

Cosmetic Covers for Prosthetics: Recent Advances in Materials, Fabrication Technologies, and User Acceptance

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ABSTRACT:- Cosmetic prosthetic covers play an important role in improving body image, confidence, and social participation among individuals using prosthetic limbs. Beyond functional restoration, aesthetic appearance can significantly influence psychosocial rehabilitation outcomes. This narrative review summarizes recent developments in cosmetic prosthetic covers, with emphasis on material advancements, fabrication techniques, aesthetic customization, and user acceptance. The reviewed literature highlights the continued use of silicone elastomers for achieving realistic appearance, alongside emerging applications of additive manufacturing to improve customization and accessibility. Challenges related to durability, discoloration, biocompatibility, and long-term clinical performance remain evident. User-centered design and shared decision-making are increasingly recognized as key factors in enhancing satisfaction and prosthesis embodiment. Overall, this review underscores the need for interdisciplinary collaboration to develop cosmetic prosthetic solutions that support both functional rehabilitation and psychosocial well-being.

Keywords:- Cosmetic prosthesis; prosthetic covers; rehabilitation; user acceptance; silicone materials; additive manufacturing

I. INTRODUCTION

Limb loss can have a profound impact on an individual's physical function, self-image, and social participation. While prosthetic devices primarily aim to restore mobility and functional independence, their cosmetic appearance plays a critical role in psychosocial rehabilitation. The visual realism of a prosthesis can influence confidence, perceived embodiment, and social acceptance, particularly in environments where prostheses are visible during daily activities.

Cosmetic prosthetic covers are designed to replicate the appearance of natural limbs by mimicking skin colour, texture, and anatomical contours. Traditionally, these covers have been fabricated using silicone-based materials due to their softness, translucency, and ability to achieve realistic aesthetic outcomes. However, conventional fabrication techniques are often time-consuming, costly, and dependent on skilled craftsmanship, limiting accessibility for many users.

In recent years, advances in digital technologies have introduced new possibilities for the design and fabrication of cosmetic prosthetic covers. Three-dimensional scanning, computer-aided design, and additive manufacturing have enabled improved personalization, faster production, and greater consistency. Alongside material innovation, there has been increasing recognition of the importance of user involvement in cosmetic decision-making, emphasizing shared decision processes and individual aesthetic preferences.

Despite these developments, several challenges remain. Issues related to durability, colour stability, biocompatibility, and long-term clinical performance continue to affect user satisfaction. Furthermore, psychosocial outcomes related to cosmetic appearance are not consistently evaluated in existing studies, highlighting a gap between technological innovation and rehabilitation-centered assessment.

The aim of this narrative review is to summarize recent advances in cosmetic prosthetic covers, with a focus on materials, fabrication techniques, aesthetic strategies, and user acceptance. By synthesizing current evidence, this review seeks to identify persistent limitations and future directions relevant to clinical rehabilitation practice.

II. METHODS

A narrative literature review was conducted to identify recent studies related to cosmetic prosthetic covers and their role in rehabilitation. Electronic searches were performed using databases including Google Scholar and PubMed for articles published between 2020 and 2025. Search terms included combinations of “cosmetic prosthesis,” “prosthetic cover,” “silicone prosthesis,” “aesthetic prosthetics,” and “user acceptance.”

Studies were included if they discussed materials, fabrication techniques, aesthetic customization, durability, biocompatibility, or psychosocial aspects of cosmetic prosthetic covers. Only English-language, full-text articles were considered. Editorials, conference abstracts without full text, and studies focusing exclusively on mechanical prosthetic components without cosmetic relevance were excluded.

Relevant articles were screened based on titles and abstracts, followed by full-text review where necessary. The selected literature was synthesized thematically to highlight trends, challenges, and rehabilitation-relevant outcomes associated with cosmetic prosthetic covers.

III. RESULTS

The reviewed literature identified several key themes related to the development and clinical relevance of cosmetic prosthetic covers. These themes include material selection, fabrication techniques, aesthetic realism, durability and biocompatibility, emerging hybrid designs, and user-centered outcomes. Together, these findings reflect the evolving role of cosmetic prosthetic covers within rehabilitation practice.

6.1. Materials Used in Cosmetic Prosthetic Covers

Silicone elastomers remain the most commonly used materials for cosmetic prosthetic covers due to their softness, translucency, and ability to closely resemble human skin. Many studies reported high user satisfaction with silicone-based covers, particularly in terms of appearance and tactile comfort. However, limitations related to tearing, discoloration, and microbial growth were frequently noted, especially with prolonged daily use.

Alternative materials such as polyurethane and thermoplastic elastomers have been explored to improve durability and reduce cost. While these materials demonstrated improved mechanical strength, they often lacked the visual realism and skin-like deformation required for high aesthetic acceptance. As a result, silicone continues to be preferred in clinical settings where cosmetic appearance is a priority.

6.2. Fabrication and Customization Approaches

Advancements in digital fabrication technologies have significantly influenced the production of cosmetic prosthetic covers. Three-dimensional scanning and computer-aided design enable accurate replication of residual limb geometry and contralateral limb morphology. Additive manufacturing techniques are commonly used to produce molds or internal support structures, which are subsequently combined with silicone casting.

These digital workflows offer improved customization, reduced production time, and enhanced reproducibility compared to traditional handcrafted methods. However, challenges related to surface smoothness, bonding between materials, and long-term wear resistance remain barriers to widespread clinical adoption.

6.3. Aesthetic Realism and Pigmentation

Achieving realistic skin color and texture is a major determinant of user satisfaction with cosmetic prosthetic covers. Intrinsic pigmentation techniques allow color to be incorporated directly into silicone materials, while extrinsic methods involve surface coloration applied after fabrication. Although intrinsic pigmentation offers improved depth and translucency, both approaches are susceptible to fading over time.

Environmental exposure, perspiration, and repeated cleaning were identified as contributing factors to color degradation. Several studies emphasized the need for standardized pigmentation protocols and long-term testing under real-life conditions to improve aesthetic longevity.

6.4. Durability and Biocompatibility Considerations

Durability and skin compatibility are critical factors influencing continued use of cosmetic prosthetic covers. Common issues reported include tearing at stress points, loss of elasticity, and surface degradation. Biocompatibility concerns such as skin irritation, friction-related discomfort, and microbial colonization were also noted, particularly in users with sensitive skin or high activity levels.

Surface treatments and smoother finishing techniques have been shown to reduce friction and irritation. However, the literature highlights a lack of standardized testing methods for evaluating long-term durability and dermatological safety in clinical environments.

6.5. Emerging Hybrid and Functional Designs

Recent research has explored the integration of functional elements within cosmetic prosthetic covers. These hybrid designs incorporate flexible sensors or smart materials to provide tactile feedback or monitor pressure and temperature. While such approaches demonstrate potential to enhance embodiment and functional awareness, they remain largely experimental.

Challenges related to power supply, comfort, durability, and clinical feasibility currently limit widespread implementation. Further rehabilitation-focused evaluation is required to determine their practical value in routine prosthetic use.

6.6. User Acceptance and Psychosocial Outcomes

User-centered outcomes were consistently highlighted as central to the effectiveness of cosmetic prosthetic covers. Studies reported that personalized cosmetic design and active involvement of users in aesthetic decisions improved confidence, social participation, and perceived embodiment. Preferences varied widely, with some users prioritizing natural appearance while others favored visible customization.

These findings emphasize the importance of shared decision-making within rehabilitation practice. Cosmetic prosthetic solutions that align with individual identity and lifestyle were associated with higher satisfaction and long-term use.

VII. DISCUSSION

This narrative review highlights the evolving role of cosmetic prosthetic covers within contemporary rehabilitation practice. While functional restoration remains the primary goal of prosthetic intervention, cosmetic appearance continues to play a significant role in psychosocial adjustment, self-image, and social participation among individuals with limb loss. The reviewed literature reflects growing attention to the integration of material innovation, digital fabrication, and user-centered design in cosmetic prosthetics.

Silicone elastomers remain the preferred material for cosmetic prosthetic covers due to their favorable tactile properties and ability to achieve realistic aesthetic outcomes. However, persistent challenges related to durability, discoloration, and long-term skin compatibility limit their sustained clinical performance. Although alternative elastomeric materials demonstrate improved mechanical strength, they often fail to provide the visual realism required for high user acceptance, particularly among individuals who prioritize natural appearance.

Digital fabrication technologies have introduced new opportunities for customization and accessibility. Three-dimensional scanning and additive manufacturing enable improved replication of anatomical features and reduce dependence on highly skilled manual fabrication. Despite these advantages, limitations related to surface finishing, material bonding, and wear resistance continue to restrict widespread clinical adoption. Hybrid fabrication approaches combining digital and traditional techniques may represent a practical compromise within rehabilitation settings.

Psychosocial considerations remain underrepresented in many material- and technology-focused studies. Evidence suggests that involving users in cosmetic decision-making positively influences confidence, embodiment, and long-term satisfaction. Preferences for cosmetic appearance vary widely, reinforcing the importance of individualized solutions rather than standardized designs. Rehabilitation professionals play a key role in facilitating shared decision-making and aligning cosmetic prosthetic solutions with personal identity and lifestyle.

Several gaps in the current literature were identified. These include the lack of standardized testing protocols for durability and biocompatibility, limited long-term clinical evaluation, and insufficient assessment of cosmetic outcomes using rehabilitation-relevant measures. Addressing these gaps will be essential for translating technological advances into meaningful clinical benefits.

VIII. CONCLUSION

Cosmetic prosthetic covers play an important role in supporting psychosocial rehabilitation by influencing self-image, confidence, and social participation among individuals with limb loss. Recent advances in materials and fabrication technologies have expanded opportunities for personalized and aesthetically realistic prosthetic solutions. Silicone-based materials continue to provide favorable cosmetic outcomes, while digital fabrication techniques offer improved customization and efficiency.

Despite these advances, challenges related to durability, color stability, biocompatibility, and long-term clinical performance remain evident. The reviewed literature highlights the importance of user involvement in cosmetic decision-making and the need for rehabilitation-centered evaluation of cosmetic outcomes. Future research should focus on standardized testing methods, long-term clinical validation, and interdisciplinary collaboration to develop cosmetic prosthetic covers that effectively support both functional rehabilitation and psychosocial well-being.

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