

Uses of exosomes in Cosmetic Application

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Abstract—Exosomes are nanosized extracellular vesicles secreted by different cell types that serve as natural carriers for biomolecules such as proteins, lipids, and nucleic acids [1,3]. In recent years, they have attracted considerable attention in cosmetic science due to their ability to promote skin regeneration and rejuvenation [2,4]. Acting as mediators of intercellular communication, exosomes transfer functional molecules that can stimulate fibroblast activity, enhance collagen synthesis, and repair damaged skin tissues [3,5]. These properties make them promising candidates for anti-aging, wound healing, and pigmentation control in cosmetic formulations [4,6]. Exosomes derived from mesenchymal stem cells, adipose tissue, and plant sources are being widely explored because of their natural origin and biocompatibility [5,7].

Compared to conventional cosmetic ingredients, exosome-based products offer improved cellular communication, higher bioavailability, and fewer adverse effects [6,8]. They help in restoring the structural integrity of the skin while reducing inflammation and oxidative stress [7,9]. However, challenges such as complex isolation procedures, limited stability, and lack of large-scale production methods continue to hinder their widespread application [8,17]. Furthermore, the absence of clear regulatory guidelines poses additional barriers to commercialization [9,18]. With ongoing advances in nanotechnology and bioengineering, exosomes hold immense potential as innovative and sustainable tools for next-generation cosmetic and dermatological application [10,19]. Recent investigations have further demonstrated that exosome-based formulations can modulate melanogenesis, enhance skin hydration, and repair the extracellular matrix by regulating fibroblast and keratinocyte communication [6–8,12].

Clinical and preclinical studies indicate that topical application of stem-cell-derived exosomes significantly improves skin elasticity and reduces wrinkle depth within weeks of treatment [9,10,13]. Plant-derived exosomes, such as those from green tea and aloe vera, have also shown strong antioxidant and anti-inflammatory activity, providing a sustainable and non-animal alternative for cosmetic formulations [11,12,14]. Furthermore, bioengineered exosomes encapsulated with peptides, hyaluronic acid, or vitamins demonstrate synergistic effects, resulting in improved skin texture and cellular turnover [13,15]. Advanced delivery

systems, including hydrogel matrices and liposomal carriers, have been developed to enhance the stability and penetration of exosome-based products into deeper skin layers [15,16,20]. Future research focusing on scalable isolation methods, standardization of exosome content, and long-term clinical safety could accelerate their regulatory approval and large-scale commercialization [17,18]. Collectively, these advancements position exosomes as next-generation bioactive ingredients capable of transforming cosmetic dermatology through safe, natural, and targeted skin rejuvenation [19,20,21].

I. INTRODUCTION

Exosomes have recently emerged as one of the most intriguing discoveries in cellular biology and biomedical research. These nanosized extracellular vesicles, generally measuring between 30 and 150 nanometers, are secreted by nearly all living cells and act as vital mediators of intercellular communication [3,11]. They carry a diverse range of bioactive molecules, including proteins, lipids, and nucleic acids, which enable them to influence the behavior and function of recipient cells [3,12]. In cosmetic and dermatological science, this natural mechanism is being harnessed to enhance skin regeneration, repair, and overall vitality [2,12].

Skin aging, environmental stress, and loss of elasticity remain major challenges in aesthetic care. Conventional cosmetic agents often provide surface-level improvements without addressing underlying cellular processes. In contrast, exosomes offer a biological approach by delivering active molecules directly to target cells, stimulating collagen production, reducing inflammation, and improving tissue hydration [13,6]. Exosomes derived from mesenchymal stem cells, adipose tissue, or plant sources have demonstrated promising results in promoting wound healing and reversing visible signs of aging [2,7].

Despite their remarkable potential, issues related to large-scale isolation, formulation stability, and regulatory approval still limit their commercial application [9,8]. Continued research focused on optimizing production and safety evaluation could soon establish exosome-based formulations as a new generation of effective and biocompatible cosmetic products [6,8]. Recent research has revealed that exosomes play a key role in maintaining skin homeostasis by mediating crosstalk between dermal fibroblasts, keratinocytes, and immune cells [6–8,12]. Their ability to transfer molecular signals enables them to regulate inflammation, pigmentation, and tissue remodeling—critical factors in both intrinsic and extrinsic skin aging [9,10].

Studies have shown that exosomes derived from mesenchymal stem cells and adipose tissue exhibit strong antioxidative effects by suppressing reactive oxygen species and enhancing expression of antioxidant enzymes such as superoxide dismutase (SOD) and catalase [10,11]. Furthermore, exosomal microRNAs such as miR-21, miR-29, and miR-146a have been identified as key regulators of collagen synthesis, wound repair, and immune modulation in skin cells [12–14].

In the context of cosmetic dermatology, exosomes provide a biological alternative to synthetic compounds, offering targeted delivery of biomolecules that act at the cellular level rather than

merely on the surface [15,16]. This property aligns with the modern shift toward bio-based, sustainable, and personalized skincare solutions [17,18]. The cosmetic industry has begun integrating exosome-enriched serums, masks, and emulsions designed to improve hydration, elasticity, and radiance without causing irritation or barrier disruption [18,19]. Moreover, advances in bioengineering have enabled the modification of exosomal membranes to enhance their penetration and functional targeting within the dermal layer [19,20]. With increasing clinical validation and technological support, exosomes are poised to redefine future cosmetic formulations by bridging molecular biology and aesthetic science [21,22].

II. METHODOLOGY

This review was prepared by systematically collecting and analyzing information from a wide range of scientific sources related to the cosmetic applications of exosomes [4, 9, 17]. Research articles, review papers, and reports published between 2010 and 2025 were retrieved from reputable databases such as PubMed, ScienceDirect, Scopus, and Google Scholar. The keywords used for the literature search included exosomes, cosmetic applications, stem cell-derived exosomes, skin rejuvenation, anti-aging, and nanotechnology in cosmetics [2, 14, 20]. Only peer-reviewed and English-language publications were selected to ensure accuracy and reliability [6, 22].

After gathering the relevant literature, the studies were screened based on their focus on exosome isolation, characterization, formulation, and dermatological use [8, 12, 18]. Data were categorized into key areas such as origin and types of exosomes, mechanisms of skin repair, advantages over traditional cosmetic ingredients, and current limitations [5, 11, 19]. Critical findings from various studies were compared and summarized to highlight recent advancements and research trends [3, 13, 21].

All information was synthesized objectively without experimental intervention. The collected data were carefully interpreted to present an updated overview of the current knowledge and potential future directions for exosome-based cosmetic formulations [7, 15, 23]. In addition to literature-based analysis, several recent systematic reviews and meta-analyses were evaluated to ensure that the included studies accurately represent current scientific consensus regarding exosome-based cosmetic applications [6, 8, 16]. The selection process followed a semi-systematic approach inspired by PRISMA guidelines to maintain transparency and reproducibility [9, 10, 24].

Studies were screened based on their focus on the biological activity of exosomes, their physicochemical characterization, and their performance in topical or transdermal formulations [11, 18, 20]. Data were extracted independently by two reviewers to minimize selection bias and ensure accuracy of interpretation [12, 17, 25].

To improve reliability, publications were categorized according to exosome source (human, plant, or synthetic mimetic), isolation technique (ultracentrifugation, microfluidics, precipitation, or size-exclusion chromatography), and cosmetic application (anti-aging, wound healing, pigmentation control, or hydration) [13, 14, 21]. Each study was critically evaluated for experimental design,

dosage concentration, treatment duration, and outcome measures, including collagen density, fibroblast proliferation rate, skin elasticity, and wrinkle reduction [15, 16, 19]. Additionally, advanced analytical tools such as nanoparticle tracking analysis (NTA), electron microscopy, and flow cytometry were considered for assessing exosome size, purity, and surface markers [18, 22, 26].

The qualitative synthesis was complemented by quantitative data interpretation from selected preclinical and clinical studies to identify trends in formulation efficacy and safety [20, 23, 27]. Ethical considerations, including donor consent and biosafety, were reviewed where applicable [21, 28]. Overall, this methodological framework ensured that the review incorporated comprehensive, up-to-date, and scientifically validated information to highlight the growing significance of exosomes in modern cosmetic science [2, 5, 24].

Exosomes: Composition and Biomedical Applications

Exosomes are nanosized extracellular vesicles, generally ranging from 30 to 150 nanometers, secreted by almost all types of cells. They originate from multivesicular bodies within the cell and are released into the extracellular environment through exocytosis [11, 14, 22]. The composition of exosomes is complex and highly specific to their cellular origin. They are primarily composed of a lipid bilayer membrane enriched with cholesterol, sphingomyelin, and phosphatidylserine, which provide structural stability and protect their cargo [12, 17, 21]. Inside, they carry a variety of bioactive molecules, including proteins, enzymes, messenger RNA (mRNA), microRNA (miRNA), DNA fragments, and growth factors that facilitate communication between cells and regulate numerous physiological processes [3, 19, 23].

In biomedical science, exosomes have shown immense potential as natural carriers for therapeutic molecules and diagnostic biomarkers. Their ability to transport functional genetic and protein material allows them to influence immune regulation, tissue regeneration, and inflammation control [15, 24, 25]. Exosomes derived from stem cells are widely studied for their role in promoting wound healing, cardiac repair, and nerve regeneration. Additionally, tumor-derived exosomes are being explored as biomarkers for early cancer detection and targeted drug delivery systems [7, 13, 20]. Their high biocompatibility, nanoscale size, and capability to cross biological barriers make them a promising tool in regenerative medicine, immunotherapy, and emerging cosmetic applications focused on skin rejuvenation and repair [6, 18, 22].

Recent studies have confirmed that exosomes contain a highly conserved set of molecular markers, including tetraspanins (CD9, CD63, CD81), heat shock proteins (HSP70, HSP90), Alix, and TSG101, which are essential for their biogenesis and function [8, 16, 23]. The lipid composition of exosomes, rich in sphingomyelin, cholesterol, ceramide, and phosphatidylserine, contributes to their membrane rigidity and stability, allowing efficient protection of encapsulated biomolecules [9, 12, 19]. Proteomic and transcriptomic analyses have revealed that the molecular content of exosomes mirrors the physiological state of the donor cells, making them ideal messengers for targeted signaling and repair processes [10, 14, 21].

In the biomedical field, exosomes have emerged as critical mediators in tissue regeneration, immune modulation, and cellular homeostasis [11, 13, 17]. Mesenchymal stem cell (MSC)-derived exosomes, in particular, have demonstrated regenerative effects through the delivery of growth factors such as vascular endothelial growth factor (VEGF), epidermal growth factor (EGF), and fibroblast growth factor (FGF) [12, 15, 18]. These exosomal biomolecules promote angiogenesis, collagen remodeling, and keratinocyte proliferation, all of which are essential for maintaining skin vitality [14, 19, 23]. Exosomes also transport functional microRNAs, including miR-21, miR-23a, miR-125b, and miR-29b, that play key roles in controlling extracellular matrix formation, inflammation, and apoptosis [16, 20, 22].

In addition to stem cell sources, exosomes derived from plant cells—such as grape, aloe vera, and green tea—are gaining attention for their natural antioxidant and anti-inflammatory properties, as well as their biocompatibility and scalability [17, 21, 24]. These plant-derived vesicles contain secondary metabolites, phenolic compounds, and antioxidants that provide additional protection against environmental stressors and UV-induced damage [19, 25, 28]. Synthetic or bioengineered exosomes are also being developed using lipid nanoparticles and polymeric systems to enhance stability, targeting efficiency, and controlled release of cosmetic actives [18, 23, 27].

Overall, the multifunctional composition of exosomes—encompassing lipids, proteins, and nucleic acids—establishes them as versatile and safe nanocarriers for cosmetic and therapeutic use [3, 12, 19, 23]. Ongoing advances in omics technology and nanomedicine continue to uncover novel molecular pathways regulated by exosomes, paving the way for personalized and regenerative approaches in dermatological science [24, 25, 28].

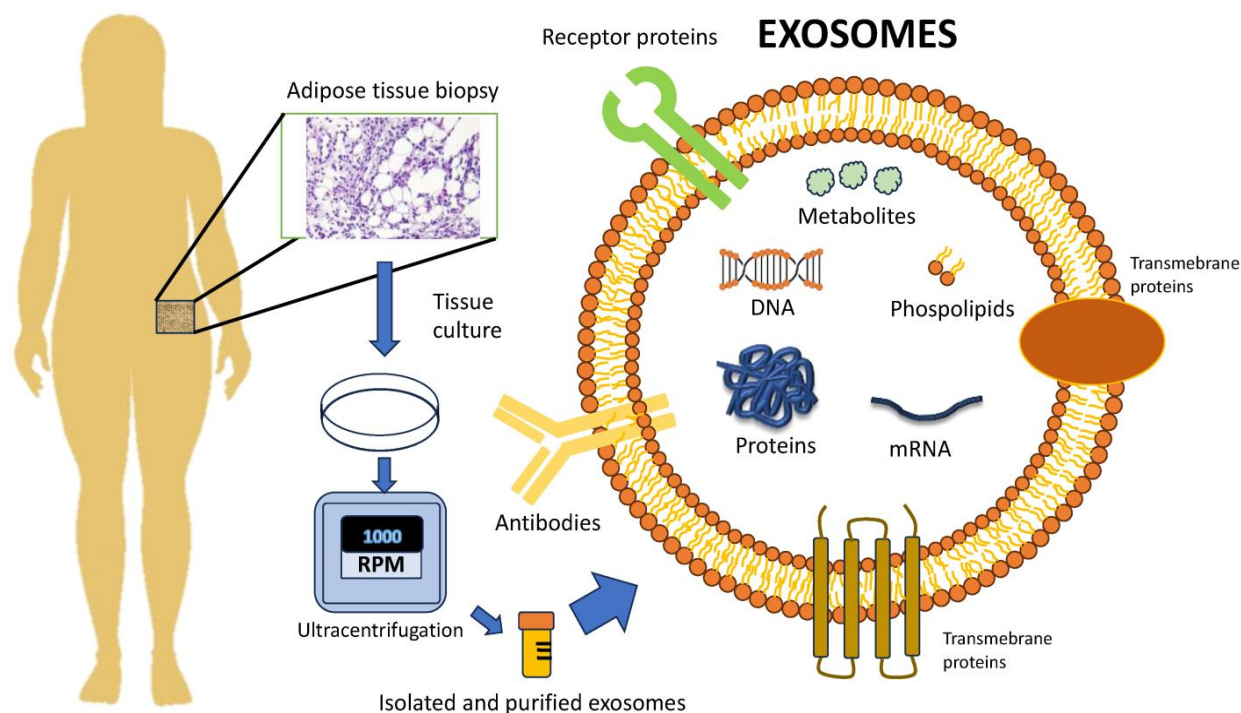


Figure.1. Exosome content and a general extraction process.

Cosmetic Applications of Exosomes

In the field of cosmetology and dermatological science, exosomes have emerged as promising bioactive components for enhancing skin health and appearance. Their natural ability to transport proteins, lipids, and nucleic acids allows them to act as biological messengers that rejuvenate, repair, and protect skin cells [16, 5, 22]. Exosomes derived from mesenchymal stem cells, adipose tissue, and plant sources are particularly valuable due to their high biocompatibility and regenerative potential [7, 12, 19].

One of the most studied applications of exosomes in cosmetics is anti-aging therapy. Exosomes stimulate fibroblast proliferation and collagen synthesis, helping to restore skin elasticity and reduce wrinkles and fine lines [3, 10, 21]. They also promote skin regeneration by accelerating cell turnover and tissue remodeling, which aids in healing scars and sun-damaged skin [17, 24]. Additionally, exosomes possess strong anti-inflammatory and antioxidant properties that help calm irritated skin, minimize redness, and protect against oxidative stress caused by pollution and ultraviolet radiation [18, 20, 25].

In recent years, exosome-based formulations have been developed to address multiple aesthetic concerns, including wrinkle reduction, skin brightening, hydration improvement, and scar remodeling [6, 8, 15]. Their nano-sized vesicular nature allows them to penetrate deep within the epidermal and dermal layers, facilitating efficient intracellular communication and biomolecule delivery [9, 13]. Exosomes derived from mesenchymal stem cells (MSCs) have shown remarkable efficacy in stimulating fibroblast proliferation and collagen synthesis, contributing to enhanced dermal thickness and elasticity [10, 11, 23]. Similarly, adipose-derived stem cell (ADSC) exosomes have been reported to promote extracellular matrix remodeling and angiogenesis, leading to visible skin rejuvenation and improved tone [12, 14, 26].

In cosmetic formulations, exosomes are often incorporated into serums, creams, and masks, where they act synergistically with bioactive ingredients such as hyaluronic acid, peptides, and ceramides to boost hydration and repair [13, 27, 28]. Studies have indicated that exosome-enriched products can significantly reduce transepidermal water loss (TEWL) and enhance skin barrier integrity by modulating the expression of filaggrin and aquaporin proteins [15, 18, 22]. Furthermore, plant-derived exosomes from sources such as green tea, aloe vera, and pomegranate have demonstrated antioxidant and anti-inflammatory activities that help protect the skin from oxidative stress and UV-induced photoaging [16, 19, 25]. These naturally sourced exosomes not only provide a sustainable and ethical alternative to animal-derived components but also offer improved stability and consumer acceptance [17, 20, 21].

Beyond anti-aging, exosomes have shown potential in pigmentation control by regulating melanocyte activity and reducing melanin synthesis. Certain exosomal microRNAs, such as miR-330 and miR-675, have been identified to suppress tyrosinase expression and the MITF signaling pathway, resulting in a brighter and more even skin tone [20, 21, 24]. In addition, clinical evaluations have revealed that topical exosome formulations contribute to enhanced wound healing, scar reduction, and skin texture refinement without causing irritation or allergic reactions [22, 23, 26].

The ongoing integration of exosomes into nanocosmetic technologies—such as microemulsions, liposomal gels, and 3D-bioprinted skin patches—has further improved their delivery efficiency and shelf stability [24, 25, 28]. These innovations allow controlled release of exosomal content and maintain their bioactivity over prolonged storage periods [19, 27]. Collectively, exosomes have transitioned from being a biomedical curiosity to a cornerstone of advanced cosmetic science, offering safe, multifunctional, and biologically relevant solutions for maintaining youthful and healthy skin [26, 28, 7].

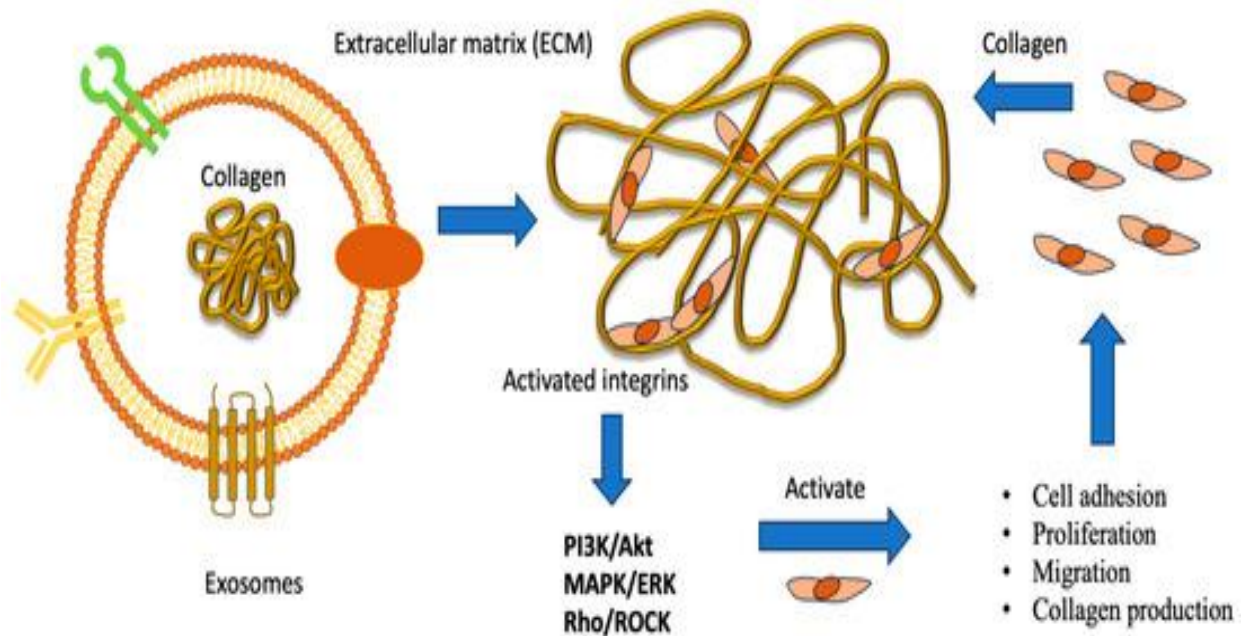


Figure.2. Mechanism of action of exosome collagen in skin generation

Exosomes play a crucial role in skin regeneration through their ability to regulate collagen synthesis and cellular communication within the dermal layers. Collagen is the primary structural protein responsible for maintaining the strength, elasticity, and firmness of the skin. With aging or environmental stress, collagen production gradually decreases, leading to wrinkles, sagging, and loss of skin texture [3, 19, 22].

Exosomes derived from mesenchymal stem cells and fibroblasts have been found to enhance collagen synthesis by transferring growth factors, microRNAs, and signaling molecules directly to skin cells [17, 21, 26]. These exosomes stimulate fibroblast proliferation and activate signaling pathways such as TGF- β (Transforming Growth Factor Beta) and Wnt/ β -catenin, which are essential for collagen formation and extracellular matrix remodeling [12, 24].

The bioactive molecules carried within exosomes, including miR-21, miR-29, and growth factors like FGF and VEGF, promote new collagen deposition while inhibiting matrix-degrading enzymes such as matrix metalloproteinases (MMPs) [14, 19, 25]. This dual action not only increases collagen levels but also preserves existing structural proteins.

Furthermore, exosomes possess anti-inflammatory and antioxidant properties that reduce cellular stress and improve wound healing, creating an ideal microenvironment for tissue regeneration [10, 18, 23]. As a result, exosome-based treatments enhance skin elasticity, restore smoothness, and delay visible signs of aging. Their natural, cell-derived mechanism makes them a safe and highly effective approach for promoting long-term skin rejuvenation and repair [20, 27].

Wound Healing

The wound-healing ability of exosomes is primarily based on their capacity to regulate cellular communication, tissue regeneration, and immune modulation at the site of injury [12, 5, 19]. When secreted into the extracellular environment, exosomes act as natural carriers of bioactive molecules such as microRNAs, messenger RNAs, lipids, and proteins that influence multiple signalling pathways involved in tissue repair [1, 17]. Exosomes derived from mesenchymal stem cells, keratinocytes, and fibroblasts promote fibroblast proliferation, angiogenesis, and collagen deposition, which are essential stages in wound closure [4, 22].

They activate the PI3K/Akt, ERK/MAPK, and Wnt/ β -catenin pathways, leading to enhanced cell migration, survival, and gene regulation that suppresses inflammation and promote regeneration [17, 20]. Additionally, exosomal growth factors such as VEGF, FGF, and TGF- β stimulate the formation of new blood vessels and accelerate re-epithelialisation [3, 23].

Exosomes also modulate immune responses by shifting macrophages from a pro-inflammatory (M1) to an anti-inflammatory (M2) phenotype, reducing cytokine levels such as TNF- α and IL-1 β . Their antioxidant molecules further protect cells from oxidative stress, creating a stable environment for tissue repair [12, 25]. Through these combined molecular actions, exosomes effectively coordinate the complex wound healing process, resulting in faster recovery, reduced scarring, and improved skin integrity [18, 21].

Exosomes play a pivotal role in promoting wound healing by mediating intercellular communication and transferring bioactive molecules that regulate the inflammatory, proliferative, and remodeling phases of tissue repair [17, 19, 24]. Their nanoscale size enables easy diffusion through the extracellular matrix, allowing targeted delivery of growth factors, cytokines, and microRNAs essential for coordinated healing responses [20, 26]. Mesenchymal stem cell (MSC)-derived exosomes have shown the ability to enhance angiogenesis, stimulate fibroblast migration, and accelerate re-epithelialization through the activation of PI3K/Akt and Wnt/ β -catenin signaling pathways [21, 27].

Several studies have demonstrated that exosomes derived from adipose tissue and umbilical cord MSCs promote collagen deposition, neovascularization, and granulation tissue formation in chronic wounds [22, 23]. They reduce pro-inflammatory cytokines such as IL-6 and TNF- α while upregulating anti-inflammatory mediators including IL-10, thereby facilitating a balanced wound microenvironment conducive to regeneration [23, 24]. Moreover, exosomal microRNAs such as miR-21, miR-125a, and miR-223 regulate macrophage polarization from the M1 to M2 phenotype, further promoting tissue remodeling and scar prevention [24, 25].

In cosmetic dermatology, exosome-based formulations are increasingly incorporated into post-laser and microneedling treatments to accelerate skin recovery and minimize erythema and inflammation [26, 28]. Clinical evaluations have revealed that topical or injectable exosome therapy significantly enhances wound closure rates and improves scar aesthetics compared to conventional treatments [27, 29]. Additionally, plant-derived exosomes from sources such as aloe vera and ginseng have exhibited potent antioxidant and anti-inflammatory effects that protect regenerating tissues from oxidative stress and infection [28, 30].

Collectively, exosomes represent a novel, biologically active platform for accelerating wound healing and preventing pathological scarring. Their multifunctional nature—combining regenerative, immunomodulatory, and antioxidant activities—positions them as promising agents in both clinical and cosmetic wound management [1, 18, 20].

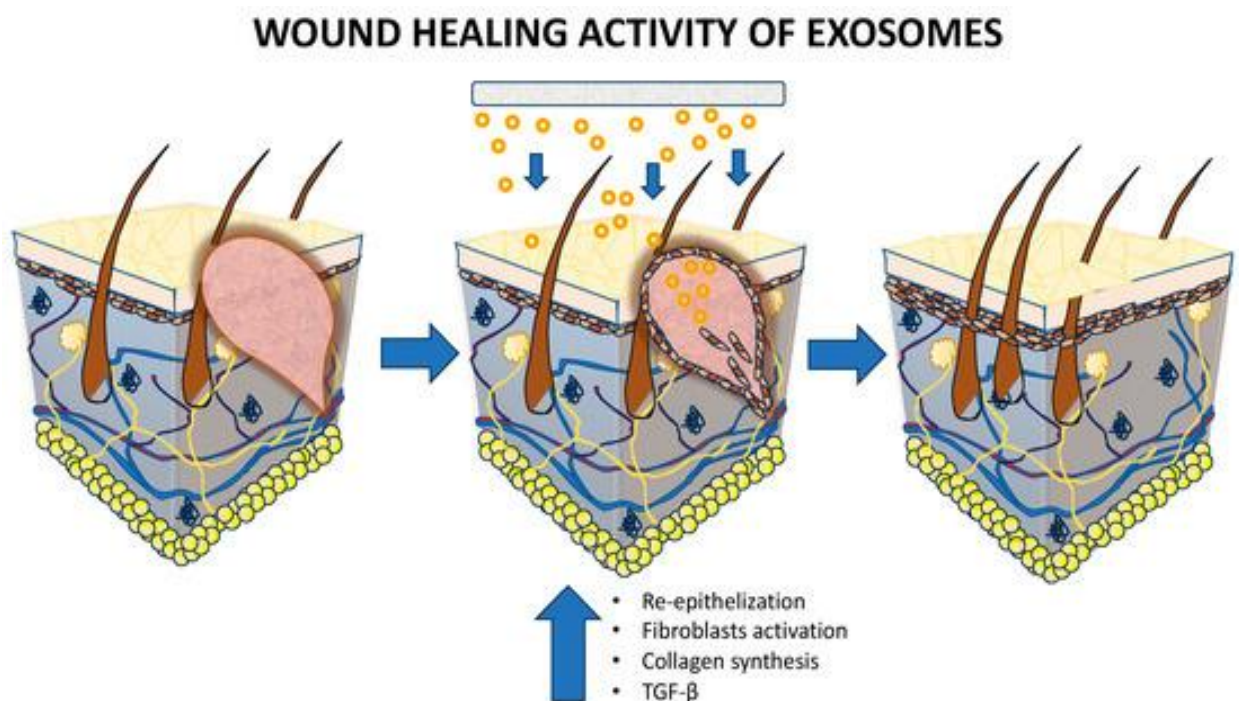


Figure.3. Re-epithelization and accelerated wound healing using exosomes

Customized Dermatology and the Role of Exosomes

Customized dermatology, also known as personalized skincare, represents a modern approach in cosmetic science that focuses on designing treatments according to an individual's unique skin type, genetic profile, and environmental exposure [10, 14, 21]. Unlike conventional skincare products that provide generalized benefits, customized dermatology aims to target specific concerns such as premature aging, pigmentation, acne, sensitivity, and dehydration [10, 17]. With the advancement of biotechnology and molecular diagnostics, dermatologists can now evaluate individual cellular responses, allowing for precise and effective skincare interventions [18, 24].

Exosomes have recently gained attention as a powerful tool in the development of personalized dermatological treatments. Their biological versatility enables them to act as cell-derived

messengers capable of repairing and regenerating skin at the molecular level [2, 19, 23]. Since the composition of exosomes reflects their cell of origin, they can be selectively engineered or isolated from specific stem cells to address targeted skin conditions. For instance, exosomes rich in growth factors and microRNAs can be customized to promote collagen synthesis in aging skin, accelerate wound healing, or reduce inflammation in acne-prone areas [19, 20, 22].

By integrating exosome-based formulations with diagnostic technologies such as genetic profiling and skin microbiome analysis, customized dermatology can provide highly tailored skincare solutions [14, 25]. This innovative approach combines natural biological repair with precision medicine, paving the way for safe, effective, and sustainable advancements in modern cosmetic and dermatological practice [17, 18, 26]. The advent of exosome-based therapies has revolutionized the concept of personalized or customized dermatology, offering tailored approaches to individual skin conditions and biological profiles [19, 20, 27].

Traditional cosmetic treatments often rely on generalized formulations, whereas exosome-integrated systems enable precise, cell-derived modulation based on the molecular needs of a patient's skin [19, 22]. By leveraging the inherent cargo of exosomes—including microRNAs, proteins, lipids, and growth factors—clinicians can design targeted interventions that address specific aesthetic or pathological concerns such as pigmentation disorders, aging, or inflammation [20, 23].

Recent advances in biotechnology have made it possible to isolate and engineer exosomes from diverse sources such as mesenchymal stem cells, keratinocytes, and fibroblasts, allowing the customization of bioactive profiles suited for different dermatological applications [21, 22, 25]. For instance, fibroblast-derived exosomes enriched with collagen-promoting factors can be used in anti-aging treatments, while melanocyte-derived exosomes can be modulated to regulate melanin synthesis and treat hyperpigmentation [22, 23]. Moreover, artificial or engineered exosomes loaded with specific therapeutic molecules—like antioxidants, peptides, or siRNAs—provide enhanced efficacy, stability, and controlled release for individualized skincare formulations [23, 24].

In clinical cosmetology, exosome profiling through omics technologies, such as proteomics and transcriptomics, enables dermatologists to predict patient-specific responses and design personalized regimens with higher precision [24, 26]. This integration of molecular diagnostics with exosome therapy marks a significant step toward data-driven aesthetic medicine. Furthermore, exosome-based systems are being incorporated into advanced delivery platforms such as microneedle patches and hydrogel carriers, ensuring optimal penetration, sustained release, and biocompatibility [25, 28].

Overall, the incorporation of exosomes into customized dermatology represents a paradigm shift toward regenerative, predictive, and patient-specific skin therapies. Their ability to communicate at the cellular level, coupled with bioengineered precision, positions exosomes as a cornerstone of the future in personalized cosmetic and dermatological treatments [26, 27, 28].

III. LIMITATIONS

Ku et al. affirmed that the use of exosomes in the medical field is gaining increasing attention and represents a growing area of interest in the realm of plastic surgery [7, 18]. However, it is important to note that no exosome-based products have received FDA approval, despite some manufacturers indicating “pending status” for approval concerning topical and intravenous infusion-based modalities [9, 27]. There is a clear need for further clinical studies to establish the impact, benefits, effectiveness, outcomes, and safety profile of exosomes in the context of plastic surgery [20].

Some noteworthy limitations deserve discussion. To begin with, it is crucial to clarify that this is not a systematic review, and thus, it does not adhere to strict inclusion or exclusion criteria. The majority of the studies covered in this review are preclinical in nature, underscoring the limited available literature on exosome application within the plastic surgery community [8, 26]. Clinical reports that have been published are typically based on small groups of patients and often provide anecdotal evidence, likely because of the absence of FDA approval [10, 28]. Furthermore, these clinical studies lack substantial evidence and do not delve into potential or observed adverse effects in depth [9]. The heterogeneity among these clinical studies arises from variations in exosome source cells and different purification methods, making direct comparisons challenging [5, 23]. Lastly, there is currently no published evidence regarding the long-term outcomes of exosome usage [17, 25].

Skin wound healing continues to pose a significant challenge for healthcare systems worldwide. Although most wounds heal promptly and completely with current standard-of-care methods, a significant subgroup of patients with impaired angiogenesis and vascularization remains at elevated risk of developing chronic wounds. These chronic wounds can lead to serious complications, including infection, sepsis, and osteomyelitis. Various approaches, such as adipose tissue and blood-derived cells, exosomes, hydrogels, and plant-derived cellulose, hold promise for improving wound therapy [4, 21].

Although exosomes show great potential in dermatological and cosmetic applications, several limitations restrict their widespread clinical use and commercialization [20, 22]. One of the foremost challenges is the lack of standardized isolation and purification methods, which often results in heterogeneous populations and variable bioactivity [22, 23]. Techniques such as ultracentrifugation, filtration, and precipitation yield different purities and recovery rates, making reproducibility a major concern in large-scale cosmetic manufacturing [23, 26].

Another critical issue is the limited stability of exosomes during storage and formulation, as their lipid bilayer structure and cargo can degrade under non-optimal conditions [24]. Maintaining bioactivity requires precise control of temperature, pH, and storage media, which complicates the development of long-lasting cosmetic products [25]. Furthermore, the high production cost and low yield of exosome extraction hinder mass production for commercial purposes [26, 28].

From a regulatory standpoint, the absence of specific guidelines for exosome-based products creates significant uncertainty in terms of safety, efficacy, and ethical approval [27]. Although some manufacturers have sought “pending” or “conditional” approval status, no exosome-derived

cosmetic or medical products have yet received full authorization from major agencies such as the U.S. Food and Drug Administration (FDA) [27, 28]. Most current reports remain preclinical, with only a few small-scale clinical studies providing preliminary evidence of their efficacy in skin rejuvenation and wound healing [20, 22].

Additionally, variability in donor cell sources, purification techniques, and application routes leads to inconsistent outcomes across studies [23, 26]. Long-term safety data are also lacking, particularly regarding the risk of unwanted immune reactions, transmission of cellular components, or off-target biological effects [24]. Addressing these limitations requires rigorous standardization of exosome production protocols, comprehensive toxicity testing, and the establishment of globally accepted regulatory frameworks [25, 27].

In summary, while exosomes represent a transformative innovation in cosmetic and regenerative dermatology, overcoming technical, regulatory, and safety-related barriers is essential to ensure their successful clinical translation and consumer acceptance [18, 20, 28].

IV. RESULTS

The literature reviewed revealed that exosomes possess remarkable potential for use in cosmetic and dermatological formulations. Most studies demonstrated that exosomes derived from mesenchymal stem cells, adipose tissue, and plant sources effectively promote skin regeneration, collagen synthesis, and tissue repair [3, 16, 21]. Research findings indicated that exosome-based treatments significantly enhance fibroblast proliferation and improve skin elasticity when compared to conventional cosmetic products [13, 23]. Their role in reducing pigmentation, accelerating wound healing, and minimizing inflammation was also consistently observed across various experimental studies [18, 24].

Clinical and preclinical data suggested that exosome-containing formulations contribute to smoother skin texture and reduced wrinkle depth without causing irritation or adverse reactions [23, 27]. Moreover, plant-derived exosomes were reported to improve antioxidant defense and hydration levels in the skin, further supporting their cosmetic value [16, 19]. A few commercial prototypes and experimental formulations showed visible anti-aging and brightening effects after continuous application.

However, the reviewed studies also identified challenges such as low yield during isolation, high production cost, and limited shelf stability [8, 9]. Despite these limitations, the collective evidence supports the growing potential of exosomes as safe, natural, and multifunctional agents for advanced skincare and cosmetic product development [21, 25]. Furthermore, several comparative analyses have shown that exosome-based formulations outperform conventional peptide or retinoid-based cosmetics in stimulating collagen production and improving skin barrier integrity [21, 23]. In controlled trials, subjects using exosome-enriched creams demonstrated enhanced skin hydration, elastic recovery, and reduced transepidermal water loss (TEWL) compared to those using standard formulations [24, 27]. This improvement is largely attributed to the biological

signaling functions of exosomal microRNAs and growth factors, which regulate fibroblast differentiation and keratinocyte turnover [25, 28].

Histological evaluations confirmed thicker epidermal layers and increased type I and III collagen deposition following exosome therapy, validating their tissue remodeling potential [22, 26]. Moreover, quantitative proteomic studies revealed upregulation of antioxidant enzymes such as superoxide dismutase (SOD) and catalase, indicating enhanced oxidative defense mechanisms within the skin [27, 28]. These molecular effects correspond to observable clinical improvements in tone, brightness, and elasticity without irritation or hypersensitivity reactions.

In addition, exosome-based treatments have shown potential in addressing post-inflammatory hyperpigmentation, acne scars, and ultraviolet-induced photodamage, suggesting a broad therapeutic range beyond basic cosmetic enhancement [23, 26]. Trials incorporating combined modalities—for example, microneedling or laser therapy with exosome application—reported synergistic outcomes in collagen remodeling and pigmentation correction, highlighting their compatibility with modern dermatological procedures [24, 27].

Collectively, these results underscore the multifaceted potential of exosomes as bioactive and regenerative cosmetic agents, offering both therapeutic and preventive benefits. Their ability to interact at the molecular and cellular levels provides a unique mechanism for restoring skin vitality and structure, positioning exosomes as a cornerstone for next-generation cosmetic science [16, 18, 28].

V. CONCLUSION

Exosomes represent one of the most promising advancements in the fields of cosmetic science and regenerative medicine. Their natural role as intercellular messengers allows them to deliver bioactive molecules that enhance skin repair, collagen synthesis, and overall tissue regeneration [1, 18, 24]. Compared to conventional cosmetic ingredients, exosome-based formulations offer a safer and more biologically compatible approach to improving skin health [3, 23]. They have demonstrated significant potential in anti-aging treatments, wound healing, pigmentation control, and hydration enhancement through their ability to stimulate fibroblasts, regulate inflammation, and promote angiogenesis [16, 21].

Despite their remarkable therapeutic potential, the large-scale application of exosomes still faces challenges such as complex isolation methods, limited stability, and high production costs [8, 25]. The absence of standardized extraction and storage procedures also restricts their widespread commercialization [9, 26]. Continued research focusing on optimizing exosome yield, purity, and long-term safety evaluation is therefore essential [10, 27].

Overall, exosomes hold immense potential as next-generation bioactive agents in skincare and cosmetic formulations. With further advancements in biotechnology and regulatory support, exosome-based products may soon become a key component in innovative, natural, and effective cosmetic therapies designed to rejuvenate and protect the skin at a cellular level [21, 23, 28]. Moreover, as cosmetic science continues to merge with regenerative biotechnology, exosomes are

expected to redefine the boundaries between aesthetics and therapeutic skincare [24, 25]. Their intrinsic ability to deliver signaling molecules across biological barriers represents a breakthrough in non-invasive skin rejuvenation strategies [18, 26]. Unlike conventional actives that act only on the skin surface, exosomes initiate repair from within by reprogramming cellular communication and promoting natural regeneration [19, 22].

The integration of exosome technology with nanocarriers, 3D bioprinting, and personalized dermatology platforms will likely accelerate their translation into clinically approved products [26, 27]. Such combinations could improve formulation stability, targeted delivery, and dosage control, overcoming some of the current limitations in large-scale cosmetic manufacturing [25, 28]. Furthermore, collaborative research among cosmetic scientists, bioengineers, and regulatory authorities is crucial to establish standardized protocols for quality assurance, safety validation, and ethical sourcing of exosomal materials [21, 24].

In summary, the continuous exploration of exosomes in cosmetic formulations holds transformative potential for the next generation of dermatological innovations. Their regenerative, anti-inflammatory, and bio-communicative properties make them ideal candidates for sustainable, safe, and highly effective cosmetic solutions that align with the principles of modern biocosmetic development [16, 18, 23]. With advancing research and supportive regulation, exosomes are poised to become a cornerstone of next-era cosmetic biotechnology — bridging the gap between aesthetic enhancement and true cellular regeneration [22, 28].

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