularization, Thereby Treating Diabetic Rat Skin Defect. Diabetes, Metabolic Syndrome and Obesity: Targets and Therapy 13: 4897-4908.

19. Huang H, Tang X, Li S, Huang D, Lu D, et al. (2022) Advanced platelet-rich fibrin promotes the paracrine function and proliferation of adipose-derived stem cells and contributes to micro-autologous fat transplantation by modulating and. Annals of Translational Medicine 10(2): 60.

20. He Y, Zhang Z, Li Z, Lin M, Ding S, et al. (2023) Three-dimensional spheroid formation of adipose-derived stem cells improves the survival of fat transplantation by enhance their therapeutic effect. Biotechnology Journal 18(10): e2300021.

21. Wu HC, Fan X, Hu CH, Chao YC, Liu CS, et al. (2020) Comparison of mitochondrial transplantation by using a stamp-type multineedle injector and platelet-rich plasma therapy for hair aging in naturally aging mice. Biomedicine & Pharmacotherapy 130: 110520.

22. Morselli PG, Sorbi G, Feliziani C, Muscari C (2020) Deferoxamine Protects Stromal/Stem Cells of "Lull pgm System"-Processed Lipoaspirates Against Damages Induced by Mitochondrial Respiration Inhibition. Aesthetic Plastic Surgery 44(1): 168-176.

23. Berkane Y, Oubari H, Van Dieren L, Charlès L, Lupon E, et al. (2024) Tissue engineering strategies for breast reconstruction: a literature review of current advances and future directions. Annals of Translational Medicine 12(1): 15.

24. Goncharov EN, Koval OA, Igorevich EI, Encarnacion MDJR, Nurmukhametov R, et al. (2024) Analyzing the Clinical Potential of Stromal Vascular Fraction: A Comprehensive Literature Review. Medicina 60(2): 1-19.

25. Jia X, Chai Y, Zhu J, Zhang X, Jiang C, et al. (2024) Enhancing Fat Graft Survival via Upregulating Autophagy of Adipocytes. Aesthetic Plastic Surgery.

26. Tay JQ, Tay JS (2022) Re: Correlation between tissue-harvesting method and donor-site with the yield of spheroids from adipose-derived stem cells. Journal of plastic, reconstructive & aesthetic surgery 75(10): 3877-3903.

27. Kuykendall L, Threet A, Le NK, Moffitt J, McLaughlin M, et al. (2023) Syringe Suction Yields Greater Adipocyte Viability for Fat Grafting: Fact or Fiction?. Annals of Plastic Surgery 90(6S): S430-S432.

28. Shapira E, Plonski L, Menashe S, Ofek A, Rosenthal A, et al. (2022) High-Quality Lipoaspirate Following 1470-nm Radial Emitting Laser-Assisted Liposuction. Annals of Plastic Surgery 89(6): e60-e68.

29. Otani N, Tomita K, Kobayashi Y, Kuroda K, Kobayashi H, et al. (2023) "Hydrogen-generating Si-based agent improves fat graft survival in rats". Plastic and Reconstructive Surgery.

30. Quintero Sierra LA, Biswas R, Conti A, Busato A, Ossanna R, et al. (2023) Highly Pluripotent Adipose-Derived Stem Cell-Enriched Nanofat: A Novel Translational System in Stem Cell Therapy. Cell Transplantation 32: 1-16.

31. Tiryaki T, Cohen SR, Turkay SC, Kocak P, Sterodimas A, et al. (2022) Hybrid Stromal Vascular Fraction (Hybrid-SVF): A New Paradigm in Mechanical Regenerative Cell Processing. Plastic and Reconstructive Surgery Global Open 10(12): e4702.

32. Zare F, Ghafouri-Fard S, Shamosi A, Pahlavan S, Mahboudi H, et al. (2023) Oleoylethanolamide protects mesenchymal stem/stromal cells (MSCs) from oxidative stress and reduces adipogenic related genes expression in adipose-derived MSCs undergoing adipocyte differentiation. Molecular Biology Reports 51(1): 33.

33. Pattani N, Sanghera J, Langridge BJ, Frommer ML, Abu-Hanna J, et al. (2024) Exploring the mechanisms behind autologous lipotransfer for radiation-induced fibrosis: A systematic review. PloS One 19(1): e0292013.

34. Jordao A, Cléret D, Dhayer M, Rest ML, Cao S, et al. (2023) Engineering 3D-Printed Bioresorbable Scaffold to Improve Non-Vascularized Fat Grafting: A Proof-of-Concept Study. Biomedicines 11(12):3337.

35. Quan Y, Li J, Cai J, Liao Y, Zhang Y, et al. (2024) Transplantation of beige adipose organoids fabricated using adipose acellular matrix hydrogel improves

metabolic dysfunction in high-fat diet-induced obesity and type 2 diabetes mice. Journal of Cellular Physiology 239: e31191.

36. Wang ZH, Peng JH, Liu YC, Zhu QH, Sun C, et al. (2024) CCNB1 may as a biomarker for the adipogenic differentiation of adipose-derived stem cells in the postoperative fat transplantation of breast cancer. Gland Surgery 13(1): 45-58.

37. Niu X, Zhang Y, Lai Z, Huang X, Guo L, et al. (2024) Lipolysis inhibition improves the survival of fat grafts through ameliorating lipotoxicity and inflammation. FASEB Journal 38(5): e23520.

38. Li Z, Lu J, Dong Z, Liang J, Li S, et al. (2024) Glutathione supplementation improves fat graft survival by inhibiting ferroptosis via the SLC7A11/GPX4 axis. Stem Cell Research & Therapy 15(1): 25.

39. Zhu Q, Cao Y, Yuan J, Hu Y (2024) Adipose-derived stem cell exosomes promote tumor characterization and immunosuppressive microenvironment in breast cancer. Cancer Immunology, Immunotherapy 73(2): 39.

40. Arpornmaeklong P, Boonyuen S, Apinyauppatham K, Pripatnanont P (2024) Effects of Oral Cavity Stem Cell Sources and Serum-Free Cell Culture on Hydrogel Encapsulation of Mesenchymal Stem Cells for Bone Regeneration: An In Vitro Investigation. Bioengineering 11(1): 59.

41. Depoortère C, Faglin P, Dekerle L, Marchetti P, Duquennoy-Martinot V, et al. (2022) Breast Reconstruction Using a Three-Dimensional Absorbable Mesh Scaffold and Autologous Fat Grafting: A Composite Strategy Based on Tissue-Engineering Principles. Plastic and Reconstructive Surgery 149(6): 1251e-1252e.

42. Kim DH, Kim DS, Ha HJ, Jung JW, Baek SW, et al. (2022) Fat Graft with Allograft Adipose Matrix and Magnesium Hydroxide-Incorporated PLGA Microspheres for Effective Soft Tissue Reconstruction. Tissue Engineering and Regenerative Medicine 19(3): 553-563.

43. Huynh TD, Nguyen HK, Inchingolo AM, Tran HLB, Dipalma G, et al. (2023) Soft tissue regeneration in animal models using grafts from adipose mesenchymal stem cells and peripheral blood fibrin gel. European Review for Medical and Pharmacological Sciences 27(8): 3670-3680.

44. Karanfil AS, Louis F, Matsusaki M (2023) Biofabrication of vascularized adipose tissues and their biomedical applications. Materials Horizons 10(5): 1539-1558.