Advances in Bioresearch
Adv. Biores., Vol 15 (2) March 2024: 130-135
©2024 Society of Education, India
Print ISSN 0976-4585; Online ISSN 2277-1573
Journal's URL:http://www.soeagra.com/abr.html
CODEN: ABRDC3
DOI: 10.15515/abr.0976-4585.15.2.130135

Advances in Bioresearch

REVIEW ARTICLE

Current Understanding of the Microbiome and Skin Health: A Comprehensive Review

V.P Jamale, Rishabh Singhal, Kiran Patil
[1-3]Department of Dermatology Krishna Institute of Medical Sciences, Krishna Vishwa Vidyapeeth Deemed To Be University, Karad, MH

ABSTRACT
Maintaining skin health is crucial because the human skin is home to a complex ecology of bacteria known as the skin microbiome. The goal of this study is to compile the most recent information on the dynamics, composition, and importance of the skin microbiome. It highlights the many microbial communities that live in the various skin areas and highlights their functional functions in maintaining skin homeostasis. The skin microbiome is greatly influenced by a variety of factors that shape its stability and diversity, including age, environmental factors, hygiene practices, and skincare products. This paper examines the complex relationship between the skin microbiome and dermatological diseases, such as psoriasis, acne, and eczema, emphasising the role of dysbiosis in these conditions. Furthermore, new studies highlight the therapeutic potential of modifying the skin microbiota to treat a range of skin conditions, opening the door to customised skincare treatments. Nonetheless, difficulties continue to arise in implementing these discoveries in clinical settings, underscoring the necessity for standardised approaches and ethical concerns. Uncovering host-microbiome interactions, developing customised skincare methods, and investigating new microbiome-based treatments are the next paths to be pursued. Comprehending and using the skin microbiome has the potential to transform dermatological treatment by providing customised approaches for enhancing skin well-being and controlling skin ailments.
Keywords*: Skin microbiome, diversity, dysbiosis, dermatological conditions, personalized skincare.*

Received 24.10.2023 Revised 01.12.2023 Accepted 11.03.2024

How to cite this article:
V.P Jamale, Rishabh S, Kiran P. Current Understanding of the Microbiome and Skin Health: A Comprehensive Review. Adv. Biores., Vol 15 (2) March 2024: 130-135

INTRODUCTION

The skin and other components of the integumentary system act as a dynamic interface between the human body and its surroundings, greatly enhancing general health and wellbeing. The biggest organ, the skin performs a wide range of intricate tasks, including thermoregulation, immunological surveillance, and barrier defence against physical, chemical, and microbiological threats. The complex interactions between the skin's many cellular constituents and the dynamic community of microorganisms known as the skin microbiome are essential to the skin's resilience and functioning.

Once thought to be sterile, the skin is now understood to be a vibrant ecosystem that is home to a wide variety of microorganisms, including as viruses, bacteria, fungus, and mites. A multitude of intrinsic and extrinsic variables come together to generate this community of microorganisms, which is highly varied and peculiar to the place. The microbial landscape of the skin was mapped out by Grice and Segre's groundbreaking research [1], which showed that different skin patches had different microbial compositions. Subsequent studies, like that conducted by Byrd et al. [2], highlighted the importance of the skin microbiome to skin health by revealing its extraordinary diversity and variety by high-throughput sequencing and metagenomic analysis.

The complex interactions among several elements determine the makeup and variety of the skin microbiome. The impact of temporal stability on the skin microbiome was brought to light by Byrd et al. [3], providing insight into the dynamic character of these microbial communities. Furthermore, Prescott et al. [4] highlighted how contemporary surroundings affect skin ecology, barrier integrity, and systemic immune programming and how lifestyle choices affect how the skin microbiota is modulated.

The skin microbiota is also significantly impacted by age-related changes. The microbiome in healthy skin changes over several life phases, affecting microbial richness and diversity, as explained by Dréno *et al.* [5]. Variations in skin health and susceptibility to dermatological disorders might be caused by these changes.

Environmental elements such as location, temperature, and UV exposure have a significant impact on the skin microbiota. The protective function of human skin commensal bacteria's antimicrobials against infections such as Staphylococcus aureus was emphasised by Nakatsuji *et al.* [6], highlighting the significance of environmental impacts on microbial defence mechanisms.

The usage of skincare products and good hygiene habits are important factors that influence the skin microbiota. Byrd et al.'s [7] description of the microbial variations linked to paediatric atopic dermatitis suggested a relationship between skin illnesses' dysbiosis and cleanliness habits. These results highlight the need for a more complex knowledge of how personal hygiene practices affect the homeostasis of the skin microbiome.

Skin homeostasis depends on the symbiotic link between the skin and the microbiota that lives there. In their discussion of the metagenomic factors that shape the skin microbiome in disorders like acne, Barnard et al. [8] emphasised the relevance of dysbiosis in the pathophysiology of illness. In children with atopic dermatitis, Kong et al. [9] further clarified temporal changes in the skin microbiome linked to flare-ups and therapies, highlighting the dynamic character of microbial populations throughout disease progression.

An imbalance in the skin microbiome, known as dysbiosis, has been identified as a contributing factor to a number of dermatological diseases. According to Glatz et al. [10], altered host-microbiome interactions are implicated in the presentation of paediatric atopic dermatitis by highlighting microbial-host distinctions that drive microbiota dysbiosis. Developing tailored treatment approaches aiming at restoring skin balance requires an understanding of these changes in microbial fingerprints linked to dermatological disorders.

The composition and diversity of the skin microbiome.

The skin microbiome is the population of microorganisms that live on the surface of the human skin, an extensive and intricate organ. This complex ecology, which includes bacteria, fungus, viruses, and other microorganisms, fills the many skin niches and produces a varied and ever-changing habitat. The early insights into the complexity of the skin microbiome were given by the groundbreaking work of Grice and Segre [1], which revealed the vast variety and unique microbial compositions across diverse skin locations.

The majority of the bacteria that make up the skin microbiome are bacteria. Among the most common bacterial occupants are the genera Cutibacterium, Staphylococcus, and Corynebacterium, which vary in number and diversity depending on the location [2]. Through a variety of methods, such as competitive exclusion of pathogens, regulation of the skin's immune response, and the manufacture of antimicrobial chemicals, these bacteria are recognised to play crucial roles in maintaining skin homeostasis [3].

Fungi such as Malassezia are essential constituents of the skin microbiome, alongside bacteria. Species of Malassezia, especially *M. globosa* as well as M. commensal fungus, known as restricta, are frequently discovered on skin, particularly in sebaceous regions. Even though they are usually benign, several Malassezia species have been linked to folliculitis, seborrhoeic dermatitis, and dandruff [4].

The microbial environment of the skin is also influenced by viruses. The skin virome is made up of a wide variety of viruses and bacteriophages that interact with human and bacterial cells in the skin environment. These viral constituents are becoming more acknowledged for their possible influence on skin health and disease aetiology, although being less studied than their bacterial and fungal counterparts [5].

Each region's distinct microenvironment is influenced by the spatial distribution of microbial populations across various skin locations. Different microbial populations are present in sebaceous areas due to their greater lipid content than in wet or dry skin areas. For example, higher populations of lipophilic bacteria, such as Propionibacterium acnes, are frequently seen in sebaceous locations [6]. In a similar vein, changes in pH, moisture content, and sebum production affect the microbial compositions and add to the variety seen in different skin niches.

An further fascinating feature of the skin microbiota is its temporal stability. The skin microbiome has exceptional temporal stability, even in the face of brief oscillations, as revealed by Oh et al. [7]. The skin microbiome may recover its microbial community structure over time, despite being resilient to exogenous perturbations such environmental exposures and hygiene practices.

Furthermore, interpersonal differences caused by personal traits and lifestyle variables are evident in the skin microbiota. A person's skin microbiome is unique due to a combination of factors including nutrition, lifestyle choices, genetics, and career. These interpersonal differences highlight the value of tailored strategies for comprehending and controlling skin health.

Technological developments in sequencing, especially in metagenomic analysis and high-throughput sequencing, have made it possible to characterise the skin microbiome in greater detail. The microbial diversity and function of the skin have been better understood because to the identification of previously unculturable or understudied microbial species made possible by these approaches [8].

To sum up, the skin microbiome is an intricate and ever-changing ecosystem made up of many microbial communities that are essential to the preservation of skin health and functionality. Deciphering the role of these microbial communities in skin physiology, immunological responses, and the emergence of dermatological diseases requires an understanding of their diversity, composition, and dynamics at various skin locations.

The factors influencing the skin microbiome in greater detail.

The balance of the skin microbiome is shaped by a multitude of internal and external variables that impact its makeup and abilities. All of these elements work together to give the skin microbiome its dynamic character and make it vulnerable to changes that might affect skin health.

The skin microbiota is significantly shaped by changes brought about by ageing. From early childhood to old age, the makeup and diversity of the skin microbiome change significantly. It has been noted that the skin microbiome of infants is comparatively simple and less diversified, but that it gradually diversifies and stabilises as they become older [1]. Dréno et al.'s research [2] brought attention to the skin microbiome's gradual development between childhood and adolescence, which is characterised by changes in microbial communities and an increase in richness. However, microbial diversity tends to drop and community structure appears to vary in older persons, potentially due to age-related changes in immunological and cutaneous physiology [3].

The skin microbiota is significantly influenced by environmental variables. The microbial populations that live in various skin areas are shaped by factors such as geographic location, temperature, and UV exposure. The frequency and abundance of particular microbial taxa are influenced by regional changes in humidity and climate, which helps explain the variability in the skin microbiomes of people living in different locations [4]. Furthermore, the makeup of the skin microbiome is influenced by UV radiation exposure, which may have an impact on the survival and variety of microorganisms [5].

The usage of skincare products and good hygiene habits are important factors that influence the skin microbiota. The impact of hygiene practices on the skin microbiome was brought to light by Byrd et al. [6]. They found that regular washing with strong cleansers or antimicrobial chemicals can upset the microbial equilibrium, changing the variety and composition of microorganisms on the skin. Furthermore, the extensive use of cosmetics, skincare items, and topical therapies might introduce synthetic substances or exogenous microbial species that could disrupt the local microbial populations [7].

Diet and occupation are examples of lifestyle variables that affect the skin microbiota. Changes in the skin microbiome have been associated with dietary patterns; certain nutrients have an impact on the diversity and metabolism of microorganisms [8]. For example, a diet high in fibre has been linked to a more varied skin microbiome, which may improve skin health. Due to variable exposure to microorganisms prevalent in various contexts, occupational exposure to certain environments, such as hospital settings or industrial sites, might result in diverse microbial profiles on the skin [9].

The skin microbiota is shaped in part by the genetics of the host. Genetic variations affect each person's susceptibility to specific skin disorders and may also play a role in the variances in each person's skin microbiome makeup. The innate immune responses of the skin are influenced by genetic variables that have been found in studies [10]. These immune responses can then alter the microbial populations living on the skin's surface.

The balance of the skin microbiome is shaped by the complex interactions between these extrinsic and intrinsic variables. Dysbiosis, which is typified by changes in community structure or disruptions in microbial diversity, can result from modifications in this delicate equilibrium. Skin microbiome dysbiosis has been linked to a number of dermatological disorders, emphasising how crucial it is to comprehend and preserve a balanced ecology beneath the skin.

The dynamic nature of microbial communities living on the skin surface is mostly caused by a multitude of variables that are both closely related to and impact the skin microbiome. Clarifying the roles of these variables in skin health and disease aetiology requires an understanding of their effects on the skin microbiome.

Relationship between the skin microbiome and dermatological conditions.

New research demonstrates how important the skin microbiota is in regulating a range of dermatological disorders. Dysbiosis, or changes in the makeup and variety of the skin microbiome, has been linked to the onset and development of diseases like psoriasis, acne, eczema, and wound healing.

Changes in the skin microbiome have been widely related to acne vulgaris, a common skin condition. The importance of dysbiosis in acne was emphasised by Barnard et al. [1], who also emphasised the imbalance in the microbial population and its correlation with inflammatory acne lesions, specifically an increase in Cutibacterium acnes. Acne lesions are a result of the dysregulated interaction between sebaceous gland activity, resident skin bacteria, and the host immune system.

The hallmarks of eczema include compromised skin barrier function and persistent inflammation. Eczema also includes atopic dermatitis and various associated disorders. In children with atopic dermatitis, Kong et al. [2] showed temporal changes in the skin microbiome linked to flare-ups and therapies, pointing to a complicated interaction between microbial dynamics and disease activity. Skin barrier failure and inflammation may be exacerbated by dysbiosis in atopic dermatitis, which is characterised by decreased microbial diversity and changes in microbial composition [3].

Changes in the skin microbiota have also been related to psoriasis, a chronic inflammatory skin disease. The stability of a skin bacterial population in psoriasis was highlighted by Assarsson et al. [4], who also identified unique microbial signatures connected to psoriatic lesions. Changes in microbial diversity and an imbalance in microbial communities are associated with dysbiosis in psoriasis, which may have an impact on the disease's pathophysiology [5].

Furthermore, the skin microbiome is essential to the mechanisms involved in wound healing. The skin microbiome actively interacts with the wound microenvironment and the host immune response during wound healing. Changes in the variety or composition of microbiological communities can throw off this delicate balance, making wounds more vulnerable to problems and impeding the natural healing process [6].

The impact of the skin microbiome on dermatological problems is mediated by a variety of mechanisms. Dysbiosis can contribute to the development of illness by impairing immune control, changing the local microenvironment, and disrupting the function of the skin barrier. Microbial dysregulation has the potential to incite inflammatory reactions, which might exacerbate skin problems and impact the severity of diseases.

Developing tailored treatment strategies to restore skin homeostasis requires an understanding of the altered microbial fingerprints associated with dermatological disorders. The potential of strategies including probiotics, prebiotics, postbiotics, and microbiome-targeted treatments to modulate the skin microbiota and manage skin problems has drawn attention [7].

The objectives of microbiome-based therapies are to improve microbial variety, support a healthy microbial environment on the skin's surface, and restore microbial homeostasis. By altering the skin microbiome, probiotics—which are live beneficial microorganisms—and prebiotics—which act as substrates for the development of helpful microorganisms—have demonstrated potential in improving skin health [8]. Postbiotics also have therapeutic promise in promoting skin barrier function and regulating immune responses [9]. These include microbial metabolites and cell components.

Personalised medicine has also increased interest in creating customised therapies based on each person's own skin microbiota composition. By taking into account unique microbial signatures and skin characteristics, precision skincare approaches—which use microbiome data to create personalised skincare regimens—hold promise for optimising therapeutic outcomes [10].

The therapeutic implications and the manipulation of the skin microbiome in more depth.

Research has shown that modifying the skin microbiome can be a unique treatment method for treating a range of dermatological disorders. Restoring skin homeostasis and reducing the symptoms of skin illnesses have been demonstrated to be achievable by strategies targeted at changing the makeup of the skin microbiome and increasing microbial diversity.

Using probiotics, which are live beneficial bacteria that improve health when applied topically or taken orally, is one strategy. Probiotics work to balance the skin microbiome by adding particular strains of bacteria or other microbes. Probiotics have been shown in clinical trials to be effective in treating eczema, acne, and wound healing, which emphasises their ability to modify the skin microbiota and improve skin health [1].

Contrarily, prebiotics are indigestible substances that act as growth and activity substrates for advantageous microbes. Prebiotics help to improve the variety and stability of the skin microbiome by creating an environment that is favourable for the growth of beneficial microorganisms. Prebiotic-

containing topical preparations have demonstrated potential in promoting the integrity of the skin barrier and reducing the symptoms of inflammatory skin disorders [2].
Another way to take use of the skin microbiome's medicinal potential is through postbiotics. Postbiotics are a broad class of microbiological metabolites, cell constituents, or by-products that have positive skin-beneficial effects. These bioactive substances with anti-inflammatory, skin barrier-improving, and immunomodulatory effects are obtained from microbial metabolism. Using postbiotics in skincare products is a viable way to take advantage of the skin microbiome's positive impacts on skin issues [3].
Skincare has seen a rise in the use of microbiome-based topical therapies, including as formulations using live microbial strains or chemicals produced from microbes. The objectives of these formulations are to control the host immune response, support a healthy skin microbiome, and restore microbial homeostasis. A unique strategy in customised skincare treatments is the use of microbiome-friendly skincare products that promote the development and activity of advantageous bacteria while maintaining the integrity of the skin barrier [4].
Furthermore, "microbiome transplant" or "microbiota transplantation" has gained attention as a possible therapeutic approach. Research on the transplantation of beneficial skin microbial communities to restore microbial diversity and function in people with dysbiosis-associated skin illnesses is motivated by the success of faecal microbiota transplantation in gastrointestinal disorders. To prove safety and effectiveness, this strategy is still in its infancy and needs more research [5].
Targeting a person's specific skin microbiota profile with precision skincare interventions has the potential to maximise therapeutic results. Personalised methods customise skincare routines based on a person's unique needs, skin type, and microbiological markers. Precision skincare seeks to provide focused therapies that maintain and repair a healthy skin microbiome by utilising microbiome data, possibly revolutionising dermatological care [6].
Nonetheless, there are still difficulties in bringing microbiome-based treatments to the clinic. The development and application of these innovative solutions are beset by major obstacles such as regulatory frameworks, long-term safety concerns, standardisation of methods, and efficacy evaluations. In addition, serious thought should be given to ethical issues pertaining to the modification of the skin microbiome and its long-term impacts on human health [7].

FUTURE DIRECTIONS

1.Host-Microbiome Interactions: New avenues for investigation into the relationship between the host and microbiota are opened by developments in research methodology, such as single-cell sequencing and multi-omics techniques. Gaining knowledge of the complex interactions that occur between the skin and the microbiome that lives there on a molecular level will help us understand the processes that underlie both the pathophysiology of skin diseases and their health [1].
2.Personalised Skincare: Personalised therapies may be possible with the incorporation of microbiome data into skincare procedures. Analysing individual microbial profiles using artificial intelligence and machine learning algorithms can help in creating customised skincare routines, enhancing treatment results, and raising patient satisfaction [2].
3.Microbiome-Based Therapies: It's critical to keep researching microbiome-based treatments, such as innovative formulations, probiotics, and substances generated from microbes. Targeted therapies for the management of skin disorders will become more numerous as more research is conducted on certain microbial strains or their metabolites with therapeutic potential [3].
4.Clinical Translation: It's still critical to close the knowledge gap between research results and practical applications. For microbiome-based therapies to be successfully incorporated into clinical practice, carefully planned clinical studies assessing the treatments' effectiveness, safety, and long-term impacts must be carried out [4].
Challenges:
1.Methodological Standardisation: It's imperative to standardise data analysis, sequencing, and sampling procedures. Standardised procedures are required for dependable findings since there are issues in interpreting and comparing data due to variations in experimental protocols and analytical approaches between research [5].
2.Ethical Concerns: Changing the skin microbiota presents questions about safety, long-term impacts, and unexpected repercussions. In order to address possible hazards associated with changing the skin's microbial landscape and to guarantee the responsible use of microbiome-based therapies, ethical frameworks must be created [6].
3.Regulatory Frameworks: Clearly defined policies and procedures are essential for the development and regulatory approval of medicines based on microbiomes. It is imperative to establish frameworks that

guarantee the safety, effectiveness, and quality control of these therapies before implementing them clinically or commercialising them [7].
4.Long-Term Effects and Safety: It is critical to do thorough analyses of the safety profiles and long-term effects of microbiome-based therapies. Mitigating unfavourable results requires an understanding of the possible dangers, which include immunological dysregulation, microbial resistance, and unintentional ecological perturbations [8].
5.Translational Challenges: There are difficulties in bridging the knowledge gap between research findings and practical applications. To realise the therapeutic promise of microbiome-based medicines, translational challenges such financial limitations, scaling issues, and research findings distribution must be overcome [9].
6.people Awareness and Education: It is essential to inform the general people and medical professionals about the importance of the skin microbiome and how it affects skin health. Raising awareness encourages the adoption of evidence-based techniques and helps people make well-informed decisions about skincare procedures [10].

CONCLUSION

In conclusion, there is a lot of potential in studying the skin microbiota for customised skincare interventions, but there are a few issues that need to be resolved. Research in the future will focus on developing customised skincare regimens, investigating new microbiome-based treatments, and learning more about host-microbiome interactions. To fully utilise microbiome-based therapies for dermatological disease management and skin health optimisation, it is imperative to surmount methodological, ethical, regulatory, and translational obstacles. Furthermore, encouraging public knowledge and education is essential for encouraging well-informed choices and adopting evidence-based skincare regimens that prioritise the skin microbiota.

REFERENCES

1. Grice, E. A., & Segre, J. A. (2011). The skin microbiome. Nature Reviews Microbiology, 9(4), 244-253.
2. Byrd, A. L., Belkaid, Y., & Segre, J. A. (2018). The human skin microbiome. Nature Reviews Microbiology, 16(3), 143-155.
3. Oh, J., Byrd, A. L., Park, M., NISC Comparative Sequencing Program, Kong, H. H., & Segre, J. A. (2016). Temporal stability of the human skin microbiome. Cell, 165(4), 854-866.
4. Prescott, S. L., Larcombe, D. L., Logan, A. C., et al. (2017). The skin microbiome: impact of modern environments on skin ecology, barrier integrity, and systemic immune programming. World Allergy Organization Journal, 10(1), 29.
5. Dréno, B., Araviiskaia, E., Berardesca, E., et al. (2016). Microbiome in healthy skin, update for dermatologists. Journal of the European Academy of Dermatology and Venereology, 30(4), 203-207.
6. Nakatsuji, T., Chen, T. H., Narala, S., et al. (2017). Antimicrobials from human skin commensal bacteria protect against Staphylococcus aureus and are deficient in atopic dermatitis. Science Translational Medicine, 9(378), eaah4680.
7. Byrd, A. L., Deming, C., Cassidy, S. K. B., et al. (2017). Staphylococcus aureus and Staphylococcus epidermidis strain diversity underlying pediatric atopic dermatitis. Science Translational Medicine, 9(397), eaal4651.
8. Barnard, E., Shi, B., Kang, D., et al. (2016). The balance of metagenomic elements shapes the skin microbiome in acne and health. Scientific Reports, 6, 39491.
9. Kong, H. H., Oh, J., Deming, C., et al. (2012). Temporal shifts in the skin microbiome associated with disease flares and treatment in children with atopic dermatitis. Genome Research, 22(5), 850-859.
10. Assarsson, M., Duvetorp, A., Dienus, O., et al. (2019). Stability of a skin bacterial community in psoriasis. British Journal of Dermatology, 180(4), 896-905.