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Nanocarriers and Bioadhesive Systems for Enhanced Cosmeceutical Efficacy

Gouthami Ammapalli, Suruthi Ramamoorthy, Varsha Senthil Kumar Buvaneswari, Nithya Vijayan, Saraswati Patel*

Department of Pharmacology, SIMATS College of Pharmacy, Chennai, India

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KEYWORDS

Skin anatomy, Stratum corneum permeation, Semisolid dosage form, Percutaneous absorption, Bioavailability enhancement

ABSTRACT:

Cosmeceuticals are cosmetic-pharmaceutical's hybrid that has recently experienced a fast development proclaiming to combine aesthetic enhancement with therapeutic effectiveness. This review investigates the historical development, physiological targets, and scientific mechanism that lies behind cosmeceutical applications via skin and mucosal routes. Active ingredients like retinoids, peptides, anti-oxidants, and botanical extracts have multi-fold effects such as anti-aging, pigment control, wound healing, and disposition of hair. The review explores into transdermal and mucosal delivery routes, exploring new technologies such as nanocarriers, microneedles hydrogels and bio adhesive formulations that optimize bioavailability and specific action. Moreover, the therapeutic significance of cosmeceuticals in dermatological problems – acne, psoriasis, rosacea, hyperpigmentation is discussed in specific for different skin types. Exosomes, plant-based compounds, and multifunctional agents are all indicative of how the field is changing into personalized and sustainable approaches. Existing difficulties associated with regulation are related to ambiguity of category and claim substantiation. however, the rise of the non-animal-testing and AI-integrated systems promise safer individualized alternative to traditional skincare.

1. Introduction

Cosmetics were discovered to have their health advantages for the first time by the ancient Egyptians. The establishment of the first modern pharmaceutical company produced the separation between cosmetics and pharmaceuticals that took place before the nineteenth century. Hydroxy acids functioned as exfoliants, which caused the cosmetics industry to expand quickly in the 1980s. A cosmeceutical term was first introduced by Raymond Reed in 1961, preceding Albert Klingman's development of retinoic acid mixtures for treating wrinkled and UV-damaged skin in 1971 (Preetha & Karthika, 2009). The unregulated cosmeceutical category of dermatology makes use of biologically active substances to improve skin health. Formulated components act to retain active ingredient purity, and they deliver active substances to the skin in biological form while ensuring proper delivery to target areas as well as controlled ingredient release (Rajendran et al, 2025). The United States demands specific market, packaging, and aesthetic standards when selling cosmeceuticals as cosmetics. Testing clinical results of skin benefits remains a necessary procedure to authenticate product performance and back marketing declarations. Zoe Diana Draelos, MD, 2009, reported that the present government regulations on effectiveness claims restrict cosmetic-derivative development, so products would shift from cosmetics to medicines when their active functions enhance, leading to category ambiguity (Draelos, 2009). Exosomes, which are tiny extracellular nanovesicles, show potential use in dermatological disorders as well as skin care cosmetics and tissue regeneration. Exosomes modify the cellular environment and control gene activation, and drive cellular specialization to deliver health benefits to skin tissues. Through the use of exosomes, cosmetic products can help minimize wrinkles while boosting skin elasticity and enhancing the skin surface while simultaneously easing sunburn inflammation (Thakur et al., 2023). Exosomes serve as medication for dermatological conditions, including systemic lupus erythematosus and psoriasis, atopic dermatitis, alongside systemic sclerosis, pigment control, vitiligo, and hair development. The cells use exosomes to encourage the new growth of tissue in skin wounds. This research examines exosome therapeutic advantages for dermatological diseases, together with their use in skin treatments and tissue

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restoration applications, and cosmetic needs due to their potential clinical value (Thakur, 2023). The oral mucosal route functions as a systematic drug administration pathway for pharmacological compounds that includes nitro-glycerine, which has received sublingual delivery during the last 100 years. The delivery of medicines through the oral mucosal tissue provides better performance compared to entering through injectables or the gastrointestinal tract. The delivery process through this method blocks the hepatic metabolism at first pass and stomach acidity and enzyme breakdown while ensuring faster medication activation. Intestinal failure patients, as well as patients who experience swallowing complications or nausea and vomiting, can use this method because it avoids invasive procedures while being less frightening. Oral mucosal delivery costs less than invasive treatments because patients do not need to purchase specialized knowledge or technological equipment such as infusion pumps (Rajesh & Elumalai, 2025). The comprehension of both internal and external causes of facial change has pushed practitioners toward employing multiple cosmetic treatment modalities to obtain superior therapeutic results. Noninvasive or minimally invasive cosmetic procedures in the United States during 2014 included combinations of simultaneous operations by nearly fifty percent of patients who followed contemporary aesthetic standards (Nandhini J, Karthikeyan E, 2024). Carruthers et al., 2016 Studies demonstrated that the therapeutic procedure which combines Microfocused ultrasound with visualization and incorporates calcium hydroxylapatite and botulinum toxin while using both hyaluronic acid and Microfocused ultrasound with visualization (Carruthers et al., 2016). Taj & Jhanjhi, 2022 research studies demonstrated that the cosmeceutical market by looking at historical background, active components, production strategies, efficacy data and current market trends together with market problems. The sector maintains a rich connection between manufacturing dynamics and consumer wants and technological innovations which leads to modern personalized and creative cosmetic development through intelligent systems and artificial intelligence revolutions (Taj & Jhanjhi, 2022). Conscientious consumption has become the trend because companies concentrate on clean beauty and sustainable product offerings alongside diverse appeal.

2. Anatomy and Physiology of the Skin and Mucosa

Venus M et al., 2011 studies demonstrated that at 15% of adult body weight the skin stands as the body's largest organ. The skin acts as both a water preservation barrier and regulates body temperature while defending the body from outside dangers (Venus et al., 2011). The skin is composed of three layers: epidermis, dermis, and subcutaneous tissue. Keratinocytes present in the epidermis create keratin which acts as a protective protein. Located beneath the panniculus sits the dermis which contains collagen as its main substance epidermis above it, the eyelid and back possess a dermis that reaches 30-40 times its thickness (Nicol, 2005). Different bodily compartments and organs have an inner lining called mucosa that comprises three primary structures: epithelial layer and lamina propria, and muscularis mucosae. A tissue complex makes up the mucosa, comprising its top epithelial layer together with the lamina propria and the muscularis mucosae (Squier & Brogden, 2013). The epithelium layer functions as both a protective barrier and an absorption/secretion facilitator, depending on organ-specific structural transformations. The connective tissue layer known as lamina propria both supports epithelial tissue and promotes immunological Defense and nutrition exchange through its abundant lymphatics, blood vessels and immune cells (Zhou et al., 2020). Local mucosal movement arises from a smooth muscle layer to enable both absorption and digestion. Nutrition absorption and defence against infections depend on this layer to function properly, with its role in hormone secretion, enzyme production, and mucus generation. Beyond these immunologic elements, it contains lymphoid follicles. The skin and mucosa play a very important role in protection, regulation, and physiology. The mucosa helps in the immunological Defense and absorption; skin serves as a barrier and a thermoregulator. Their structural complexity is their indication of significance in underpinning the overall health and balance (McColl, 2005).

Structure of the Skin

Human skin has two main parts of the integumentary system the epidermis and dermis. The epidermis structure is comprised of renewing epithelial tissue, which is composed of many layers over the so-called dermis layer, which is followed by the stratum corneum

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(Ibrahim et al., 2021). The major physical barrier is the stratum corneum, whereas chemical and biochemical barriers are cell-cell junctions and cytoskeletal proteins. The immunologic barrier is both immunologic, cellular, and humoral aspects of the immune system (Baroni et al., 2012). An integrated system of the dermis consists of fibrous tissue, amorphous connective tissue, fibroblasts, macrophages, mast cells, nerve networks, vascular networks, and epidermal appendages (Yousef et al., 2020). In the non-fibrous and fibrous connective tissue matrix, fibroblasts conduct the process of synthesis and degradation of proteins (Hance & Crystal, 1975). These are the normal cells located in the dermis, with the three normal cells being the fibroblasts, macrophages, and mast cells, which undertake the coagulation, wound healing, and tissue remodeling (Figure 1) (Mikkola & Millar, 2006). The ectodermal embryonic stage gives rise to various skin appendages such as teeth, hairs, feathers, as well as mammary glands (Mikkola, 2009). Based on the interactions of the ectodermal epithelium with the mesoderm, mesenchyme, or the neural crest cells, skin appendages develop (Fore-Pfliger, 2004). The previous study has revealed that environmental exposures like using soap products can enhance the occurrence of atopic eczema and other dry skin conditions (Cork & Danby, 2009). To ensure that the barrier integrity develops, emollients should be used, and the skin must be properly taken care of (Elias, 2007).

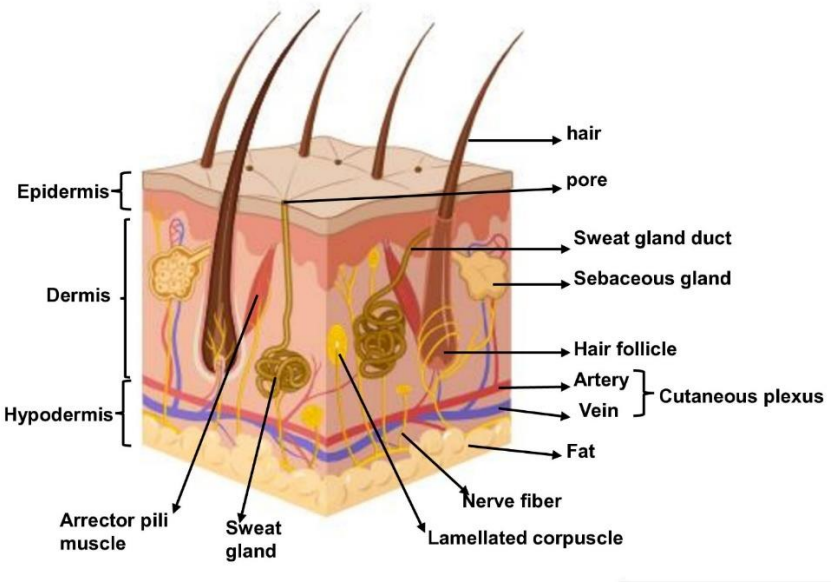

Figure 1: The diagram depicts the human skin's three primary layers: epidermis, dermis, and hypodermis. This depiction demonstrates how pores exist with hair structures along with sebaceous glands and sweat glands at each hair follicle position within every basic skin layer beneath nerve fibers and arrector pili muscles and vascular networks, together with fat cells and pressure-sensitive receptors in the hypodermis.

Mucosal Sites Relevant for Cosmeceuticals

Aspinall et al., 2021 studies demonstrated that the mouth fresheners and dentifrices serve as the main focus of this chapter's discussion about oral hygiene cosmetics. Internal oral preparations known as mouth fresheners prevent discomfort, as external preparations called dentifrices help clean teeth and the surrounding dental areas. The preventive power of dentifrices supports dental caries protection and periodontal disease prevention while offering toothpaste and fluid-form toothpaste and tooth powder and moist tooth powder, and liquid form dentifrice as separate treatment options (Aspinall et al., 2021). Mouthwash serves as a liquid dentifrice. Mouthwash usage for cleaning purposes and breath freshening, alongside halitosis prevention, is examined in this chapter with special focus on its role in avoiding periodontal diseases and tooth decay. Oral hygiene products such as mouthwashes and toothpastes help consumers maintain their dental health easily, yet dental caries continues to affect many people. Product development for advanced oral hygiene formulations proves difficult because their complex compositions

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match the complexities of the oral cavity alongside consumer requirements. Cosmetic and reconstructive procedures perform notable changes to the nose at the internal-external junction, which directly affects both airway resistance and the filtering ability. The surgical focus needs to combine management of invisible nasal cavity structures with external structural needs because nasal appearance directly impacts functionality (Lane, 2006). Skin pigmentation develops when the body produces extra melanin or deposits the pigment because of age-related changes and hormonal activities and specific diseases and inflammatory processes, and various forms of radiation. Latent conditions and post-inflammatory skin alterations, as well as melasma, develop from dermatologic triggers. Surface treatments for skin lightening are effective, but patients experience problems with diminished results when they stop using them (Juhasz & Levin, 2018). Lin et al., 2024 studies demonstrated that the periorbital area responds to cosmetic therapy with hydroquinone and retinoids and chemical peels that can either boost or reduce melanin levels. Scientists created an all-in-one skincare therapy that contained THD ascorbate alongside prebiotic Inula Helenium and bioavailable peptides and botanical extracts and caffeine to combat melanin buildup while addressing microvasculature congestion and puffiness, leading to improved infraorbital dark circle and puffiness reduction (Lin et al., 2024). Cosmetics for dental hygiene and cosmetic dermatology are essential for dental health promotion and the elimination of such conditions as periodontitis and cavities.

Permeation Pathways and Drug Absorption Dynamics

For drugs originating from extravascular deliveries, the biological barriers need to be crossed for distribution into the systemic circulation. When medications degrade excessively, combined with limited skin penetration, their bioavailability becomes reduced. The improvement of drug absorption occurs through the combined use of chemical permeation enhancers and enzymes alongside efflux transporter inhibitors and chemical modifications with unique drug delivery systems. (Sahlgren et al., 2017). Hartmanshenn et al., 2016 studies demonstrated that the multiple techniques exist to improve drug availability including the delivering of chemical permeation enhancers together with enzymes and efflux transporter blockage. Valid assessments require physiologically representative models together with tailored dosage formats to evaluate this strategy effectiveness (Hartmanshenn et al., 2016). Scientists use ex vivo tissue together with in vitro cell culture models to evaluate the effectiveness of these techniques. The studies demonstrated that the drug permeation enhancement methods employed for transdermal and nasal delivery and Oromucosal, pulmonary, oral, and rectal administration routes using both in vitro and ex vivo experimental approaches. Methods such as chemical permeation enhancers, enzyme use and efflux transporter weakening are required to sensitize medication bioavailability from extra vascular route. (Mitchell et al., 2021).

3. Cosmeceutical Agents and Their Mechanisms of Action

Tsai & Hantash, 2008 studies demonstrated that the cosmetics present an effective therapeutic choice which helps treat wrinkles and both photoaging and hyperpigmentation of the skin. An examination of cosmeceutical compounds through published literature evaluates their healing properties for wounds and dermatological disorders. The study outlines chemical basics and examines published research findings before forecasting the agent's functionality for skin restoration (Table1) (Tsai & Hantash, 2008). The analysis concentrates on understanding how agents contribute to skin regeneration as the skin care market continues its fast-paced evolution. Skin diseases can be cured with cosmeceuticals such as Vitamin C, glycolic acid, salicylic acid, arbutin, and ceramides. These compounds help in the repair and reconstruction of the barrier and external source of energy, and play an increasingly significant role in dermatology and cosmetic therapies as the dependence on the skincare industry grows (Torres et al., 2023).

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Table 1: Role of cosmeceutical agent

Cosmeceutical agent	Category	Mechanism of action	Aesthetic/ Medical applications	Ref.
Vitamin C (Ascorbic Acid)	Antioxidant	Neutralizes free radicals, boosts collagen, inhibits melanin production	Brightening, anti-aging, photoprotection, melasma	(Tsai & Hantash, 2008)
Glycolic Acid	Hydroxy Acid	Exfoliates by breaking corneocyte bonds, stimulates dermal remodeling	Fine lines, uneven texture, hyperpigmentation	(Tsai & Hantash, 2008)
Salicylic Acid	Beta Hydroxy Acid	Penetrates pores, exfoliates inside follicles, anti-inflammatory	Acne, oily skin, clogged pores	(Tsai & Hantash, 2008)
Arbutin	Natural Skin Lightener	Tyrosinase inhibitor; decreases melanin production	Hyperpigmentation, melasma, skin brightening	(Tsai & Hantash, 2008)
Ceramide	Lipid Component	Restore skin barrier, retain moisture	Eczema, dry/sensitive skin, barrier repair	(Tsai & Hantash, 2008)

Anti-aging and Skin Rejuvenation Devices

Beckenbach et al. 2015 studies demonstrated that the skin benefits from natural and synthetic Retinoids, which control cell reproduction and cell type transformation. This class of compounds has established itself as essential components of dermatopharmacology because they regulate keratinocyte proliferation and differentiation patterns. To administer medicines safely, healthcare providers need complete patient details alongside an extensive list of potential adverse reactions (Beckenbach et al., 2015). Synthetic peptides started their journey in the skin care field during the 1980s before becoming commonly utilized in cosmetics manufacturing throughout the subsequent years. A 7.2% increase in peptides in cosmetics has been documented by anti-aging research alongside an 88.5% expansion of peptide combinations used in cosmetics. Anti-aging cosmetics now obtain their peptides through biotechnological processing primarily by using palmitoyl tetrapeptide-7, palmitoyl oligopeptide, and acetyl hexapeptide-8 (Ferreira et al., 2020). Baxter, 2008. Studies demonstrated that red wine antioxidants known as resveratrol demonstrate anti-aging potential, which benefits Alzheimer's disease treatment and cancer prevention and cardiovascular health, along with antimicrobial effects. Resveratrol-based skin care products demonstrate 17 times greater antioxidant potential than idebenone while researchers examine their photoaging prevention mechanisms (Baxter, 2008). Antiaging products containing alpha hydroxy acids (AHAs) have gained popularity for their ability to reduce signs of aging. The cosmeceutical industry relies heavily on hydrophilic organic acids called alpha-hydroxy acids (AHAs). According to legend Cleopatra soaked in lactic acid during baths to maintain a youthful appearance. Nine et al., 2015 Studies demonstrated that nicotinamide – the active form of vitamin B3 – delivers antiaging results which strengthen skin elasticity and minimize redness with hyperpigmentation reduction while reducing wrinkles and promoting the development of keratinocytes (Nine et al., 2015). Such active compounds as retinoids, peptides, resveratrol, AHAs, and nicotinamide are essential for anti-ageing skincare products, regulating the turnover of cells, increasing the suppleness, decreasing hyperpigmentation, and providing antioxidant protection. Scientific improvements make it easy to formulate and apply them effectively to dermatological and cosmetic procedures for aging issues on the skin (Dreno et al., 2014).

High Intensity Focused Ultrasonic (HIFU) is a skin rejuvenation technique that is non-invasive since it uses ultrasound waves which penetrate deep to the skin. It provides the dermis and superficial muscular aponeurotic system (SMAS) with the thermal energy and causes effects by stimulating new collagen and elastin generation. It causes skin tightening, lifting and wrinkles- particularly on the jawline, neck and brows (De Lucca Trombini & Januzzi Santos, 2023). Intense Pulsed Light (IPL) Devices: IPL devices produce light that is wide-spectrum and is used to treat pigments, red color

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and sun damage. Melanin or hemoglobin absorbs the light energy and this destroys the dark spots and enhances the skin tone and texture. IPL works best with photoaging, rosacea, freckles and light wrinkles and presents noticeable improvement with minimal time (Babilas et al., 2010).

Skin Brightening and Pigmentation Control

Skin care with the help of functional products can be divided into three stages: preventive intervention, immediately following the therapy, and a long-term period after therapy. Pre-treatment is a preparation stage that includes the cleaning, reheating, and softening of the skin to enhance its original status (Madnani et al., 2022). Sun protection is essential. Anti-calming products help avoid negative reactions and PIH, while anti-oxidant products fight the effects of oxidative stress and help in the formation of collagen. Cosmetics that are used in long-term post-treatment have an additive moisturizing effect and protect the skin from the sun, which allows for maintaining the positive effects of treatment without side effects. These enhance skin recovery processes and sustain all the medical aesthetics solutions delivered to individuals (Figure 2) (Ding et al., 2023). Skin hyperpigmentation is a dermatological disease that results in darkening of the skin as a result of increased melanin production caused by genetic factors, hormonal changes, exposure to sun and Inflammation. Thus, the purpose of this research is to investigate the efficiency of some cosmeceuticals for the treatment of hyperpigmentation, with a reference to some countries of the tropical climate like Brazil (Sarkar et al., 2013) The paper discusses the forms of hyperpigmentation such as melasma, post-inflammatory hyperpigmentation, and solar lentigines, their pathogenesis and clinical characteristics. It describes initial steps resulting to hyperpigmentation and belonged components such as hydroquinone, retinol, vitamin C, kojic acid, arbutin, and niacinamide used to treat hyperpigmentation in cosmetics, cosmetics, and skin renewal (Chaowattanapanit et al., 2017).

Micro needling Equipment: Micro needling entails superficial needles that inflict micro-injuries unto the skin inducing the body to heal itself. This activates the production of collagen and elastin enhancing fine lines, acne scar and skin tone. More sophisticated equipment can be used, which incorporates micro needling and radiofrequency (RF), providing deeper remodeling of the tissues, especially in the case of improving the firmness and radiance of the skin (Dixon et al., 2021). Radiofrequency (RF) Devices: RF devices penetrate radiofrequency energy into the skin and produce precise heat on the dermal surface. This heat stimulates rearrangement of collagen resulting in tightening of the skin, reduction in wrinkles and enhancement of elasticity. RF can be applied on the face, neck, under eyes and may be either applied individually or in combination with micro needling (Weiner, 2019)

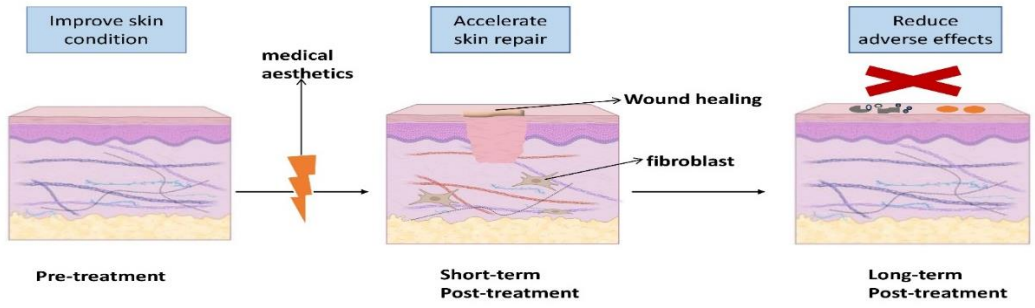

Figure 2: Some of the major activities associated with skincare range from washing, calming, moistening, as well as protection from the UV radiation. Cosmeceuticals standardize the skin at the pre-treatment stage and boost healing in addition to collagen remodelling in the early and later phases of post-treatment, including post-inflammatory hyperpigmentation (PIHP) and erythema. Skincare is a three-phase strategy that is successful: pre-treatment, immediate post-treatment, and long-term care. It aims at cleaning, calming, hydrating, and protecting the skin from UV rays and inflammation. Treatment of disorders such as hyperpigmentation requires Cosmeceuticals such as hydroquinone, retinol, and vitamin C.

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Hair Growth and Scalp Therapies

Inhibition of PDE enzymes by caffeine can raise the intracellular cAMP levels and promote cell development and metabolism. This may be useful for anyone who wishes to arrest hair loss problems occasioned by early sprouting of hair. Hair loss affects the quality of life and potentially causes anxiety and sadness among affected people (Williamson et al., 2001). It also has a detrimental impact on self-esteem, self-consciousness, and confidence, that discombobulates a person's self-identity. Androgenetic alopecia (AGA) is a slightly progressive type of hair loss disorder that occurs with advancing age and affects more than fifty percent of men over the age of fifty years. AGA is sequential, androgen-controlled, and genetic. Recent studies are pointing towards the direct relationship of androgen in females suffering from AGA. AGA is also referred to as female pattern hair loss, and affects some 33 to 40% of women over the age of 70. The general conception of hair growth science can help in understanding hair loss in AGA (Völker et al., 2020). The studies demonstrated that on the action of minoxidil in normal human hair growth, with emphasis on androgenetic alopecia. Male pattern baldness (androgenetic alopecia) means a protracted latent phase in the hair cycle, reduced anagen duration, and smaller size of hair follicles. While the distinction between male balding and female androgenetic alopecia is debatable, the follicules have similar alterations. Minoxidil, a topical medicine for hair loss, results in a fast exponential growth of hair, with a pronounced 1979pisode of said growth in 6-8 weeks of therapy only to subsequently ritually spike at the 12–16-week mark, serving nevertheless to cause no extension of a latent period in women (Messenger & Rundegren, 2004). This research studies demonstrated that is aimed at examining the effect of aloe vera content on dandruff in men. It aims to explain the cause of more sebum production, causing more people to use over-the-counter products such as pomade on sensitive scalps, which results in skin irritation and issues with the hair. 23 respondents were involved in the study and were selected through complete sampling under a pre-experimental research, pre-post-test group. Statistical significance was measured in paired-t tests with a level of less than 0.05. Androgenetic alopecia (AGA) has an adverse effect on self-esteem and psychological wellbeing (Huang et al., 2021). Hair growth and cAMP levels are encouraged by such treatments as minoxidil and coffee. The research is pointing and focusing on androgen role in AGA and topical application like aloe vera in treating dandruff and scalp. Hair biology and focused therapies understanding is important for effective management (Lim et al., 2019). Scalp lines make use of numerous sophisticated equipments both in terms of diagnosis assessment and therapeutic service. Trichoscope and dermatoscope are not only crucial devices in the diagnosis process as they ensure one is able to zoom into the scalp and shaft of hairs and identify diseases such as alopecia, seborrheic dermatitis and even psoriasis of the scalp. Mesotherapy guns /injectors are also used to administer vitamins, enzymes, medications intradermally to rejuvenate the scalp. HydraFacial scalp systems facilitate the removal of sebum and other debris to cleanse and exfoliate as well as enhance scalp healthy condition (Kaur & Kaur, 2021)

Mucosal Aesthetic Agents

White teeth are world-wide preferred because of quality of life. Oral care products for teeth whitening include toothpaste, mouthwash and gel, both for professional use and at home. Formulations used in whitening are usually abrasive agents, chemical agents, or optical agents. However, these may have adverse unintended effects such as gingiva and exposed dentin damage. Previous research has been conducted around less abrasive nonoxidative teeth-whitening chemicals: particulate hydroxyapatite (HAP) a calcium phosphate member. Biomimetic HAP is also used in preventives of oral health care having multiple applications, such as antibiofilm characteristics, which has been copied from the natural enamel crystallites (Sarembe et al., 2020). Modern mucosal care utilizes mucosal hydration chemistries in form of hyaluronic acid-based gels and bioactive moisturizers for xerostomia and vaginal dryness. These agents are restoring the function of the mucosal barrier, minimizing the discomfort and avoiding infections. They also enhance mucosal tissue texture and aspect in making one youthful. Vaginal rejuvenation product that includes topical preparations and energy treatments manage conditions such as genitourinary syndrome of menopause, vaginismus, vaginal laxity, urinary incontinence and external appearance and sexual satisfaction (Digesu et al., 2019). Fish skin mucus used in medicine and cosmetics by extracting and treating it. Collecting the mucus, it is then subjected to first stage processing methods which include lyophilization,

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centrifugation, filtration, homogenization and water bath. Then, the mucus is subjected to a variety of solvents to yield individual extracts such as aqueous, organic, acidic, crude extracts, etc. (Lee et al., 2020). Such bioactive substances can be used to make medicines and skincare products. Some fish skin mucus is scraped using a scraping instrument and then it is retrieved and refined for further use (Figure 3). The recent development in oral and mucosal care is focused on the issues of safety and efficacy, with biomimetic substance such as hyaluronic acid used for hydrating the mucosa and hydroxyapatite for tooth whitening. These methods emphasize comfort and beauty, abandoning bad effects of traditional chemicals. The fish skin mucus has new bioactive substances for medicine and cosmetics (Díaz-Puertas et al., 2023).

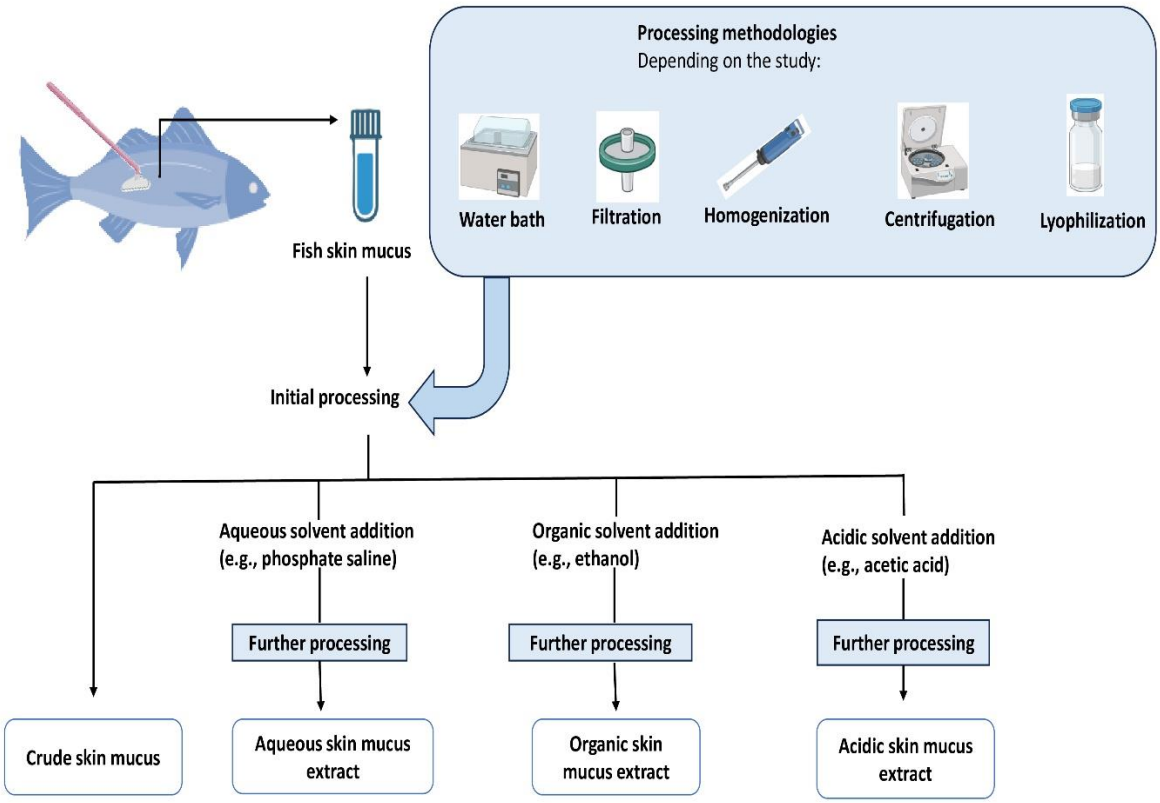

Figure 3: The inherent diagram illustrates the mode of fish skin mucus collection and processing. The skin surface is scraped to get mucus and the sample is put in to tube. Various extraction techniques are used; direct swabbing of the skin, or the use of organic, aqueous or acidic solvent is used. Filtration, substance separation by centrifugation, homogenization, aqueous treatment, or freeze-drying are further steps which produce aqueous, organic, or acidic skin mucus extracts.

4. Therapeutic Agents with Cosmeceutical Relevance

Treatment of Acne, Rosacea, and Hyperpigmentation

Acne vulgaris affects between 40–50 million US citizens, with a substantial portion of this group being people of color (SOC). Shamban, 2011 studies demonstrated that Asians (30%) and Blacks (37%), and Hispanics (32%) have higher rates of acne than Whites (24%) and Continental Indians (23%). People from Asian heritages experience greater inflammatory acne lesions than other populations, and patients from Asian and different groups of color most commonly develop both inflammatory and comedonal acne patterns. Black and Hispanic individuals frequently experience post-inflammatory hyperpigmentation (PIH) along with atrophic scars, making them seek medical help for their

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issues (Shamban, 2011). Davis & Callender, 2010 studies demonstrated that all ethnic groups experience acne as an identical set of pathophysiological processes involving inflammation, together with follicular hyperkeratinisation and enhanced sebum production and Cutibacterium acnes growth (Davis & Callender, 2010a). In SOC individuals, subclinical inflammation seems to play a key role in developing post-inflammatory hyperpigmentation. Focusing on sun protection and cosmetic usage together with hair and skin routines and keloid history enables the discovery of exacerbating factors like pomade acne or acne cosmetic. The use of witch hazel and alcohol-based exfoliants as well as toners can lead to both skin dryness and irritation; thus, they should be completely avoided. Interventions for SOC Patients: The basic treatment methods work similarly for all skin types yet Special needs exist for SOC patients to minimize both inflammation and post-inflammatory hyperpigmentation. People with acne should receive immediate and aggressive treatment to avoid the development of pigment changes and scars(J. Rao, 2011). Medical practitioners combine several topical medications, including benzoyl peroxide, antibiotics, retinoids, dapsone, and azelaic acid for treatment. The first-line treatment consists of retinoids that doctors should introduce slowly and use with moisturizing products for improved patient experience (Khalil et al., 2017). Janssens et al., 2007 studies demonstrated that oral therapies that include doxycycline, minocycline, isotretinoin, oral contraceptives, or spironolactone demonstrate effectiveness in treating serious or treatment-resistant cases. The treatment of acne with isotretinoin has proven effective for mitigating the development of PIH because of acne. Cared-for procedures include both comedonal extraction, which becomes more effective after retinoid treatment, along with the use of intralesional corticosteroid injections to treat inflammatory lesions (Janssens et al., 2007). Halder & Nootheti, 2003 studies demonstrated that treatment of PIH includes sun protection together with topical depigmenting solutions, including hydroquinone or azelaic acid, and superficial chemical peel solutions such as salicylic acid and glycolic acid, trichloroacetic acid, and Jessner's solution, with oral medications. Intralesional corticosteroid injections using 20–40 mg/mL triamcinolone work to treat both keloids and hypertrophic scars when given every 4 weeks (Halder & Nootheti, 2003).

Scarring and Laser Therapy in SOC

Pandya et al., 2016 Studies demonstrated that SOC professionals select appropriate treatments such as subcision and micro needling and punch excision and dermal grafting, and dermabrasion according to the characteristics and levels of scar severity (Pandya et al., 2016). The laser procedure known as fractional photo thermolysis functions both safely and effectively for darker skin types in the range Fitzpatrick IV–VI. This procedure provides for a controlled thermal injury that does not target melanin, thus minimizing the chance of pigment changes, encouraging collagen remodelling (Helbig & Paasch, 2011). It is concluded that Acne in skin of color (SOC) requires early and specific treatment for preventing pigmentations and scars. Conscientious specific choices of therapies reduce irritation and make post-inflammatory hyperpigmentation less of a possibility (M. Rao et al., 2023). The advanced treatments, such as fractional photo thermolysis, provide for safe scar remodelling. Bringing together medical and aesthetic care improves the clinical outcomes and the confidence of the clients (Vlahos et al., 2022).

Rosacea in Skin of Color (SOC)

SOC professionals select appropriate treatments such as subcision and micro needling and punch excision and dermal grafting, and dermabrasion according to the characteristics and levels of scar severity. Chong et al., 2009 studies demonstrated that the laser procedure known as fractional photo thermolysis functions both safely and effectively for darker skin types in the range Fitzpatrick IV–VI. This procedure provides for a controlled thermal injury that does not target melanin, thus minimizing the chance of pigment changes, encouraging collagen remodelling. Rosacea is a chronic skin disorder that primarily affects hair follicles and the face's blood vessels (Chong et al., 2009). Although persons with Fitzpatrick skin types I and II are more likely to experience it, people with skin of color (SOC) can also experience it. Al-Dabagh et al., 2014 Studies demonstrated that research suggests that approximately 4% of rosacea patients in the United States are Asian, Latino, or African American, even though these populations are not as commonly diagnosed with the condition. The difficulty in identifying facial redness

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around the eyes, which is less noticeable on darker skin tones, may be the cause of this underdiagnosis (Al-Dabagh et al., 2014). Instead of the characteristic redness, rosacea may manifest in more subtle ways in people with SOC, such as whitening of the skin around the face or small lumps, which might result in a misdiagnosis. Seborrheic dermatitis, lupus erythematosus, and contact dermatitis are among the differential diagnoses in SOC; if the clinical picture is not apparent, further testing with patch testing, laboratory testing, or biopsy is necessary. Although the exact cause of rosacea is unknown, immunological dysregulation, neurovascular instability, expansion of Demodex mites, ultraviolet (UV) damage, and compromised skin barrier function are most likely involved (Chen et al., 2023). Clinically, rosacea can be divided into four subtypes: papulopustular, ocular, erythematotelangiectatic, and phymatids. Although surgical or laser intervention may be required in more advanced cases, isotretinoin may help diminish early rhinophyma in people with phymatids alterations. Although SOC treatment should be customized to prevent irritation and pigmentary modification, the main concepts are identical to those for lighter skin types (Thawabteh et al., 2023). The daily sun protection (SPF 30+), barrier-repair creams, and mild skin care are all part of the standard regimen (Del Rosso & Brandt, 2013). Azelaic acid, ivermectin, sodium sulfacetamide/sulphur, metronidazole, and low-dose retinoids are examples of topical medications that work well. Oral treatments for severe or refractory instances include isotretinoin and sub-antimicrobial doses of doxycycline. Topical vasoconstrictors such as oxymetazoline and brimonidine can be used to treat persistent facial erythema problems (Okwundu et al., 2021). Although light-based therapies such as pulsed dye lasers and vascular lasers may be helpful for telangiectasias, Fitzpatrick skin types IV–VI should not receive intense pulsed light (IPL) because of the increased risk of hyperpigmentation following treatment. In conclusion, the skin of color (SOC) patients, management of acne should come early and be tailored to prevent post-inflammatory hyperpigmentation and scarring. Treatments should be with low irritation but aimed at reducing the level of inflammation and pigmentation (Davis & Callender, 2010b)). Highly advanced methods, such as fractional photo thermolysis, safely remodel scars, leaving their melanin unharmed. A combination of medical and cosmetic strategies provides the best outcomes and is satisfying to patients (Vitagliano et al., 2023)

Hyperpigmentation in Skin of Color

Among dermatological conditions, skin of color patients rank hyperpigmentation as their number one concern, particularly when their skin phototype falls within Fitzpatrick scale types IV through VI. Taylor et al., 2012 studies demonstrated that Skin patients with darker phototypes show greater vulnerability to develop melasma and post-inflammatory hyperpigmentation (PIH) and UV hyperpigmentation than patients with skin types I-III experience photodamage and solar lentigines. Research on Skin of Color women found hyperpigmented skin and a generally darker skin tone among the most distressing PIH effects from inflammatory skin reactions to dermatologic procedures like acne treatment and eczema and chemical peeling, and laser surgery (Taylor et al., 2012). The medical phenomenon, which results from skin inflammation or injury and leads to dark spots in skin tissue, is diagnosed as post inflammatory hyperpigmentation. Acne and different surgical dermatological procedures, including both chemical peels and lasers, serve as primary causes of this condition. The chronic pigmentation disease known as melasma primarily affects women, while 90% of Caucasian individuals with skin types fitting Fitzpatrick 3 through 5 experience it (Coleman et al., 2023). Motor skin-face disorders linked to contact dermatitis cases or neo acanthosis negro sick or exogenous a chronic overdose of drugs enabled in and lupitts represent less common etiologist. To conclude, hyperpigmentation remains the most significant dermatological concern among patients with skin of color, especially those with the Fitzpatrick skin types IV to VI. Conditions such as post-inflammatory hyperpigmentation (PIH) and melasma are particularly widespread and problematic because of their chronic nature and the associated skin aspect and psychosocial health (Maghfour et al., 2022) Inflammatory skin conditions, dermatological procedures, hormonal, and drug-induced stimuli play a major role in the development of these pigmentary irregularities. Individualized approaches to treatment and procedural precautions are prerequisites for managing and controlling this disorder in this segment of the population with attention to the culturally-sensitive dermatologic

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care. In the management of acne, the utilization of blue light therapy devices (non-laser light-emitting diode systems) in both clinics and at home is usually applied to suppress the bacterial populations and inflammation. Photodynamic therapy (PDT) devices combine light-emitting diode (LED) light with a photosensitizing agent and are applied through a particular applicator system in addressing moderate-to-severe acne. Microdermabrasion instruments also work to exfoliate the skin and help to beautify comedonal acne by eradicating the dead skin cells and better usage of the drug topically. Also employed as a treatment for acne scars is the use of microneedling pens that produce controlled micro-injury to stimulate collagen (Li et al., 2021). In rosacea, intense pulsed light (IPL) equipment (non-laser broadband light) is applied with a special robotic device to minimize blood redness and vascular outbursts. Adjunctive treatment can also be applied through such equipment as cryotherapy devices and cooling masks to minimize inflammation and tenderize skin. One of the methods that would be useful in this process is the use of Bioimpedance diagnostic devices to determine skin hydration and inflammation rates to negotiate personal treatment plans (Zerbinati et al., 2012). With hyperpigmentation, these kinds of devices such as hyperpigmentation dermarollers and microneedling devices. Hydrodermabrasion machines (Ex, Hydrafacial systems) combine non-aggressive exfoliation with a vacuum-driven serum delivery to assist in pigment removal and skin tone enhancement. In order to deposit depigmenting agents deep in the skin, without the use of physical needles, electroporation and iontophoresis devices are employed and this increase skin permeability.

Management of Psoriasis and Eczema

Waldheim et al.,2023 studies demonstrated that Patients who have psoriasis experience a long-term autoimmune disorder that demonstrates serious consequences on their skin condition and their overall day-to-day existence. Red scaly skin areas and their presence across the body show up most frequently on the scalp and elbows and knees, and back. The management of psoriasis is multidisciplinary, involving translucent, characteristic care for aesthetic functioning augmented to improve outcomes and self-esteem, and collaboration (Waldheim et al., 2023). Patients receive medical care through topical treatments consisting of corticosteroids and vitamin D analogues, as well as calcineurin inhibitors to decrease inflammation and scaling symptoms. Patients with moderate to severe cases receive systemic treatment with methotrexate and cyclosporine and newer biologic agents targeting TNF-alpha and IL-17 to manage their symptoms. The treatment of widespread lesions can be effectively managed through phototherapy with either UVB or PUVA exposure. From the aesthetic view, the treatments aim to improve the appearance of the skin to decrease social stigma and to improve psychological well-being. Keratolytic agents combined with moisturizers help soften plaques to prevent dry skin. Cosmetic camouflage methods provide patients with a temporary method to conceal their lesions, which brings psychological relief (Levy & Emer, 2012). Combining aesthetic dermatology with traditional treatment leads to greater treatment compliance and satisfaction among patients, showing both clinical symptoms and the physical manifestation of the psoriasis. In conclusion, management of psoriasis is multidisciplinary and includes the medical application of drugs as well as the aesthetic measures aimed at alleviating the clinical symptoms of psoriasis and the psychological aspect that the disease prompts. Topical treatment, systemic therapy and phototherapy are vital in controlling the inflammation and scaling whereas aesthetic intervention such as moisturisers, keratolytic agent and cosmetic camouflage enhance the skin appearance and increases in self-confidence by the patient (Bonamigo et al., 2023) Such an integrated approach does not only increase the treatment compliance level, but also improves the global quality of life for the individuals with psoriasis considerably. Management of edema requires a detailed assessment to uncover the underlying cause − cardiac, renal, hepatic, lymphatic, side effects from a drug, or systemic disease. A complete history, physical examination, and focused investigations as outlined in serum electrolytes, renal and liver function tests, ECG, echocardiogram, and urinalysis, are necessary to define the etiology of DKA. Lifestyle changes represent the first line of treatment and incorporate salt restriction in diet, restriction of fluid intake, and low body weight, elevation of the limb and at times, the use of diuretics, in addition to other treatments (Samadian et al., 2016). In specific dependent or venous oedema, compression treatment using stockings or bandages reduces fluid accumulation and facilitates venous return. The basis for pharmaceutical treatments determines the underlying

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cause and treatment intensity. Furosemide loop diuretics remain clinically effective in treating patients with heart failure and renal diseases, and acute pulmonary edema because of their strong ability to eliminate sodium from the body. Patients with mild edema and hypertension-related fluid retention should take Thiazide diuretics. The diuretic spironolactone keeps fluids in the body and prevents potassium loss in two ways: patients with hypokalaemia need it, and patients with cirrhosis-related ascites benefit from it. Consultations for electrolyte abnormalities, as well as blood pressure, along with renal function tests, need to be regularly monitored when using diuretics. Combination therapy using loop and thiazide diuretics or tests for secondary factors, including nephrotic syndrome and liver disease, and hypothyroidism, must be considered when standard treatments prove ineffective (Qavi et al., 2015) The treatment of lymphedema requires medical lymphatic drainage (MLD) along with intermittent pneumatic compression and an exercise system, along with proper skin care. Medical treatments typically show no success against lymphedema. Idiopathic edema requires controlled diets and emotional counselling, and occasionally doctors monitor diuretic administration for women patients. Whenever medications such as calcium channel blockers or NSAIDs cause edema, patients need to stop using the medication or replace it with another drug (Sica, 2003). Combining care from physicians with dietitians and physiotherapists, and dermatologists leads to enhanced patient results in long-term treatments or complicated conditions. Conclusively, management of edema entails thorough assessment for its cause so as to offer personalized treatments such as lifestyle adjustments, diuretics, compression therapy, and special treatment in cases of lymphedema among others. Electrolyte monitoring, renal functioning, and blood pressure monitoring are necessary, especially when diuretics are used or concerning secondary factor, (Foeldvari et al., 2024).

Skin moisture measurement devices utilize two main technologies; Bioimpedance Analysis (BIA) and Capacitance Method. The BIA device does this by applying a small but steady electric current, which is usually 50 kHz, across the skin surface with the help of two metal electrodes. This device is used to measure the electrical impedance, which would change depending on the abundance of water being surrounding the top most layer of the skin (stratum corneum). they lack a high degree of accuracy and cannot be used as the gold standard when measuring skin moisture. Capacitance method devices however are more accurate. The measurement principle of these devices consists in the use of interdigital capacitor (IDC) sensor to detect shifts in capacitance produced by the presence of water in the skin (as a dielectrical material). It is formed by a probe which is linked to a bigger processing unit and it has credible skin hydration measurements (Bartels et al., 2015).

Anti-Inflammatory and Immunomodulatory Topicals

Withania somnifera has anti-inflammatory and immunomodulatory power through different mechanisms, which is possessed by its bioactive compound, mainly with an oldie, which is withaferin A treated; it effectively reduces the levels of pro-inflammatory cytokines TNF-α, il-1β, and IL-6; on the other hand, it raises the levels of anti-inflammatory cytokine IL-10. Through its mechanism of action, *Withania somnifera* blocks the inflammatory signaling of NF-κB to decrease the production of inflammatory enzymes COX-2 and iNOS(Devkar et al., 2016) (Devkar et al., 2016). It also upregulates the antioxidant Defense system by escalating catalase, superoxide dismutase (SOD) and glutathione peroxidase helping in reducing oxidative stress which typically exacerbates inflammation. In addition, *W. somnifera* enhances macrophage polarization to the anti-inflammatory M2 phenotype and modulates the T cell responses by promoting Th1 response and inhibiting Th2-driven inflammation, making it supportive in balancing the immune. Results from experimental models have shown its efficacy by reducing inflammatory damage and eliminating the production of autoantibodies when utilized to treat rheumatoid arthritis and LPS-induced inflammation and carrageenan-induced paw edema(C. Kaur et al., 2024) The plant is also found to be good for immune strengthening in stress as well as drug-mediated immunosuppressed system and functions as an immunomodulator by modulation of the hypothalamic–pituitary–adrenal (HPA) axis, thus revealing its adaptogenic action. In conclusion, *Withania somnifera* has great anti-inflammatory and immunomodulatory effects as a result of its bioactive components, especially withanolides. Via controlling pro-inflammatory cytokines, augmenting antioxidant defence and

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modulating immune reactions, it helps in eliminating inflammation and oxidative stress. Its adaptogenic activity also helps to reinforce the immune system and thus can be used for rheumatoid arthritis, inflammation as well as suppression of the body's immune system, and in doing so, revealing its potential as a therapeutic agent in the treatment of inflammatory disorders (Sharma & Goel, 2023)

Healing Agents for Wounds, Ulcers, and Mucosal Lesions

Various substances and technological solutions belong to the classification of healing agents that boost the biological healing capabilities of the human body. Classic local treatments, similar, aloe vera, and medical grade honey, such as manuka and heather honey, have some powerful anti-inflammatory and anti - micro-bedic properties that promote tissue regeneration. Shedoeva et al., 2019 studies demonstrated that higher-level wound dressings –Stylesheet hydrogels, foam dressings, and alginate dressings – are designed to keep moisture at optimal levels, to absorb high water levels, and prevent infections. Platelet-rich plasma therapy (PRP), alongside recombinant platelet-derived growth factors, helps cells migrate and multiply better to speed up tissue repair. Nanogels, as a novel approach, deliver drugs to specific targets, and smart bandages that have embedded sensors and electrical stimulation allow real-time monitoring of wounds and facilitate faster healing (Shedoeva et al., 2019) Comprising these healing agents constitutes a holistic approach to effective and easy wound healing. Management of ulcers (from pressure ulcers, diabetic foot ulcers, and venous leg ulcers) needs a healing response connected to knowledge of both the existing plant cells and existing pathology and the regeneration of skin integrity. Medially. the foundation for treating ulcers with wound debridement, infection management, and the promotion of cutaneous tumor regeneration. Common treatments and healing agents are topical antimicrobial agents such as silver sulfadiazine, iodine, containing dressings, and enzymes cleansing debrides to remove necrotic tissue. Wound dressings with hydrocolloids, along with hydrogels and alginates, and foam types, create an essential moist environment needed for re-epithelialization (Nuutila & Eriksson, 2021). Platelet growth factor (PDGF), epidermal growth factor (EGF), and vascular endothelial growth factor (VEGF) are used in clinical settings to shift cell yield and angiogenesis. More vital objectives, the systemic treatments, include optimal glucose control in the diabetic, nutritional support in the form of protein, zinc, and vitamins A and C, and intravenous antibiotics for infected wounds. Finally, the current wound healing approaches involve combining traditional agents, advanced dressings, growth factors, and systemic treatments for effective tissue regeneration. From natural substances such as honey and aloe vera to modern technologies such as nanogels and smart bandages, such solutions help to achieve proper conditions for different wounds (Sindhu et al., 2022). They help to speed up the healing process. Full awareness of pathology also plays an important role in efficient ulcer management, as it requires a mixed approach to addressing ulcers that involves topical and systemic treatments to establish skin integrity and improve patient outcomes. For an aesthetic perspective, prevention of long-lasting skin damage, discoloration, and scarring is very important, particularly in those ulcers on the face, neck, or legs. Post-ulcer scarring benefits from treatment with Silicone gel sheets as well as onion extract gels and contracture-preventing agents. Post-healing treatments, including fractional laser therapy, micro needling, and platelet-rich plasma (PRP) treatments, are consistently employed to enhance the texture of the skin, stimulate collagen regeneration, and erase post-inflammatory pigmentation. The fragile skin will tolerate the anti-inflammatory and antioxidant effects of natural remedies that include turmeric (curcumin), Centella asiatica and aloe vera, and honey. Moreover, newer regenerative therapies such as stem cell therapy, and skin substitutes engineered biologically are meanwhile studied for that, which could involve scarless and full skin regeneration (Jorgensen et al., 2023). Effective ulcer management additionally consists of way of life modifications as well as precaution measures, including pressure offloading, smoking cessation, as well as appropriate footwear in diabetic patients. By combining clinical treatment with cosmetic effects, patients heal physically faster and build better self-esteem, social abilities, and feel better about their lives. Medical science, when integrated with cosmetic dermatology, produces an all-encompassing patient-focused approach to the treatment of ulcers. Mucosal healing (MH) is gaining acceptance as a major therapeutic objective in the treatment of inflammatory bowel disease (IBD), including Crohn's disease and

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ulcerative colitis. Endoscopic and histological remission of MH delivers multiple long-term benefits which include persistent clinical remission along with decreased hospital stays and colorectal cancer risk as well as reduced rates of hospital stays and colorectal cancer risk. Gary et al., 2010 study demonstrated that it acts as a more objective evaluation than symptom-based evaluation and could herald a good orthodox disease course. The implementation of biologics and targeted therapies has substantially improved the possibility of reaching MH goals. However, there are currently many challenges, including the absence of standardized definitions and assessment tools, and both treatment efficiency and safety/and economics (Gary et al., 2010) Current research investigates the integration of MH into treat-to-target strategies, the identification of non-invasive biomarkers, and the role of MH in histological healing and improvement of patient-reported outcomes. To sum up, mucosal healing (MH) has become a central therapeutic aspiration in treating IBD and provides long-term clinical advantages and stabilized disease outcomes. Although the biologics and targeted therapies have improved the viability of achieving MH, there are issues with the standardized definitions, assessment methods, and the cost-effectiveness of these therapies (Mócsai et al., 2014). Current research concentrates on the synthesis of MH into treat-to-target approaches, the invention of reliable non-invasive biomarkers, as well as the role of MH in histological healing and patient-based care. A controlled vacuum is produced at the wound site with the Negative Pressure Wound Therapy (NPWT) devices and this eliminates excess exudate, and edema and stimulates the formation of granulation tissues. Hyperbaric Oxygen Therapy (HBOT) chambers provide 100 percent oxygen under high pressure induction in order to provide more diffusion of oxygen to the hypoxic tissue to encourage the activation of fibroblast and angiogenesis (Snyder, 2008). Electrical stimulation (E-stim) devices are designed to stimulate the proliferation of cells, increase the production of ATP and the local microcirculation through low voltage electrical currents. Either Low-Level Laser Therapy (LLLT) or Photobiomodulation (PBM) devices involve light intensity red or near-infrared light that influences mitochondrial activation of cellular healing processes and mitigates inflammation. The devices used in the cold plasma therapy produce non-thermal plasma to disinfect the wounds and induce the regeneration of the epithelial layer by utilizing the reactive oxygen species(Glass, 2021) Hydrosurgical debridement equipment works to remove necrotic tissue with precision using high pressure of saline jet and ultrasound wound therapy equipment uses low frequency sound waves that stimulate the cells and also, improve perfusion. Soft tissue diode lasers are used when taking care of mucosal lesions because they aid in closing microvasculature, inflammation reduction, and faster mucosal healing.

5. Novel Delivery Systems for Skin and Mucosa

Nanocarriers (Liposomes, Niosomes, SLNs, NLCs)

Natural or synthetic phospholipid-based liposomes form bilayers that self-assemble into vesicles with hydrophilic drug placement in the core region and lipophilic drug presence in the bilayer membranes. Maherani et al.,2011, studies demonstrated that Liposome systems work well for delivering drugs to both body tissues and skin because they pose no harmful effects on biological systems. Liposomes can be adorned with surface ligands for targeted drug delivery, and their size, charge, and lamellarity can be formulated to govern the release of the drug in a controlled fashion. Stability problems from drug leakages and phospholipid oxidation can be addressed by PEGylation or freeze-drying methods (Maherani et al., 2011) Karim et al., 2010, studies demonstrated that Niosomes differ from liposomes because they use non-ionic surfactants with cholesterol while skipping phospholipids, making them more chemically resistant and cheaper to produce. These vesicles maintain better storage life while needing less production expense and maintain their shape well. Niosomes enable the loading of many drugs and make them better absorbed by the body while easing the release of medication over time. Scientists use these structures for better drug application to skin and explore cancer treatments, vaccine delivery, and anti-inflammation medicine. Furthermore, the properties, such as the size of the vesicles, the efficiency of encapsulation, and the release of the drug, can also be adjusted according to the intended application of the surfactant composition (Karim et al., 2010). Solid Lipid Nanoparticles contain solid lipids that maintain their solid state at room temperature and body temperature, thereby forming a rigid structure to incorporate drugs. The technological features of liposomes and emulsions exist within these

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carriers, which show improved characteristics compared to both methods. Souto, SLNs possess improved thermostability, controlled and prolonged drug release, and also protect sensitive compounds forms degradation and do not require organic solvents during manufacturing. They can handle different doses through different methods, such as pills and injections, plus skin patches and eye drops. Storage conditions cause lipid crystallization that leads to reduced drug loading and possible drug expulsion from SLNs. The second-generation lipid nanoparticles, called Nanostructured Lipid Carriers (NLCs) were developed to address the shortcomings of SLNs (Müller et al., 2016) The combination of solid lipids with liquid lipids (oils) during manufacturing forms an imperfect crystal structure to achieve higher drug loading capacity and lower drug expulsion. NLCs give much flexibility in drug formulation and high loading capacity for poorly water-soluble drugs, plus long-term stability. Specifically, they are excellent for delivering lipophilic drugs and have been found useful in targeting particular tissues and organs with modification of the surface. NLCs, additionally, show enforced penetration across biological barriers and diminished cytotoxicity, which makes them useful in many pharmacological and cosmetic applications (Souto et al., 2022) In conclusion, lipid-based nanocarriers – liposomes, niosomes, SLNs and NLCs- are versatile and effective drug and cosmetic carrier systems with biocompatibility, adaptability, and controlled release properties. Liposomes and niosomes offer targeted delivery and structural variability, SLNs and NLCs enhance the stability, loading capacity, drug release control. These systems provide efficacious, safe and flexible modality of treatments that spurs both therapeutic as well as aesthetic practices in a variety of routes of administration. Uniform nanosized carriers with improved stability and bioavailability usually are prepared using high-pressure homogenizers and microfluidizers. The instrument set of ultrasonication devices uses sound waves of a high frequency to decrease the size of the particle and dispersion of nanoparticles achieved. Thin-film hydration of liposome and niosome preparation methods rely on the use of rotary evaporators. To preserve the nanocarrier suspensions or to reduce weights and volumes during long-term storage, spray dryers and freeze dryers (lyophilizers) are used to dry the nanocarrier suspensions into stable dry powders (Abdelwahed et al., 2006) To deliver the drugs topically or on the mucosa, methods aerosolizers, microneedle patches, and electroporation devices can be applied to increase the penetration of nanocarriers across the skin or mucosal barrier. Besides this, some form of application of nano-spray coating systems is also implemented so as to uniformly lay down nanocarrier formulations on wound dressings, films or oral patches (Qu et al., 2022) Such devices are very important in facilitating effective production, stabilization as well as controlled delivery of nanoformulations in dermatological and mucosal medication.

Hydrogels, Films, and Sprays

Hydrogel-based systems and their derivative hydrogel-forming microneedles (HFMs) demonstrate powerful potential in medical and aesthetic applications as biocompatible devices with swelling properties that provide extensive therapeutic agent delivery capabilities. Zagórska-Dziok & Sobczak, 2020 studies demonstrated that the use of hydrogel-forming microneedles (HFMs) provides a minimally invasive approach to delivering anti-aging compounds and cosmetic items, and vitamins transdermally, so patients experience improved skin quality without substantial tissue breakdown or discomfort. These microneedles contain swellable crosslinked polymeric materials that absorb interstitial fluid through skin insertion to create a hydrated matrix that enables controlled release of incorporated active ingredients (Zagórska-Dziok & Sobczak, 2020). Healthcare facilities are adopting HFMs as drug and vaccine and biomolecule delivery systems, which offer medical professionals an alternative to traditional hypodermic devices. The technology demonstrates great potential in chronic disease care and vaccination applications, together with wound healing, because researchers can program its response to physiological stimulus events to release therapeutic substances at precise moments. The potential for personalized medicine advances when these biomarkers integrate diagnostic features with therapeutic functionality (theranostics) capabilities. The hydrogel-forming microneedle platform stands as a flexible therapeutic solution that unites cosmetic procedures with medical therapies (Parhi, 2022).

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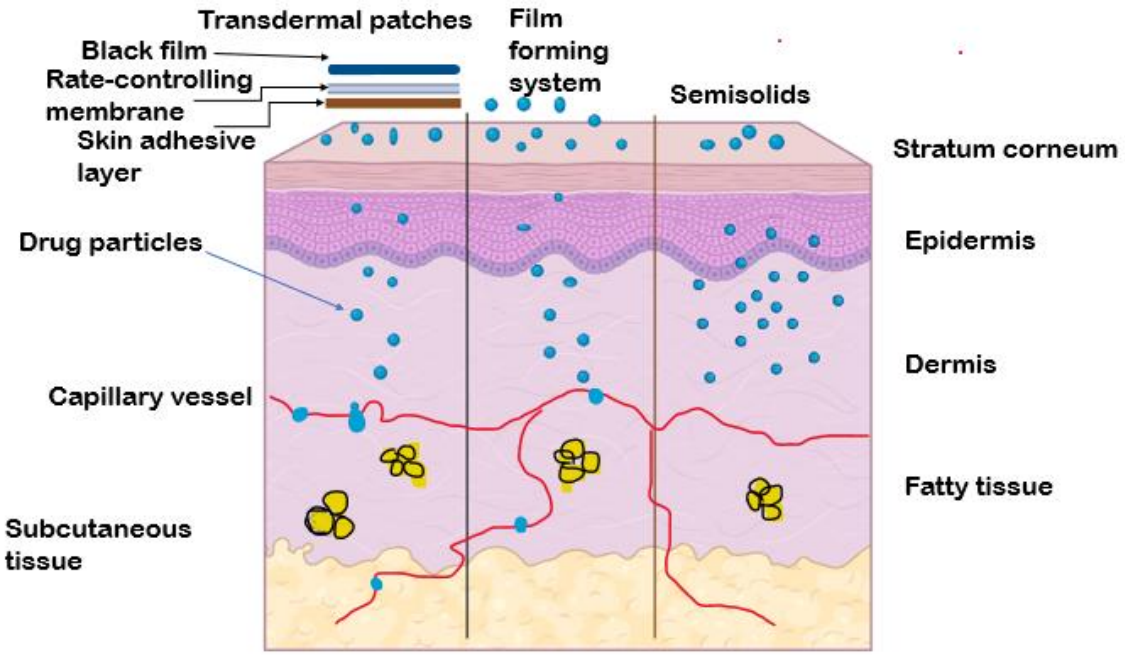

Figure 4: Drug particles are depicted in the image traveling through three different topical systems: Transdermal patches, film-forming systems, and semisolid formulas are examples of ways to give a medication that works through the skin. They communicate with the skin by delivering drugs in a controlled way. This graph shows how well the layers of the skin absorb each drug delivery method.

Novel skin and mucosal drug delivery methods use films as effective delivery systems because they produce controlled therapeutic agent distribution through localized delivery (Figure 4). Kathe & Kathpalia, 2017, demonstrated that Polymer structures designed as thin adaptable layers maintain direct contact with application areas to maximize drug delivery through the skin or mucosal interface, achieving better therapeutic outcomes (Twinkle Garg et al., 2024). When used for skin treatment applications, films present multiple benefits, including extended drug release together with protective coverage for wound sites and increased adherence from patients (Kathe & Kathpalia, 2017). Mucosal delivery using films enables medication to bypass first-pass metabolism while providing rapid effects which make mucosal administration ideal for both systemic and localized drug application. The addition of mucoadhesive properties to these systems leads to better retention times, which boosts drug availability(Shaikh et al., 2011). Film technology enables the incorporation of various drug compounds, including small molecules and biologics, while using permeation enhancers together with enzymes and nanoparticles to enhance delivery results. Their manufacturing methods, which include solvent casting combined with hot-melt extrusion and 3D printing, enable both scale-up processing and personalized treatments designed to target specific patient requirements (Figure 5). The film delivery system demonstrates potential as an attractive platform for drug delivery because it offers flexible options combined with effective drug transport and user-friendly drug administration methods (Jacob et al., 2021).

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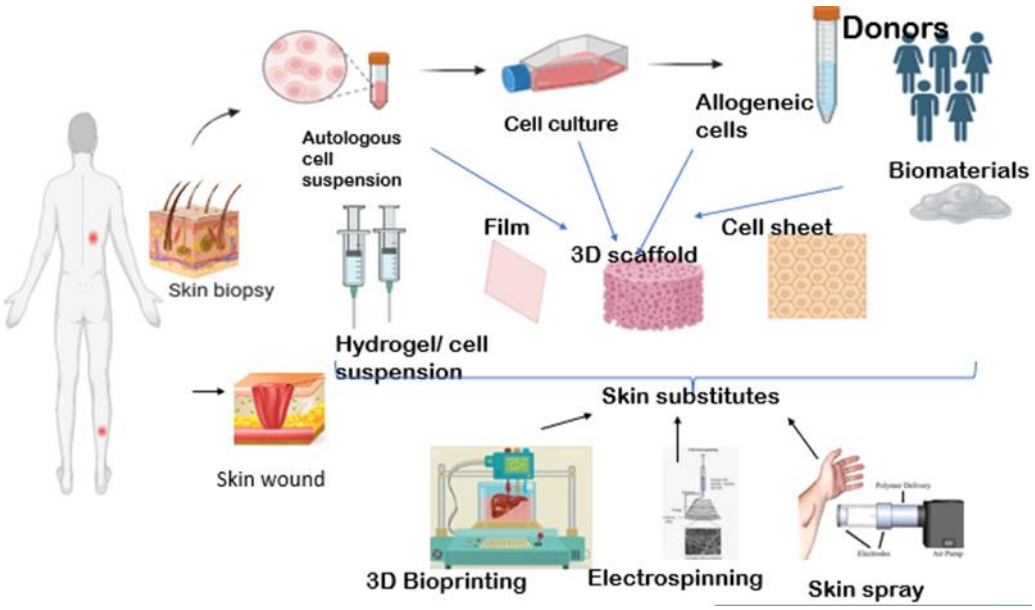

Figure 5: Current therapeutic approaches for wound healing. Skin wounds can be covered and treated with different skin substitutes such as cell suspensions, hydrogels, cell sheets, films, or 3D scaffolds, which can be fabricated by techniques like 3D bioprinting, electrospinning or skin sprays.

The ability of spray technologies to deliver accurately measured doses of active ingredients makes them important for aesthetic and medical applications. Spray delivery systems have become common for skincare because they provide direct application of moisturizers and antioxidants, and anti-aging agents through skin penetration, which reduces product waste (Souto et al., 2020). Spray technique produces uniform active distribution patterns that improve skin therapy responsiveness and cosmetic dermatology treatments, including pigmentation remedy and skin hydration and rejuvenation methods, which function optimally. Medically speaking, sprays deliver solutions through non-invasive routes to treat skin conditions effectively while managing wounds and localized infections without causing pain. The combination of advanced sprayer technology produces precise delivery of small particles, which boosts drug bioavailability while minimizing side effects that travel throughout the body and framework of the patient (Vega-Vásquez et al., 2020). Modern spray technology based on bio adhesive formulations and nano formulation enables more effective therapy for skin ulcers and chronic wounds, and burns. Spray delivery approaches continue to demonstrate increasing value and adaptability in building patient adherence and therapeutic results in aesthetic and clinical dermatology fields. In summary, hydrogel forming Microneedles, Polymeric films, and Spray technologies are transforming the transdermal and mucosal drug delivery process for both the medical as well as cosmetic contexts (Saraswati Patel et al., 2024). These systems provide accurate, non-invasive, and patient-friendly tools for the delivery of active agents with improved bioavailability and specificity. The adaptation to individualized formulations and administration, as well as the inclusion into contemporary dermatology and wound care, complements both effective results in the treatments and patients' compliance (Eicher et al., 2019).

Microneedles, Ionophoresis, and Electroporation

Both medical and aesthetic fields show considerable interest in three emerging non-invasive transdermal delivery approaches, which include microneedles and both iontophoresis and electroporation. The stratum corneum receives microchannels from microneedle applications, which allow active agent transportation while eliminating pain and bleeding, thus becoming suitable for anti-aging peptide delivery as well as vaccine and insulin distribution. Furthermore, in aesthetic dermatology, the utilization of microneedles optimizes the delivery of cosmeceuticals, including antioxidants and skin-whitening ingredients, which leads to enhanced

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dermatological rejuvenation results. An electrical current of minimal strength drives charged skin molecules during the ionophoresis procedure (Santi & Guy, 1996). The method demonstrates effectiveness for improving the delivery of peptides and hydrophilic drugs, specifically when treating patients with hyperhidrosis and localized pain management. The skin lipid bilayers become permeable during short bursts of high-voltage electricity in electroporation, which creates pathways for polar molecules and large drug molecules to enter the body. Professionals in the aesthetic sector use electroporation as an optimization technique for anti-aging treatments, while medical applications examine its potential for vaccine distribution and gene delivery. Transdermal therapy's future shows promise through technologies that deliver targeted therapeutic agents while maintaining efficiency and patient-friendly mechanisms. In conclusion, microneedles, iontophoresis, and electroporation are revolutionary non-invasive transdermal delivery techniques that have great potential in both a medical and an aesthetic sense. Such technologies increase the penetration of active agents while maintaining a patient's comfort and security. In the course of research, they are expected to be highly central in developing targeted, efficient, and user-friendly therapeutic and cosmetic procedures.

Mucoadhesive and Bioadhesive Formulations

The mucoadhesive and bioadhesive formulation group represents essential delivery systems in medical and cosmetic applications because these systems demonstrate exclusive adherence properties towards epithelial surfaces along with mucosal tissues. By increasing localized drug delivery, these systems extend drug residence time at the target site, which leads to reduced systemic effects while increasing patient medication adherence. Bioadhesive formulations demonstrate outstanding potential for medical applications which enable specific drug delivery while sustaining treatment effects to manage oral, ophthalmic and gastrointestinal and vaginal disorders (Mittal et al., 2020). Bio-adhesive materials find application in skincare and wound healing through their dual ability to form skin and mucosa-protective films and their capacity to enhance tissue regeneration as well as direct active ingredient delivery to skin and mucosal surfaces. Modern biomaterial research using hydrogels and polysaccharide-based polymers, and synthetic copolymers has substantially enhanced mucoadhesive system effectiveness by avoiding unfavourable mucosal interactions and replicating biological adhesive processes. Surface energy analysis coupled with atomic force microscopy provides advanced interface testing, which guides developers to create formulations that demonstrate both effectiveness and biocompatibility. Modern therapeutic and cosmetic strategies depend heavily on mucoadhesive and bioadhesive formulations because these innovations are transforming the development of personalized site-specific treatments (A. Kumar et al., 2020). Conclusively, mucoadhesive and bioadhesive formulations are changing the face of medical and cosmetic delivery systems with the power of accurate, localized, and sustained treatment with minimal systemic exposure. The certainty of the advances in the field of biomaterials and analytical techniques to improve their efficacy and safety provides for the development of biocompatible site-specific treatments. These innovations are vitally important for the development of personalized care that has specialized solutions for a variety of conditions in healthcare and skincare areas. Mucoadhesive and bioadhesive formulation. In formulation, evenly suspending polymers, e.g. chitosan, carbomers, or polyacrylates, with active ingredients: magnetic stirrers, high-shear mixers, and ultrasonication devices are needed, in order to come up with gels, pastes, or suspensions (Bayer, 2022) In the case of solvent-based systems rotary evaporators are utilized to concentrate or discard solvents in a regulated environment. Mucoadhesive films and inserts made by hot-melt extruders allow thermal processing (no solvents) through cyanoacrylate technology to form mucoadhesive films; freeze dryers (lyophilizers) are also used to stabilize moisture-sensitive mucoadhesive systems into solid dosage forms. To form and coat, casting machines. Mucoadhesive tablets or mucoadhesive buccal discs are manufactured by tablet compression machines and application of polymers that act as adhesive coating to films, granules or inserts are done via spray coating devices to increase the mucosal adherence (Morales & McConville, 2011). Regarding delivery, there are oral and buccal applicators that are used to apply gels or pastes in a specific area on the mucosal surfaces. Bioadhesive formulation can be specifically delivered to the nasal or buccal mucosa via nasal spray devices and transmucosal patch dispensers.

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6. Synergy Between Cosmetics and Therapeutics

Dual-action products: aesthetic and medical benefits

The synergy between cosmetics and therapeutics is powerfully reflected in the rise of dual-action products, often termed cosmeceuticals, which combine aesthetic enhancement with therapeutic benefits. These sophisticated formulations advance beauty by integrating active substances that demonstrate well-defined biological actions within the skin tissue. Retinoids direct collagen synthesis and speed up cell replacement, while peptides maintain skin elasticity, and antioxidants, vitamin C and E, protect against oxidative stress, and botanical extracts present anti-inflammatory antimicrobial properties (Fernandes et al., 2023). These products show great value for managing persistent skin conditions including acne and rosacea and hyperpigmentation and photoaging while improving skin texture and tone and appearance. Multifunctional agents permit non-invasive forms of treatment which opens doors to dermatological procedures with less aggressiveness. The increasing need for individualized preventive skincare has triggered innovations that produce specific formulations which unite cosmetic requirements with proven medical benefits. Regulatory bodies have started adapting new guidelines to handle the emerging hybrid category while providing safety inspections for medical claims made by these products. Cosmeceuticals help drive an essential transition from traditional dermatological treatments by delivering complete healthcare solutions which protect skin health and beauty needs simultaneously. Examples: Combining two skin treatment functions becomes possible through products that fight aging while reducing inflammation and controlling pigmentation along with their antioxidant properties (Eassa et al., 2020). Modernity has seen dermatology practices adopt integrated treatments which unite anti-aging with anti-inflammatory approaches because of their combined advantages. Anti-inflammatory medications decrease chronic inflammation as an aging mechanism while supporting skin barrier strength and protective capabilities. These treatments show enhanced efficacy with anti-aging interventions like retinoids and peptides to decrease aging signs, protect from skin damage, while improving appearance. The treatment outcomes for pigmentation control significantly improve when healthcare providers use antioxidant-based therapies. The antioxidants vitamin C and niacinamide, and glutathione minimize oxidative stress, which leads to hyperpigmentation and uneven skin color, while supporting agents that regulate melanin production. Both aesthetic and therapeutic skin problems are addressed by this dual mechanism, which demonstrates society's increasing preference for complete skincare solutions (Salvioni et al., 2021). In conclusion, the combination of therapeutic and cosmetic skincare in cosmeceuticals proves the growing concern about holistic, non-surgical, healthy skin approaches that can address beauty issues and medical problems. These two-in-one products are examples of dermatological innovation as they are the combination of certain biological effects with noticeable changes for the skin. While keeping up with the evolving regulatory landscapes to accommodate this hybrid category, cosmeceuticals keep on changing the face of skincare with personalized treatments that improve the skin’s aesthetic appeal and health

Challenges in product classification and claim substantiation

Modern combination effects between cosmetic and therapeutic products create complex difficulties when establishing product categories and verifying product claims. Modern products often combine two distinct functions through their formulations, which integrate anti-aging and anti-inflammatory effects or pigmentation control with antioxidant therapy. The combination of multiple functions in products creates confusion for regulators trying to distinguish cosmetic from pharmaceutical products (GABRIELLA & KENNETH S., 2015) The U.S. FDA, together with the EU and ASEAN regions, enforces diverse regulatory definitions that determine cosmetic product status from therapeutic product classification. Market regulatory discrepancies generate confusion for product development operations and marketing methods, while making compliance oversight across different markets more complicated. The demonstration of claims from cosmetic to therapeutic products needs substantial scientific support, which involves comprehensive clinical evidence coupled with biomarker testing and extensive long-term performance assessments. The lack of harmonized regulations alongside clear guidelines demonstrates an urgent requirement to promote innovation with sufficient protection of consumer trust and product integrity. Summing up, the confluence of cosmetic and therapeutic

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claims into new products makes it difficult to use straightforward classification and substantiation of the claims. Product development and adherence to the regulations are made complex even at the regional level due to the lack of uniformity in regulations. Scientific support requires strong confirmation for claims. Harmonised guidelines are critically called for to ensure innovation, confidence among consumers, as well as product integrity (Ramsay, 2016)

Natural and Plant-Based Cosmeceuticals

Natural and plant-based cosmeceuticals gained prominence as doubles-up for skincare enhancement and therapy delivery because of their contained phytochemicals which demonstrate proven pharmacological effects. Plant-based materials give better skin safety through gentle effects which benefit people who have sensitive skin (Selwyn & Govindaraj, 2023) The materials used do not contain synthetic chemicals therefore they reduce skin reactions together with allergies. Plant-based materials deliver vital skin nutrients in conjunction with antioxidant elements which support nourishment along with entire health advantages. The food contains bioactive compounds including vitamins and minerals alongside fatty acids as well as polyphenols and carotenoids which benefit the health of the skin. Plant extracts along with their components now undergo development to address both dermatologic disorders and visible signs of aging. Aloe vera stands as one of the best-known plants regarding skin care practices. Aloe vera exhibits a comprehensive list of therapeutic properties extending from its antibacterial to antifungal as well as antiviral activities that are valuable for internal treatment and external applications (Danish et al., 2020). Green tea became a historical beverage that people utilized for wellness reasons, which included improving digestion and mental focus and treating headaches, plus helping people manage their weight (Cooper, 2012). The plant finds employment in cosmeceutical products along with its several widespread applications. The product serves as a major ingredient within anti-aging pharmaceutical cosmetics. Turmeric functions at its maximum level as an agent to cleanse blood while supporting tissue regenerative processes (Kumar, 2009) Turmeric activates a cleansing mechanism through which it combats disorders triggered by elements contained in foreign blood plasma (Chattopadhyay et al., 2004). Studies conducted by scientists demonstrate turmeric has exceptional medical properties to treat allergies while reducing inflammation levels in tissue structures. (Table 2) describes the main bioactive ingredients, pharmacological effects, and cosmeceutical skincare uses for popular natural and plant-based cosmeceuticals. These botanicals are of value in modern cosmeceutical formulations as they present therapeutic benefits including anti-aging, anti-inflammatory and wound healing properties. Multiple medical studies confirm that turmeric generates superb therapeutic effects against allergies while blocking tissue inflammation. Disciplinary investigations show health benefits along with disease prevention results from human disease studies on curcumin and turmeric stay uncertain. Medical research has not verified curcumin's capability to reduce inflammation since the beginning of 2020. Research evidence indicates turmeric extracts could represent a potential treatment method for knee osteoarthritis patients. These natural products are frequently used in skin care cosmetics, including topical care products, fragrances, moisturizers, UV protective, and anti-wrinkle products (Xie et al., 2024). The combination of contemporary pharmaceutical research with traditional plant-based medicine enables researchers to develop better drugs by using transdermal systems microneedle-patch technology with encapsulation methods (Isopencu et al., 2023). Researchers created accelerated wound healing treatment through their combination of curcumin-loaded liposomes with aloe vera hydrogels (Alven et al., 2020). Cosmeceuticals serve a double purpose to shield skin while offering therapeutic possibilities for dermatologic treatment as well as mucosal therapy (Rahul & Sreedhar, 2022). Natural and plant-based cosmeceuticals come with the added advantage of skincare improvement and generation of therapeutic benefits due to their high content in phytochemicals and skin friendliness (Pandey et al., 2023). The development of secure and effective dermatological therapies is highly awaited if the integration of traditional botanicals and modern ones in drug delivery technologies is furthered.

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Table 2: Natural and Plant-Based Cosmeceuticals: Bioactive, Pharmacological Effects, and Applications

Plant Source	Key Bioactive Compounds	Pharmacological Properties	Cosmeceutical Applications
Aloe vera	Polysaccharides, vitamins (A, C, E), enzymes	Antibacterial, antifungal, antiviral, wound healing, moisturizing	Soothing gels, moisturizers, wound healing hydrogels, anti-inflammatory creams
Green tea (Camellia sinensis)	Catechins (EGCG), polyphenols, caffeine	Antioxidant, anti-aging, anti-inflammatory, UV protection	Anti-aging serums, sun protection creams, facial cleansers
Turmeric (Curcuma longa)	Curcumin, volatile oils	Anti-inflammatory, antimicrobial, antioxidant, tissue regeneration	Anti-wrinkle creams, scar reduction, skin brightening, acne treatment
Chamomile (Matricaria chamomilla)	Apigenin, bisabolol	Anti-inflammatory, calming, anti-allergic	Soothing creams, under-eye gels, moisturizers
Liquorice (Glycyrrhiza glabra)	Glabridin, glycyrrhizin	Skin lightening, anti-inflammatory, antioxidant	Brightening creams, hyperpigmentation serums
Neem (Azadirachta indica)	Azadirachtin, nimbin, quercetin	Antibacterial, antifungal, wound healing	Acne control products, antiseptic creams, cleansers
Sandalwood (Santalum album)	Santalol, sesquiterpenes	Anti-inflammatory, antimicrobial, calming	Fragrances, skin tones, soothing balms
Rose (Rosa damascena)	Phenolics, flavonoids, vitamin C	Antioxidant, anti-aging, hydrating	Facial mists, serums, moisturizers
Witch hazel (Hamamelis virginiana)	Tannins, flavonoids, essential oils	Astringent, anti-inflammatory, antimicrobial	Toners, pore refiners, aftershave lotions
Calendula (Calendula officinalis)	Triterpenoids, flavonoids	Wound healing, anti-inflammatory, soothing	Healing balms, diaper rash creams, sensitive-skin moisturizers
Carrot (Daucus carota)	Beta-carotene, vitamin A, carotenoids	Skin rejuvenation, antioxidant	Anti-aging creams, sun damage repair products
Sea buckthorn (Hippophae rhamnoides)	Omega fatty acids, carotenoids, vitamin E	Anti-aging, moisturizing, tissue repair	Facial oils, rejuvenating creams, scar treatments
Coconut oil (Cocos nucifera)	Medium-chain fatty acids (lauric acid), vitamin E	Antibacterial, emollient, antioxidant	Hair care oils, lip balms, moisturizers

Regulatory Perspectives and Safety Assessment

Since cosmeceuticals are neither medicines nor cosmetics, their classification and regulation are yet problematic. Physiologically active products that can show therapeutic properties similar to those of drugs are commonly discovered in cosmeceuticals (Darbre, 2023). They bypass however, the norms of the system of approving pharmaceutical drugs that creates grave considerations in the long term in terms of safety and quality control. According to the authors – national bodies entrusted with ensuring product safety are terribly overwhelmed by this regulatory vacuum. FDA of the US does not recognize the word “cosmeceutical” and classifies such goods either as medications or cosmetics depending on what they are designed for (Millikan, 2001). This brings under control the monitoring of

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several formulations that make pharmacological claims. But Pandey et al. also observed that before marketing is allowed, the European Union requires a stringent safety assessment, including toxicological profiling and skin sensitization testing under cosmetics regulation (EC) No. 1223/2009. Just as that, the Drugs and Cosmetics Act of 1940 regulates cosmetics in India through the Central Drugs Standard Control Organization (CDSCO). Yet the framework of CDSCO does not include any regulations that are especially for cosmeceuticals that add to the regulatory uncertainties. Ta et al. (2021) point out rise in the number of non-animal alternative testing models that are commonly used to improve safety issues such the human Cell Line Activation Test (h-CLAT), KeratinoSensTM and the Direct Peptide Reactivity Assay (Such methods diminish the ethical questions about animal testing because they allow producers and regulators to determine possible allergenicity and skin irritation in vitro(Ta et al., 2021) The authors also encourage in silico techniques, which are computer-based simulations using biological interactions as well as chemical structure analysis, to predict a sensitization potential(Russo et al., 2022). These methods find increasingly greater importance for eliminating the harmful synthetic and botanical factors prior to product development. When used together, these testing methods and regulatory systems attempt to ensure that cosmeceuticals deliver therapeutic effects with no risk to user safety. Since there are no particular regulations regarding the regulatory categorization of cosmeceuticals doubts in regards to safety or quality are posed. However, the growing application of in silico and non-animal testing procedures offer promising tools to fill moral and legal gaps and ensure products' security.

7. Conclusion

Cosmeceuticals have gained prominence as a game-changing category in dermatology due to their ability to combine cosmetic enhancement and therapeutic intervention. By using biologically active ingredients and modern delivery technologies, they treat broad variants of skin mucus problems, including anti-aging and pigmentation control, wound healing, and inflammatory diseases. Their ability to provide not only the instant cosmetic effects but also long-term therapeutic outcomes makes them a necessary part of the contemporary skincare and mucosal care practices. In addition, increasing demands for natural, plant-based, and personalized products have fuelled formulation strategies, product design, and delivery systems' developments. Notwithstanding, there is still a challenge in terms of regulation given inconsistencies in classification and claim validation, hence the need for clearer global guidelines for ensuring safety, efficacy, and consumer trust of the products. Moving forward, cosmeceuticals' future is in the area of biotechnology, artificial intelligence, and nanoscience for target-specific data-based solutions. Breakthrough platforms, including exosome-based therapies, smart microneedles, nanocarriers, and bio-responsive hydrogels, are the future of skin- and mucosal-related therapies due to their ultimate property of targeted delivery and sustained release effect and non- or minimally-invasive character. AI-based dermato-diagnostics and telemedicine systems will complement personalized skincare treatment regimens and timely monitoring of the treatment effect. Further on, as environmental awareness combined with the consideration of safety significantly gains momentum among consumers, there will be additional emphasis on plant-based actives, green chemistry, and ethical testing practices such as in vitro and in silico models. The regulatory design will be anticipated to develop with the flow, promoting innovation without compromising on strict safety standards. Ultimately, cosmeceutical products will continue to close the gap between beauty and medicine, and provide holistic, individual, science-based solutions to the improvement of an individual's skin and mucosa health in the years to come.

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During the preparation of this work, the author(s) used Grammarly, Inc. to check the grammar and Turnitin to check the plagiarism. AI was used for refining the language. After using this tool/service, the author(s) reviewed and edited the content as needed and take(s) full responsibility for the content of the publication.

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