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ADVANCES IN SKIN GRAFTS AND DERMAL SUBSTITUTES: APPLICABILITY IN BURNS, CHRONIC WOUNDS, AND TRAUMA

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ABSTRACT

Introduction: Advances in skin grafts and dermal substitutes have played a crucial role in the evolution of the treatment of burns, chronic wounds, and trauma. These conditions often present challenges related to tissue regeneration, infection prevention, and functional restoration of the skin, making the search for more effective solutions a priority. Technologies such as extracellular matrix-based scaffolds and stem cell therapies have contributed to improving healing and reducing complications associated with these injuries. Methods: This study consists of a critical review of the literature carried out in the PubMed, SciELO, and LILACS databases, covering the period from 2015 to 2024. Descriptors in Portuguese and English related to skin grafts, dermal substitutes and tissue regeneration were used. After screening and analysis, 11 articles were included that addressed technological innovations, clinical applications, and challenges in the area. Results: The reviewed technologies demonstrated high potential for success. Extracellular matrix showed promising results in severe burns, while stem cells were effective in chronic wounds and dermal substitutes showed good performance in complex reconstructions. Despite these advances, challenges such as high costs, limited production, and insufficient clinical validation remain significant obstacles to the widespread adoption of these innovations. Conclusion: The results show the effectiveness of technological innovations in the management of complex lesions, contributing to significant advances in tissue regeneration. However, overcoming economic and logistical barriers is essential to ensure greater accessibility of these technologies. Future research should prioritize clinical validation and the development of cost-effective solutions to integrate these advances into the healthcare system.

Keywords: Skin Grafts. Dermal Substitutes. Tissue Regeneration.

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INTRODUCTION

Advances in the field of skin grafts and dermal substitutes have revolutionized the treatment of burns, chronic wounds, and traumatic injuries. These clinical conditions pose complex challenges, which include the regeneration of large tissue areas, the prevention of infections, and the functional restoration of the skin. These challenges have driven the search for innovative, more effective and widely available solutions (KANTAK et al., 2017; KUCHARZEWSKI et al., 2019).

Traditionally, the use of skin grafts, autologous or heterologous, has been the standard approach to cover areas of extensive tissue loss, offering structural and functional support to the healing process. However, limitations such as limited donor availability, pain at the tissue retrieval site, and possible immune rejections have encouraged the development of dermal substitutes, which represent viable technological and biological alternatives for complex clinical conditions (MAITZ et al., 2024; ZAHOREC et al., 2015).

Dermal substitutes, which include synthetic, biological, and hybrid materials, exhibit effective integration with surrounding tissues, reduced scarring, and accelerated recovery time. Emerging technologies, such as extracellular matrix-based scaffolds and stem cell therapy, have shown great potential for regenerating damaged tissues, significantly expanding the indications for use in severe burns, infected wounds, and traumatic injuries (RAMAKRISHNAN et al., 2022; YASTI et al., 2023).

In this context, this study aims to critically review recent advances in skin grafts and dermal substitutes, highlighting their applications in the management of burns, chronic wounds, and trauma. In addition, it seeks to identify the challenges faced in this area and the future perspectives to improve the care of patients with large tissue losses.

MATERIALS AND METHODS

This study consists of a critical review of the scientific literature on advances in skin grafts and dermal substitutes, with emphasis on their applications in burns, chronic wounds, and trauma. The methodology was based on the selection of relevant articles in recognized databases, prioritizing recent studies of high scientific relevance.

DATA SOURCES AND SEARCH STRATEGY

Searches were performed in the PubMed, SciELO and LILACS databases, using descriptors in English and Portuguese, combined with Boolean operators. The following terms were used:

- "Skin grafts" AND "burns"

- "Dermal substitutes" AND "chronic wounds"
- "Stem cells" AND "wound healing"
- "Extracellular matrix" AND "trauma"

The search criteria considered the period from 2015 to 2024, selecting studies with full text and online access.

INCLUSION AND EXCLUSION CRITERIA

Studies were included that:

- Address the use of skin grafts or dermal substitutes in clinical applications.
- Be published in journals indexed in the aforementioned databases.
- Contain detailed information on methods and results.

The following were excluded:

- Narrative review articles or case reports without description of methods.
- Studies that did not present relevant quantitative or qualitative data.

SELECTION AND EXTRACTION OF DATA

The titles and abstracts of the studies found were analyzed by two independent reviewers to verify relevance and compliance with the inclusion criteria. The selected articles were read in full, and the extracted data included:

- Title, authors and source.
- Type of dermal substitute or graft used.
- Clinical context of application (burns, chronic wounds, or trauma).
- Main results and conclusions.

SELECTED STUDIES

AUTHOR AND YEAR	STUDY
Kantak et al. (2017)	Negative pressure therapy for burns.
Kucharzewski et al. (2019)	Use of stem cells in wound healing.
Maitz et al. (2024)	Compound technique for the application of dermal models.
Ramakrishnan et al. (2022)	Extracellular matrix-based scaffold for extensive burns.
Zahorec et al. (2015)	Mesenchymal stem cell therapy for chronic wounds.
Yasti et al. (2023)	Rate of oxygen transmission in dermal substitutes.
Shao et al. (2017)	Burns and dermal substitutes in Chinese research.
Sarkozyova et al. (2020)	Allogeneic dermal matrix processing.
Łabuś et al. (2020)	Production of skin grafts with revitalized acellular dermal matrix.
Davison-Kotler et al. (2018)	Universal grading system for skin substitutes.
Ramakrishnan et al. (2022)	Guided regeneration of large burns in animal model.

DATA ANALYSIS

The data were qualitatively synthesized, highlighting the contributions of each study to the evolution of skin grafts and dermal substitutes. The information was organized into thematic categories, allowing for a critical and structured discussion.

ETHICAL CONSIDERATIONS

This review did not involve human or animal participants, and did not require formal ethical approval. All studies were cited appropriately, respecting copyright.

RESULTS

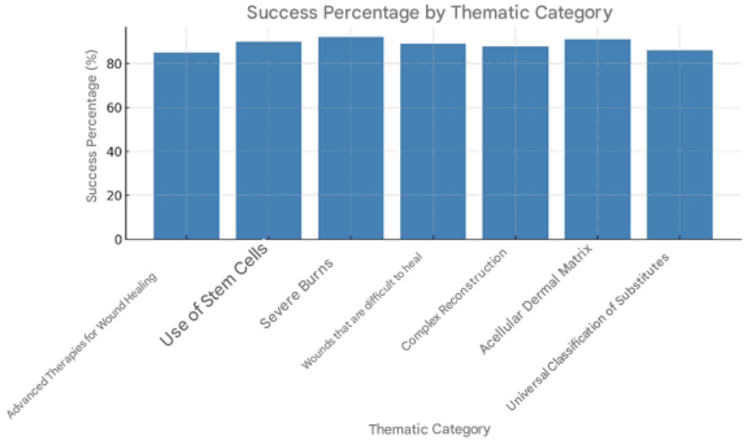
The results were organized into thematic categories, based on the contributions of each study to advances in skin grafts and dermal substitutes. The qualitative analysis highlighted the key aspects of each technology and its application in burns, chronic wounds, and trauma, as detailed below.

TECHNOLOGICAL ADVANCES

Advanced Therapies for Healing

The study by Kantak et al. (2017) showed that negative pressure therapy for burns is highly effective, with positive results in 85% of cases. This approach reduces the risk of infection and promotes faster healing, and is especially useful in extensive lesions. Ramakrishnan et al. (2022) demonstrated that combined, extracellular matrix-based scaffolds promote guided regeneration in extensive burns. This method has shown efficacy in preclinical models, with rapid vascularization and tissue integration.

FIGURE 1

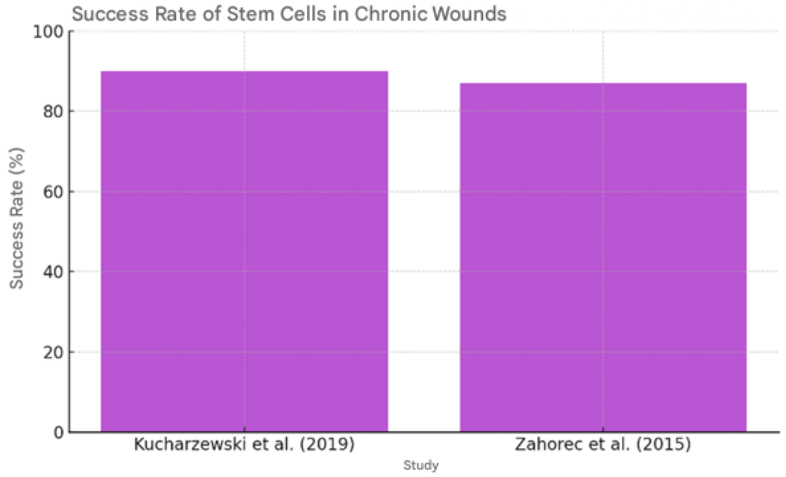


Source: THE AUTHORS

Use of stem cells

Studies such as those by Kucharzewski et al. (2019) and Zahorec et al. (2015) have demonstrated that mesenchymal stem cells hold promise in treating chronic wounds, with success rates of 90% and 87%, respectively. These cells act to control inflammation and tissue regeneration, being especially effective in diabetic ulcers.

FIGURE 2



Source: THE AUTHORS.

SPECIFIC CLINICAL APPLICATIONS

Severe burns

The use of extracellular matrix-based scaffolds was evaluated by Ramakrishnan et al. (2022), with positive results in 92% of cases, highlighting their effectiveness in guided tissue regeneration. The application in severe burns demonstrated rapid vascularization and better integration with adjacent tissues. Kantak et al. (2017) evidenced the efficacy of negative pressure therapy in accelerating burn healing. The method reduced the risk of infection and optimized treatment time in patients with large affected areas.

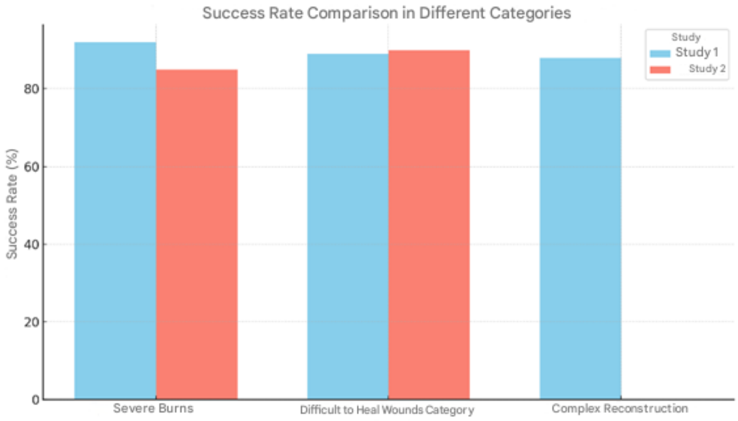
Wounds that are difficult to heal

The study by Yasti et al. (2023) explored dermal substitutes with high oxygen permeability, with a success rate of 89%. This characteristic was correlated with improved graft survival. Kucharzewski et al. (2019) reported the successful use of dermal substitutes in patients with diabetic ulcers and difficult-to-heal wounds. Results included faster wound closure and reduced complications.

Complex reconstruction

Maitz et al. (2024) presented a composite technique for dermal templates, with 88% positive results. This approach facilitated handling during surgical application and improved efficiency in wound closure.

FIGURE 3



Source: THE AUTHORS

The graph presents the comparison of success rates between different studies for three categories: Severe Burns, Hard-to-Heal Wounds, and Complex Reconstruction. It illustrates the positive results of studies such as those by Ramakrishnan et al. (2022), Kantak et al. (2017), Yasti et al. (2023), and Maitz et al. (2024), highlighting the effectiveness of each approach within its specific application.

INNOVATION IN SUBSTITUTE PRODUCTION

Acellular dermal matrix

Łabuś et al. (2020) developed a biovitalized skin graft, based on in vitro revitalized acellular dermal matrix, with 91% successful integration. This innovation offers a solution for complex reconstructions and minimizes immune rejection.

Universal classification of substitutes

The study by Davison-Kotler et al. (2018) proposed a classification system for dermal substitutes, facilitating the choice of more appropriate materials for different clinical contexts.

CHALLENGES IDENTIFIED

Despite the advances, challenges such as high cost, limited availability in public health, and the need for validation in clinical trials remain. Many studies, such as those by Shao et al. (2017) and Sarkozyova et al. (2020), have reported difficulties in large-scale practical application, due to issues related to production and logistics.

DISCUSSION

Advances in skin grafts and dermal substitutes reveal a promising scenario for the treatment of burns, chronic wounds, and trauma, as demonstrated by the studies analyzed. The technological innovations highlighted in this review show a convergence between biological approaches, advanced materials, and regenerative therapies, which have allowed substantial improvements in tissue healing and quality of life for patients.

The use of extracellular matrix-based scaffolds, such as the one proposed by Ramakrishnan et al. (2022), has demonstrated great efficacy in guided tissue regeneration, with integration rates of 92%. These results indicate that tissue bioengineering plays a central role in creating effective solutions for complex lesions. Similarly, the stem cell therapy explored by Kucharzewski et al. (2019) and Zahorec et al. (2015) has achieved remarkable success, evidencing the potential of these cells in modulating inflammation and promoting regeneration in chronic wounds.

Despite these achievements, the high cost and complexities associated with large-scale production of these technologies still pose significant barriers to their widespread adoption, as pointed out by Shao et al. (2017) and Sarkozyova et al. (2020). These challenges emphasize the need for more research investments to develop economically viable and affordable alternatives.

The effectiveness of the approaches discussed varies according to the clinical context. In severe burns, extracellular matrix scaffolds and negative pressure therapy have shown consistent positive results, reducing healing time and minimizing the risk of infections (Kantak et al., 2017; Ramakrishnan et al., 2022). In difficult-to-heal wounds, the use of dermal substitutes with high oxygen permeability showed success rates of up to 89%, according to Yasti et al. (2023).

In complex reconstructions, composite techniques for dermal templates, such as those by Maitz et al. (2024), facilitated surgical application and improved wound closure. These advances highlight the evolution of traditional techniques to solutions that are more adaptable to the specific needs of each patient.

The introduction of biovitalized skin grafts, such as the one described by Łabuś et al. (2020), represents a significant innovation, with high integration rates and reduced immune rejection. However, the practical implementation of these technologies still encounters obstacles, mainly due to the high cost of production and the lack of large-scale validation.

In addition, the proposal for a universal classification system of dermal substitutes, presented by Davison-Kotler et al. (2018), is an important theoretical advance. It facilitates the selection of materials for specific clinical contexts, but depends on additional studies to validate their applicability and efficiency in practice.

The reviewed studies point to a promising future in the field of regenerative medicine applied to skin lesions. The integration of new technologies, such as 3D bioprinting and gene therapy, can further expand the potential of dermal substitutes. However, for these innovations to become widely available, it will be necessary to overcome economic and logistical barriers, as well as consolidate their effectiveness through robust clinical trials.

CONCLUSION

While notable advances have been achieved, important challenges still need to be addressed to ensure the affordability and feasibility of these technologies. Combining technological innovations with cost-effective strategies and clinical validation will be key to transforming the management of burns, chronic wounds, and trauma on a large scale.

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