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An Overview, Limitations, and Future Prospects of Reconstructive Plastic Surgery in Burn Injuries

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Abstract

Reconstructive plastic surgery plays a crucial role in the treatment of burn injuries, aiming to restore both function and aesthetics for patients who have suffered from severe burns. The primary focus is on repairing damaged tissues, minimizing scarring, and addressing deformities caused by burn injuries, which can lead to long-term physical and psychological challenges. Techniques such as skin grafting, flap surgery, scar management, contracture release, and tissue expansion are commonly used to restore skin integrity and mobility. Innovations in regenerative medicine, stem cell therapy, tissue engineering, and 3D bioprinting hold significant promises for improving burn reconstruction outcomes in the future. Despite the progress, challenges such as scarring, donor site limitations, and psychological effects persist, requiring a multidisciplinary approach for optimal recovery.

Keywords: Burn injuries, Plastic surgery, Burn reconstruction, Limitations, Future prospects

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Introduction

Plastic surgery is a specialized branch of medicine focused on altering, reconstructing, or restoring the human body to enhance functionality, aesthetics, or both (Figure 1) [1]. Rooted in ancient practices, plastic surgery has evolved dramatically over centuries, with advances in medical techniques and technology allowing for safer and more effective procedures [3]. The discipline encompasses two primary domains: reconstructive surgery, which repairs defects or injuries, and cosmetic surgery, which aims to improve appearance [4].

Reconstructive plastic surgery

This addresses physical deformities caused by trauma, birth defects, diseases, or accidents [1]. Procedures such as skin grafts for burn victims, cleft palate repairs, and breast reconstruction following mastectomy exemplify its life-altering potential [5]. By restoring normal function and appearance, reconstructive surgery significantly improves patients' quality of life and psychological well-being, demonstrating the profound impact of medical innovation on human resilience [5].

Cosmetic plastic surgery

On the contrary, cosmetic plastic surgery is elective and focused on enhancing physical appearance through procedures such as rhinoplasty, liposuction, and facelifts [6]. While often misunderstood as purely aesthetic, these surgeries can also boost self-esteem and confidence, contributing to emotional health. Despite controversies surrounding societal pressures and ethical considerations, plastic surgery remains an invaluable field blending art and science to meet diverse human needs [7].

Reconstructive Plastic Surgery

Reconstructive plastic surgery is a crucial medical specialty aimed at restoring function, form, and normalcy to parts of the body affected by congenital abnormalities, trauma, infections, tumors, or diseases [8]. Unlike cosmetic surgery, which primarily focuses on enhancing appearance, reconstructive surgery prioritizes correcting deformities and improving physical capabilities [8]. The field is rooted in ancient practices but has evolved significantly with advancements in surgical techniques, materials, and medical imaging technologies, enabling more precise and effective interventions (Table 1).

One of the primary objectives of reconstructive plastic surgery is to repair congenital deformities, such as cleft lips, palates, and craniofacial anomalies, which can impair basic functions like eating, speaking, and breathing [9]. These procedures not only improve physiological outcomes but also foster social acceptance and emotional well-being, particularly in children and adolescents. Surgeons use innovative techniques like tissue expansion and microvascular surgery to achieve optimal results, ensuring patients regain both functionality and confidence [10].

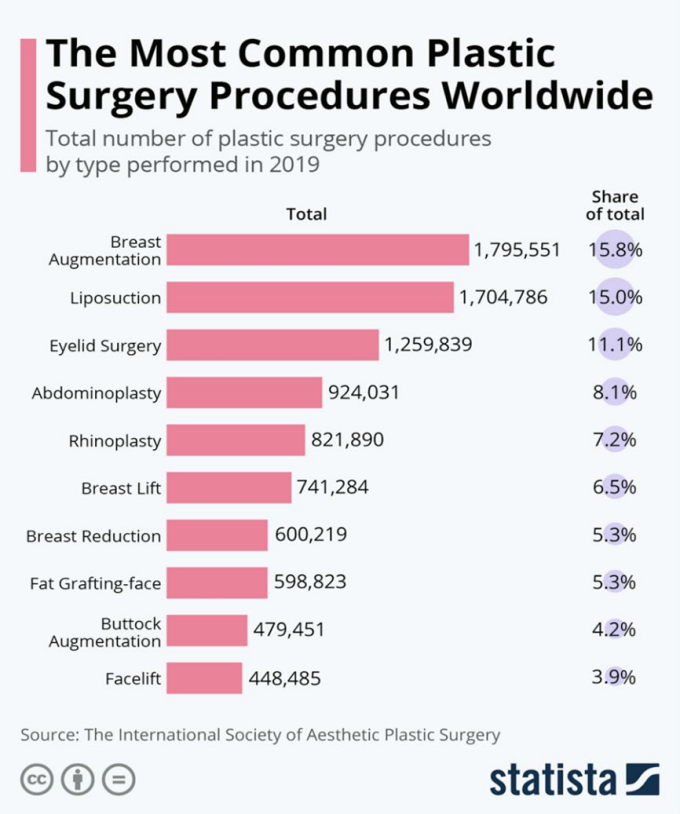

Figure 1: Common plastic surgery procedures [2].

Table 1: Overview on applications of reconstructive plastic surgery.

Application area	Description	Examples of procedures	Benefits
Burn injury reconstruction	Restores function and appearance after severe burns	Skin grafting, flap surgery, tissue expansion, and contracture release	Restores mobility, reduces scarring, and enhances quality of life
Congenital anomalies	Corrects birth defects affecting appearance and function	Cleft lip/palate repair, craniosynostosis correction, and syndactyly release	Improves speech, feeding, mobility, and social integration
Trauma repair	Addresses injuries from accidents, including fractures and soft tissue damage	Bone fixation, skin flap for exposed wounds, microsurgery for replantation of amputated parts	Restores form and function, improves healing outcomes
Cancer reconstruction	Rebuilds structures after tumor removal, particularly in breast and head/neck cancers	Breast reconstruction post-mastectomy, jaw reconstruction, and facial flap reconstructions	Restores aesthetic appearance and functionality, improving psychological recovery
Scar revision	Reduces the appearance and impact of scars from injuries, surgeries, or burns	Z-plasty, laser treatments, and steroid injections	Improves skin texture, reduces scar visibility, and restores flexibility
Hand and extremity surgery	Restores function in hands and limbs after trauma or disease	Tendon repair, nerve decompression, and finger replantation	Restores fine motor skills, sensation, and functional independence
Craniofacial reconstruction	Reconstructs facial bones and soft tissues after trauma or congenital defects	Orbital repair, maxillary/mandibular reconstruction, and soft tissue contouring	Improves appearance, chewing, breathing, and vision functionality
Gender-affirming surgery	Helps transgender individuals align physical characteristics with their gender identity	Chest reconstruction, phalloplasty, and vaginoplasty	Enhances psychological well-being, improves social integration
Limb salvage	Saves and reconstructs limbs at risk of amputation due to injury or disease	Vascularized bone grafts, skin grafts, and microsurgical flaps	Preserves functionality and prevents disability
Post-infectious reconstruction	Repairs damage caused by infections like necrotizing fasciitis	Skin grafts, and flap surgery for large tissue defects	Restores lost tissue, and prevents deformities
Reconstructive microsurgery	Uses microsurgical techniques to repair nerves and vessels for tissue transfer	Free flap transfers, nerve grafts, and vascular anastomosis	Enables precise, functional restoration for complex injuries or defects
Aesthetic enhancements in reconstruction	Combines functional repair with aesthetic improvement for better outcomes	Rhinoplasty post-trauma, breast contouring after cancer reconstruction	Boosts confidence, ensures holistic recovery

Trauma and accidents often leave individuals with devastating injuries, such as burns, fractures, and soft tissue damage [9]. Reconstructive surgery plays a vital role in such scenarios by addressing scars, nerve damage, and disfigurement through skin grafts, flap surgeries, and advanced wound management [8]. For instance, microsurgery allows the reattachment of severed fingers or limbs, showcasing the field's ability to restore physical capabilities that were once deemed irreparable.

In addition to trauma, reconstructive surgery is indispensable in oncology care, where it aids in the rehabilitation of patients undergoing treatments for cancers like breast, head, and neck malignancies [11]. Post-mastectomy breast reconstruction and facial reconstructions following tumor removal highlight the intersection of surgical precision and compassion [12]. Beyond physical restoration, these procedures significantly impact psychological recovery, underscoring the holistic value of reconstructive plastic surgery in improving lives.

Burn Injuries

Burn injuries are a significant global health concern, affecting millions of individuals annually [13]. According to the World Health Organization, approximately 11 million people worldwide require medical attention for burns each year, with a substantial number of cases resulting in long-term disabilities or fatalities [13]. Low- and middle-income countries bear the brunt of this burden, accounting for over 90% of burn-related deaths, primarily due to limited access to advanced healthcare facilities and prevention measures. In contrast, high-income countries report lower mortality rates, reflecting the efficacy of modern burn care systems [14, 15].

In the United States, the American Burn Association estimates that 450,000 individuals receive treatment for burn injuries annually, with around 3,500 deaths attributed to fire or smoke inhalation [16]. Advances in acute care have drastically improved survival rates, with nearly 97% of patients treated at burn centers surviving [17]. However, survivors often face prolonged hospital stays, extensive rehabilitation, and significant psychological and emotional challenges stemming from disfigurement and trauma. Notably, burns are more prevalent among children and young adults, with scalding injuries constituting a leading cause in domestic settings [18].

Occupational hazards are another major contributor to burn injuries, especially in industries involving chemicals, electricity, or flammable materials [19]. In India, for example, an estimated 1 million people sustain moderate to severe burns annually, with women frequently injured in domestic accidents involving open flames or unsafe cooking practices [20]. Workplace safety measures and community-based interventions have proven effective in reducing these statistics, but challenges remain in achieving widespread implementation. Table 2 presents brief overview of techniques for use in acute phase of scar maturation to diminish reconstructive needs. These techniques aim to promote optimal healing during the acute phase, thereby reducing the extent of reconstructive interventions needed later. Early and proactive management is key to achieving favorable outcomes in scar maturation and patient recovery.

Beyond the immediate physical effects, burns have far-reaching socio-economic implications [21]. Survivors often require expensive and prolonged care, including surgeries, skin grafts, and psychological support [22]. In low-resource settings, the financial strain on families can be devastating. Addressing burn injuries globally requires a multifaceted approach encompassing prevention strategies, improved access to medical care, and rehabilitation programs to ensure a better quality of life for survivors [23].

Approaches for treating burn injuries

The treatment of burn injuries involves a multidisciplinary approach tailored to the severity and type of burn, aiming to stabilize the patient, prevent complications, and promote healing (Table 3) [14]. Initial management focuses on resuscitation and wound stabilization. For severe burns, fluid resuscitation using the Parkland Formula is critical to restore circulatory volume and prevent shock [24]. Inhalation injuries, often accompanying thermal burns, require prompt oxygen therapy and ventilatory support to ensure adequate respiratory function [25].

Once the patient is stabilized, wound care becomes the central focus of treatment. Debridement, the removal of dead tissue, is essential to prevent infection and promote healthy tissue growth [26]. Antimicrobial dressings, including those infused with silver or iodine, are commonly used to reduce bacterial colonization [27]. In severe

Table 2: Techniques for use in acute phase of scar maturation to diminish reconstructive needs.

Technique	Description	Benefits	Purpose
Pressure therapy	Application of pressure garments to the burn area to flatten scars and prevent contractures	Reduces hypertrophic scar formation, controls itching, and improves skin appearance	Compression garments are used after healing second-degree burns to minimize scar thickness
Silicone therapy	Use of silicone sheets or gels on healing wounds	Softens scars, reduces redness, and improves skin texture	Silicone gel sheets applied to healing wounds on the face to prevent hypertrophic scarring
Massage therapy	Gentle massage of scar tissue to break down adhesions and improve elasticity	Increases blood flow, promotes collagen remodeling, and enhances flexibility	Massage of hand burns to prevent tendon adhesions and restore mobility
Topical agents	Application of agents like corticosteroids or onion extract-based gels	Reduces inflammation, controls scar proliferation, and improves texture	Corticosteroid creams applied to early hypertrophic scars to suppress excess collagen growth
Laser therapy	Non-invasive use of fractional CO_2 or pulsed dye lasers to target scar tissue	Improves scar color, texture, and pliability by remodeling collagen	Fractional CO_2 laser treatment for early facial scars to reduce pigmentation and thickness
Moisturization	Regular use of emollients to keep the skin hydrated and supple	Prevents cracking, itching, and excessive scar formation	Application of moisturizing ointments on partially healed burns to maintain elasticity
Steroid injections	Direct injection of corticosteroids into hypertrophic scars	Reduces inflammation, scar elevation, and associated pain	Triamcinolone injections used in raised scars on arms to flatten and soften tissue
Radiotherapy	Low-dose radiation applied immediately after skin grafting in severe cases	Prevents excessive fibroblast activity and reduces keloid formation	Use of radiotherapy in keloid-prone areas after ear or chest burns to prevent severe scarring
Splinting	Use custom-made splints to maintain proper joint positioning during healing	Prevents contractures, maintains joint function, and ensures proper wound healing alignment	Splints used for wrist burns to prevent flexion contractures during healing
Early surgical interventions	Timely excision of necrotic tissue and grafting to minimize wound complications	Reduces infection risk, shortens healing time, and prevents deep scarring	Early escharotomy and skin grafting in circumferential third-degree burns
Cryotherapy	Use of freezing techniques on early scar formations	Destroys abnormal scar tissue and reduces keloid formation	Cryotherapy applied to small keloids forming on chest post-healing

Table 3: An overview of timing of burns reconstructive surgery.

Timing	Phase description	Surgical goals	Examples of procedures
Acute phase (0 to 7 days)	Initial treatment phase, addressing life-threatening conditions and wound stabilization	Focus on saving life, preventing infection, and ensuring optimal wound healing conditions	Escharotomy for circumferential burns, early excision, and grafting for deep burns
Early phase (7 days to 3 weeks)	Period of wound closure and scar maturation begins	Minimize scar formation, promote wound closure, and prevent contractures	Skin grafting for second-degree burns, temporary skin substitutes (e.g., Biobrane)
Intermediate phase (3 weeks to 3 months)	Transition phase as scars mature and functional issues emerge	Address early scar contractures, manage mobility restrictions, and prepare for final reconstructive surgeries	Z-plasty for contractures, limited scar revisions for hypertrophic scars
Late phase (3 months to 2 years)	Scars have matured; reconstruction is focused on long-term functional and aesthetic improvement	Correct deformities, improve aesthetics, and restore function through advanced reconstructive techniques	Tissue expansion, flap reconstructions, and advanced scar revisions
Long-term phase (>2 years)	Final stage for addressing residual deformities and optimizing outcomes	Perform secondary corrections, enhance cosmetic appearance, and refine functional restoration	Secondary grafts, laser treatments for scar refinement, and aesthetic facial surgeries

Note: Surgery is only performed when the patient is medically stable to avoid complications. Timing may vary based on burn depth, extent, and location (e.g., face and hands). Reconstructive efforts are optimized when scars are mature enough to respond effectively to surgery.

Table 4: Overview of role of reconstructive plastic surgery in burn injuries.

Role	Description	Examples of procedures	Benefits
Wound closure	Addresses large or non-healing burn wounds to prevent infection and promote healing	Skin grafting, use of bioengineered skin substitutes like integra	Reduces healing time, prevents complications, and promotes tissue regeneration
Scar management	Reduces the severity of hypertrophic scars and keloids caused by burns	Laser therapy, steroid injections, silicone therapy, Z-plasty	Improves appearance, skin flexibility, and functionality of scarred areas
Contracture release	Restores mobility by releasing tight scar tissues that restrict movement	Contracture release surgery with flap or graft coverage	Improves range of motion, particularly in joints like elbows, knees, or neck
Reconstruction of aesthetic areas	Restores the appearance of visually sensitive areas such as the face, neck, or hands	Tissue expansion, facial contouring, microvascular free flap reconstructions	Enhances psychological well-being, improves confidence and social reintegration
Functional restoration	Reconstructs essential structures to restore key functions like gripping, chewing, or speaking	Hand reconstruction, jaw reconstruction, oral soft tissue grafting	Restores critical daily activities and ensures independence
Comprehensive burn coverage	Covers extensive burns using advanced surgical techniques to prevent exposure of underlying tissues	Flap surgeries, full-thickness grafts, pedicled flaps for large burns	Prevents secondary infections and minimizes future reconstructive needs
Advanced wound care	Utilizes modern methods for wound healing and tissue repair	Negative pressure wound therapy (NPWT), use of amniotic membrane grafts	Accelerates wound healing, minimizes scar tissue, and promotes better outcomes
Psychological impact mitigation	Addresses the emotional and psychological scars resulting from severe disfigurement	Reconstructive surgeries tailored to aesthetic and functional restoration	Improves mental health, boosts self-esteem, and aids in social acceptance
Pediatric burn rehabilitation	Addresses unique challenges in children such as growth-related issues and sensitive skin	Growth-compatible tissue expansion, scar release, and reconstruction procedures	Ensures better adaptation to growth and functional recovery during developmental stages
Innovative reconstructive techniques	Incorporates cutting-edge methods like 3D printing and bioengineered materials for burn treatment	3D printed scaffolds for tissue reconstruction, stem cell therapy	Reduces dependency on donor skin, customizes solutions for complex injuries

cases, skin grafting or the use of bioengineered skin substitutes may be necessary to cover large wounds, minimize scarring, and restore skin integrity [28]. Advanced technologies like laser-assisted wound healing and NPWT have also gained prominence for their effectiveness in enhancing tissue repair [29].

Pain management and infection control are critical components of burn care [30]. Burn injuries are notoriously painful, requiring a combination of systemic and topical analgesics to alleviate discomfort. Antibiotic therapy is employed prophylactically or in response to infection, a leading cause of morbidity in burn patients [31]. For more extensive burns, rehabilitation programs involving physical therapy are initiated early to prevent contractures and maintain mobility [32].

Psychological support and long-term rehabilitation are vital for improving the quality of life for burn survivors [33]. The physical disfigurement and emotional trauma associated with burns often result in depression, anxiety, and social withdrawal [34]. Psychological counseling, along with reconstructive surgery to improve appearance and functionality, can significantly aid in recovery. Innovations in reconstructive techniques, such as tissue expansion and 3D-printed skin scaffolds, have enhanced outcomes for patients, allowing for more personalized and effective care [35].

Role of reconstructive plastic surgery in burn injuries

Reconstructive plastic surgery plays a pivotal role in the management and recovery of burn injuries by addressing both functional impairments and aesthetic deformities (Table 4) [1]. Burns, especially severe ones, can cause extensive damage to the skin, underlying tissues, and structures, often leading to contractures, scarring, and loss of mobility (Figure 2) [13]. Through advanced surgical interventions, reconstructive plastic surgery provides patients with the opportunity to regain functionality, improve appearance, and enhance their quality of life (Table 5) [13].

One of the fundamental techniques in reconstructive surgery for burn injuries is skin grafting, where healthy skin is transplanted to cover large wounds [37]. There are two primary types: split-thickness grafts, used for superficial burns, and full-thickness grafts, applied to

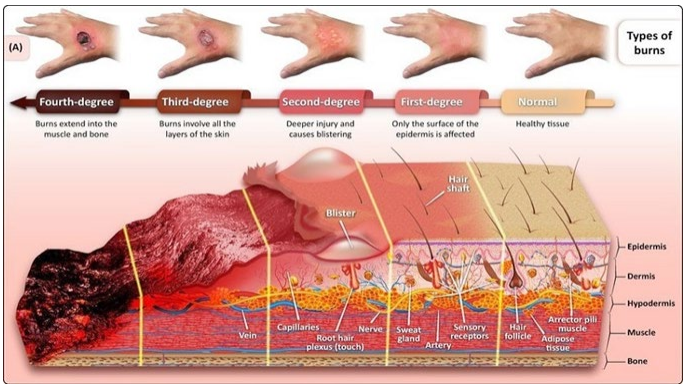

Figure 2: Anatomy of different types of burns [36].

Table 5: Overview of burn degree, plastic surgery, success rate, and rehabilitation time.

Burn degree	Characteristics	Plastic surgery role	Success rate[1]	Rehabilitation time[2]
First-degree burn	Superficial burns affecting only the epidermis (e.g., sunburn)	Usually no surgery is required; focus on topical care	Very high (nearly 100%)	1 - 2 weeks for complete recovery
Second-degree burn (partial thickness)	Damage extends to dermis; blisters, redness, and pain are present	Skin grafting for deep partial-thickness burns; scar management techniques	High (95 - 98%)	2 - 4 weeks for superficial; 1 - 2 months for deep burns
Third-degree burn (full thickness)	Destruction of epidermis and dermis; white, leathery skin; nerves may be damaged	Skin grafting, flap surgeries, use of bioengineered skin substitutes	Moderate to high (85 - 95%)	2 - 6 months, depending on wound size and complexity
Fourth-degree burn[3]	Extends to muscles, tendons, or bones; high risk of complications	Extensive reconstructive surgery, flap transfers, amputation in severe cases	Variable (60 - 80%, depending on extent)	Several months to years, including multiple surgeries and rehabilitation phases
Electrical or chemical burns	Specific subtypes cause internal or deep tissue damage	Reconstruction of damaged areas, nerve and vessel repair via microsurgery	Variable (70 - 90%, depending on severity)	Months to years, depending on depth and complexity of damage
Facial burns	Burns affect sensitive and aesthetic areas like eyes, lips, or nose	Tissue expansion, microvascular reconstructions, aesthetic refinements	High (90 - 95%)	6 months to 1 year for functional and aesthetic recovery
Pediatric burns[3]	Burns in children require special consideration for growth	Growth-compatible reconstructive surgeries, frequent follow-ups for scar management	High (85 - 95%)	Ongoing adjustments over several years

Note: [1]Success rates are generally high due to advancements in reconstructive techniques, but depend on burn severity, comorbidities, and timeliness of treatment; [2]Rehabilitation time is prolonged for severe burns due to scarring, contractures, and secondary surgeries; and [3]Customization of treatment and rehabilitation are tailored to individual needs, especially for pediatric and fourth-degree burns.

deeper injuries [38]. For example, in a patient with extensive second-degree burns covering the legs, split-thickness grafts harvested from the thigh can facilitate wound closure and minimize scarring, promoting faster recovery [38].

In cases of severe burns where skin grafts are insufficient, flap surgery offers a viable alternative. Flaps involve the transplantation of skin along with underlying tissues, such as muscles or blood vessels, to repair more complex defects [39]. For instance, a burn injury resulting in the exposure of bone or tendons on the hand may require a pedicled flap or free flap reconstruction to restore the damaged structure [40]. These procedures significantly improve functionality, particularly in areas like hands, where intricate movements are essential.

Burn scars often lead to contractures, restricting mobility and causing significant discomfort [41]. Reconstructive plastic surgeons address these complications through contracture release surgeries, wherein scar tissue is excised, and the area is repaired using skin grafts or flaps [42]. A common example is treating neck contractures in burn survivors to restore normal head movement [43]. This procedure is crucial for children, whose growing bodies can be severely impacted by untreated contractures [43].

Advancements in reconstructive techniques have introduced tissue expansion, which allows surgeons to generate additional skin for grafting purposes [3]. This technique is particularly useful for patients with extensive burns but limited donor skin. In one notable case, tissue expanders were used to reconstruct the scalp of a patient with severe third-degree burns, demonstrating its ability to restore both form and function in aesthetically sensitive areas [44].

Another groundbreaking innovation is the use of bioengineered skin substitutes like Integra and Biobrane [45]. These synthetic materials act as scaffolds for new skin growth, reducing the reliance on donor skin and minimizing the risk of rejection. For instance, burn centers have successfully used these substitutes in facial and hand reconstructions, significantly enhancing outcomes in patients with large, full-thickness burns [46].

Psychological recovery is another important dimension of reconstructive plastic surgery for burn survivors [47]. By addressing visible deformities, procedures like scar revisions and aesthetic enhancements improve self-esteem and social reintegration. For example, patients undergoing reconstructive surgeries to reduce facial scarring often report a significant boost in confidence, highlighting the emotional benefits of such interventions [48].

Reconstructive plastic surgery extends beyond physical restoration, incorporating a holistic approach to burn recovery [49]. Surgeons often collaborate with physical therapists, psychologists, and occupational therapists to ensure comprehensive care. Long-term strategies include multiple surgeries, rehabilitation programs, and innovative technologies like 3D printing, which have been used to develop personalized implants for complex reconstructions [50]. These advancements exemplify the transformative potential of reconstructive surgery in burn care.

In summary, reconstructive plastic surgery is indispensable for burn survivors, offering solutions that address both physical and psychological challenges [51]. Through a combination of established and cutting-edge techniques, surgeons not only restore functionality and aesthetics but also provide patients with renewed hope and opportunities to lead fulfilling lives.

Techniques for Burn Reconstruction

Burn reconstruction is a highly specialized area of plastic and reconstructive surgery aimed at restoring both the function and appearance of individuals who have sustained significant burn injuries [52]. The techniques used for burning reconstruction are designed to address the immediate challenges posed by tissue damage, including scarring, deformities, and loss of skin integrity [52]. These techniques can be broadly categorized into several principles and approaches that are tailored to the type, location, and severity of the burn injury. Below are some key principles and techniques used in burn reconstruction.

Early scar management and wound healing

One of the primary goals in burn reconstruction is to promote optimal wound healing and minimize scarring [53]. Early intervention is crucial in preventing hypertrophic scars, which are thick, raised scars that can limit mobility and cause discomfort. Techniques like silicone gel sheeting, pressure garments, and steroid injections are commonly used in the post-burn period to help manage scarring [54]. For example, pressure garments are applied to burn wounds after the skin has healed to exert continuous pressure on the area, reducing the chance of abnormal scarring and improving skin texture. In severe cases where skin grafting is necessary, split-thick skin grafts or full-thickness skin grafts are utilized, depending on the depth of the burn [37].

Skin grafting

Skin grafting is one of the cornerstone techniques in burn reconstruction, particularly for covering large areas of skin loss [55]. In split-thickness skin grafting, a thin layer of skin is taken from a donor site (usually the thigh or abdomen) and grafted onto the burned area [56]. This technique is commonly used for partial thickness burns or areas where large portions of the skin need to be replaced. For more extensive burns, full-thickness skin grafting may be used, where a thicker layer of skin is transplanted [57]. This is especially suitable for areas where a more durable, aesthetic result is required, such as the face or hands. The grafts are typically secured using sutures or staples and require close monitoring for signs of infection or graft rejection.

Flap surgery

When burns result in the destruction of deep tissue layers, flap surgery may be necessary for reconstructing the affected area. A flap involves taking a portion of skin, along with its underlying tissue and blood supply, from one part of the body and transferring it to the damaged area [58]. Flaps are particularly useful when burns affect areas with critical tissue structures such as the face, neck, and hands, or when large portions of skin need to be covered [59]. For example, a fasciocutaneous flap may be used for the lower limbs, where skin and underlying muscles are transferred, while a musculocutaneous flap might be used for more complex reconstructions that involve muscles and skin. The advantage of flaps is that they are well-vascularized, reducing the risk of graft failure and enhancing tissue durability [58].

Contracture release and Z-plasty

Burn injuries often result in contractures, which are deformities caused by the contraction of scar tissue, leading to a loss of mobility in joints [60]. Contracture release is an essential part of burn reconstruction, and techniques like Z-plasty are commonly employed to correct these deformities [61]. In a Z-plasty, the scar tissue is strategically incised in a Z-shaped pattern, and the resulting flaps are repositioned to release the tension and allow for more natural movement [62]. This is particularly useful for burning contractures around the neck, hands, and other joints, where mobility is vital. The technique improves both the functional and cosmetic outcomes, reducing the restriction of movement and improving the appearance of the scar.

Laser and non-surgical scar treatment

For mature burn scars that are resistant to other treatments, laser therapy has become a valuable tool in improving the appearance and texture of scars [63]. Fractional CO_2 lasers, for instance, can penetrate deep into the skin, stimulating collagen remodeling and reducing the appearance of hypertrophic scars [64]. Laser treatments are often used in conjunction with other approaches, such as pressure garments or steroid injections, to achieve optimal results. These non-surgical techniques are particularly helpful for burn survivors seeking to improve the cosmetic appearance of their scars, without the need for additional surgical procedures [65].

Tissue expansion

In some cases, tissue expansion is used to generate extra skin for reconstruction [66]. This technique involves placing a balloon expander under the healthy skin near the burn site. Over time, the expander gradually inflated, causing the skin to stretch and grow. Once extra skin has been generated, the expander is removed, and the expanded skin is used to cover the burn area. Tissue expansion is particularly useful for reconstructing areas where donor sites are limited, such as the face or hands [67]. It provides high-quality skin that matches the color and texture of the surrounding area.

Psychosocial and aesthetic considerations

Burn reconstruction is not only focused on physical healing but also on addressing the psychological and emotional impact of burn injuries. Many burns survivors experience trauma due to changes in their appearance, and a key principle of burn reconstruction is to provide holistic care [68]. This involves collaborating with psychologists and therapists to help patients cope with body image issues and social reintegration. Aesthetic techniques, such as eyebrow tattooing or lip reconstruction, are also part of the process, especially in facial burn victims, where restoring normal features is important for psychological recovery [69].

In summary, burn reconstruction is a complex, multifaceted process that requires a combination of surgical techniques, scar management strategies, and psychological support. Advances in

skin grafting, flap surgery, and scar management have significantly improved the functional and cosmetic outcomes for burn survivors [3]. Each case is unique, and a tailored approach that incorporates both medical and psychological care is essential for achieving the best results in burn reconstruction.

Limitations

While burn reconstructive surgery has made significant strides in improving the functional and aesthetic outcomes for burn survivors, several limitations still challenge its effectiveness and accessibility. One of the primary limitations is scar formation. Despite advanced techniques in skin grafting, flap surgery, and scar management, scarring remains a significant issue [70]. Even with the best care, many burn patients are left with visible scars, which can cause both functional limitations and psychological distress. Hypertrophic and keloid scars, which are thick, raised, and often painful, can result from the body's abnormal healing response to burns, and these scars are difficult to manage or eliminate completely [71]. While treatments like laser therapy and steroid injections can help, they are not always fully effective in preventing or reducing severe scarring.

Another limitation is the availability of donor skin. For extensive burn injuries, skin grafts are often required, but the availability of donor sites can be limited, especially in cases of full thickness burns or when the patient has already experienced significant skin loss [72]. This can lead to the need for artificial skin substitutes, which are often expensive and not always effective in the long term. Additionally, tissue rejection can be a concern with grafts and flaps, particularly if the donor tissue comes from a non-autologous source, such as a cadaver or synthetic skin, leading to complications and prolonged healing times [73].

Burn reconstructive surgery is also heavily dependent on the timing of intervention. Early intervention in burn care is crucial, but some burns may require multiple stages of surgery to address both functional and aesthetic concerns [74]. In cases where burn injuries are severe or not addressed early enough, the risk of contractures and permanent functional limitations increases, making subsequent reconstruction more complex and less effective [75]. Moreover, muscle and nerve damage from deep burns can complicate surgery further, leading to limited functional restoration.

Lastly, there are psychological and social limitations. Burn victims often face emotional distress related to their appearance, even after reconstruction. The psychological impact of living with visible scars or deformities is significant and requires comprehensive mental health support [76]. Burn survivors may struggle with body image issues, social reintegration, and post-traumatic stress disorder, which are not always addressed by physical reconstruction alone [77]. Even with successful surgical outcomes, the emotional and social aspects of recovery remain a challenge.

Future Prospects

The future of burn reconstructive surgery holds great promise, particularly with advances in regenerative medicine, tissue engineering, and biotechnology [78]. One of the most exciting areas of development is the use of stem cells for burn treatment. Stem cell therapy has the potential to accelerate skin regeneration and improve wound healing. Researchers are exploring ways to grow new skin or even complete skin grafts using stem cells, which could reduce reliance on donor skin and offer more natural-looking results [79]. Gene therapy may also play a key role in the future, allowing for the targeted repair of damaged tissue at the genetic level, potentially reducing scarring and improving the quality of regenerated skin [80].

In the realm of tissue engineering, bioprinting of skin is a growing field. 3D printing technologies are being used to create personalized skin grafts and even complete skin layers tailored to the specific needs of individual burn victims [81]. This could revolutionize burn reconstruction by providing highly customized, bio-printed skin that can more effectively match the patient's natural skin tone and texture. Additionally, the use of bioengineered skin substitutes, which are already being used in some clinical settings, is likely to expand, offering more options for burn patients and reducing the need for donor sites [45].

The development of novel biomaterials also holds promise in burn reconstruction [82]. For example, researchers are working on artificial skin substitutes made from collagen, chitosan, or other biocompatible materials that can promote faster healing and better functional outcomes. These materials could be integrated with smart dressings that release growth factors or antibiotics to improve healing and reduce infection, offering a more effective and less invasive approach to burn care [82].

Minimally invasive surgical techniques are another future trend that promises to enhance burn reconstruction [83]. Innovations in robotic surgery and laser technologies could allow for more precise and less invasive procedures, reducing recovery times and the risk of complications. For example, laser treatments could be used not only for scar management but also for tissue regeneration, facilitating faster healing with less scarring [64]. Advances in microsurgery and neuroplastic techniques may also improve outcomes in cases of nerve damage, allowing for better restoration of both function and sensation in areas affected by severe burns [84].

Moreover, the future of burn care will likely see a stronger integration of multidisciplinary teams, where surgeons, psychologists, physiotherapists, and other specialists work together from the early stages of recovery [85]. This holistic approach will address not only the physical healing of burn injuries but also the psychological and social aspects, helping patients to recover in a more comprehensive manner. The inclusion of virtual reality and artificial intelligence in rehabilitation could provide innovative ways to manage the emotional and psychological impact of burn injuries, supporting mental health as part of the healing process [86].

In summary, while burn reconstructive surgery faces several limitations today, the future holds exciting possibilities driven by advancements in regenerative medicine, biotechnology, and multidisciplinary care. These innovations are poised to improve the quality of life for burn survivors, offering more effective, customized, and minimally invasive treatment options. However, continued research, better access to cutting-edge technologies, and a comprehensive approach to both physical and emotional recovery will be necessary to fully realize the potential of burn reconstruction in the years to come.

Conclusions

In conclusion, reconstructive plastic surgery is an essential component of burn injury management, offering both functional and aesthetic restoration for patients who have endured significant trauma. The techniques used in burn reconstruction, including skin grafting, flap surgery, contracture release, and tissue expansion, are designed to address the complex and multifaceted nature of burn injuries. These

procedures aim to restore normal skin integrity, improve mobility, and enhance the overall appearance of the affected areas, which can be critical for a patient's physical recovery and quality of life. Early intervention and careful planning are key to achieving the best possible outcomes, and surgical options continue to evolve in response to the challenges posed by severe burns.

However, despite the advancements in burn reconstruction, several challenges remain. Scarring, particularly hypertrophic and keloid scars, continues to be a major concern even with the most advanced treatments. The limited availability of donor skin for extensive burns, complications such as tissue rejection, and the need for multi-stage surgeries can also hinder the effectiveness of reconstructive procedures. Additionally, the emotional and psychological impact of burn injuries often requires a holistic approach, integrating psychological support alongside surgical interventions to address the mental health aspects of recovery. Burn survivors may face significant body image issues, social stigma, and the long-term effects of their injuries, which underscores the need for comprehensive care that goes beyond surgery.

Looking to the future, the field of reconstructive burn surgery holds great promise with the potential for groundbreaking innovations. Advances in regenerative medicine, including stem cell therapy and tissue engineering, offer exciting possibilities for creating lab-grown skin and improving the regeneration of burned tissues. Biotechnological developments, such as 3D skin printing, are also paving the way for more personalized and effective treatments. As these innovations continue to evolve, they may significantly reduce the limitations faced in current reconstructive procedures, offering better functional and aesthetic outcomes for burn patients. Ultimately, the future of burn reconstruction lies in a combination of technological advancements, interdisciplinary collaboration, and a more holistic approach to patient care, ensuring that burn survivors receive the best possible treatment for both their physical and emotional healing.

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Conflict of Interest

None.

References

1. Lippi L, Ferrillo M, Losco L, Folli A, Marcasciano M, et al. (2024) Aesthetic rehabilitation medicine: enhancing wellbeing beyond functional recovery. Medicina 60: 603. https://doi.org/10.3390/medicina60040603
2. The Most Common Plastic Surgery Procedures Worldwide. [https://www.statista.com/chart/25322/plastic-surgery-procedures-by-type/] [Accessed January 19, 2025].
3. Ozhathil DK, Tay MW, Wolf SE, Branski LK (2021) A narrative review of the history of skin grafting in burn care. Medicina 57: 380. https://doi.org/10.3390/medicina57040380
4. Kumar R, Baldi A, Navneesh, Kumar P, Dhiman B, et al. (2024) Applications of bioscaffolds in plastic surgery. In Natural Product Inspired Scaffolds: Applications in Tissue Engineering. Springer Nature, Singapore, pp 147-75.
5. Nicksic PJ, Farmer RL, Poore SO, Rao VK, Afifi AM (2021) Dermatologic complications following cosmetic and reconstructive plastic surgery: a systematic review of the literature. Aesthetic Plast Surg 45: 1-14. https://doi.org/10.1007/s00266-021-02362-9
6. Vitagliano T, Garieri P, Lascala L, Ferro Y, Doldo P, et al. (2023) Preparing patients for cosmetic surgery and aesthetic procedures: ensuring an optimal nutritional status for successful results. Nutrients 15: 352. https://doi.org/10.3390/nu15020352
7. Ekomwereren O, Shehryar A, Yahya NA, Rehman A, Affaf M, et al. (2023) Mastering the art of dermatosurgery: aesthetic alchemy in medical excellence. Cureus 15: e49659. https://doi.org/10.7759/cureus.49659
8. Khurram MF (2024) History of plastic surgery and general concepts of reconstruction. In Prosthetic Rehabilitation of Head and Neck Cancer Patients. Elsevier, pp 79-111.
9. Carro MA, Donofrio G, Tokgöz E (2023) Surgical reconstruction of craniofacial malformations. In Cosmetic and Reconstructive Facial Plastic Surgery: A Review of Medical and Biomedical Engineering and Science Concepts. Springer Nature, Switzerland, pp 151-179.
10. Jain Y, Lanjewar R, Shinde RK (2024) Revolutionising breast surgery: a comprehensive review of robotic innovations in breast surgery and reconstruction. Cureus 16: e52695. https://doi.org/10.7759/cureus.52695
11. Højvig JH, Pedersen NJ, Charabi BW, Wessel I, Jensen LT, et al. (2020) Microvascular reconstruction in head and neck cancer - basis for the development of an enhanced recovery protocol. JPRAS Open 26: 91-100. https://doi.org/10.1016/j.jpra.2020.09.008
12. Cheng T, Causarano N, Platt J, Jones JM, Hofer SO, et al. (2018) Restoring wholeness: women's embodied experiences in considering post-mastectomy delayed breast reconstruction. Cogent Soc Sci 4: 1-14. https://doi.org/10.1080/23311886.2018.1479478
13. Jeschke MG, van Baar ME, Choudhry MA, Chung KK, Gibran NS, et al. (2020) Burn injury. Nat Rev Dis Primers 6: 11. https://doi.org/10.1038/s41572-020-0145-5
14. Radzikowska-Büchner E, Łopuszyńska I, Flieger W, Tobiasz M, Maciejewski R, et al. (2023) An overview of recent developments in the management of burn injuries. Int J Mol Sci 24: 16357. https://doi.org/10.3390/ijms242216357
15. Sagah GA, Sharif AF, Moustafa IMES, Hasan SF, Elhawary AE (2024) Medico-legal evaluation of burn trauma injuries. Epidemiological features and predictors of mortality and other adverse outcomes. Injury 55: 111276. https://doi.org/10.1016/j.injury.2023.111276
16. Johnston DW, Önder YK, Rahman MH, Ulubaşoğlu MA (2021) Evaluating wildfire exposure: using wellbeing data to estimate and value the impacts of wildfire. J Econ Behav Organ 192: 782-798. https://doi.org/10.1016/j.jebo.2021.10.029
17. Hussain Z, Thu HE, Rawas-Qalaji M, Naseem M, Khan S, et al. (2022) Recent developments and advanced strategies for promoting burn wound healing. J Drug Deliv Sci Technol 68: 103092. https://doi.org/10.1016/j.jddst.2022.103092
18. Jordan KC, Di Gennaro JL, von Saint André-von Arnim A, Stewart BT (2022) Global trends in pediatric burn injuries and care capacity from the World Health Organization Global Burn Registry. Front Pediatr 10: 1-9. https://doi.org/10.3389/fped.2022.954995
19. Ahmed AR, Etchey B, Ahmed M (2021) Explosions, burn injuries and adverse health effects of electronic nicotine delivery systems: a review of current regulations and future perspectives. J Pharm Pharm Sci 24: 462-474. https://doi.org/10.18433/jpps32242
20. Pathak A, Ogunbayo A, Trushna T, Khare S, Mathur A, et al. (2022) Perceptions and experiences of caregivers on child injuries: a qualitative study from central India. J Prev 43: 549-565. https://doi.org/10.1007/s10935-022-00682-3
21. Kalogiannidis S, Chatzitheodoridis F, Kalfas D, Patitsa C, Papagrigoriou A (2023) Socio-psychological, economic and environmental effects of forest fires. Fire 6: 280. https://doi.org/10.3390/fire6070280
22. Herrera-Restrepo O, Afroz N, Cabrera ES, Reaney M, Sowell FG, et al. (2024) Life after invasive meningococcal disease: insights from survivors and their caregivers. Infect Dis Ther 13: 2563-2579. https://doi.org/10.1007/s40121-024-01060-8
23. Khoo KH, Ross ES, Yoon JS, Lagziel T, Shamoun F, et al. (2022) What fuels the fire: a narrative review of the role social determinants of health play in burn injuries. Eur Burn J 3: 377-390. https://doi.org/10.3390/ebj3020033
24. Boehm D, Menke H (2021) A history of fluid management-from "one size fits all" to an individualized fluid therapy in burn resuscitation. Medicina 57: 187. https://doi.org/10.3390/medicina57020187
25. Datta PK, Chowdhury SR, Aravindan A, Saha S, Rapaka S (2022) Medical and surgical care of critical burn patients: a comprehensive review of current evidence and practice. Cureus 14: e31759. https://doi.org/10.7759/cureus.31550
26. Thomas DC, Tsu CL, Nain RA, Arsat N, Fun SS, et al. (2021) The role of debridement in wound bed preparation in chronic wound: a narrative review. Ann Med Surg 71: 102876. https://doi.org/10.1016/j.amsu.2021.102876
27. Shete B, Gulhane R, Hantodkar R (2022) A comprehensive review on wound dressings and their comparative effectiveness on healing of contaminated wounds and ulcers. Arch Anesthesiol Crit Care 8: 151-158. https://doi.org/10.18502/aacc.v8i2.9158
28. Przekora A (2020) A concise review on tissue engineered artificial skin grafts for chronic wound treatment: can we reconstruct functional skin tissue *in vitro*? Cells 9: 1622. https://doi.org/10.3390/cells9071622

29. Sharma Y, Ghatak S, Sen CK, Mohanty S (2024) Emerging technologies in regenerative medicine: the future of wound care and therapy. J Mol Med 102: 1-26. https://doi.org/10.1007/s00109-024-02493-x

30. Nosanov LB, Brandt JL, Schneider DM, Johnson LS (2020) Pain management in burn patients. Curr Trauma Rep 6: 161-173. https://doi.org/10.1007/s40719-020-00203-9

31. Ladhani HA, Yowler CJ, Claridge JA (2021) Burn wound colonization, infection, and sepsis. Surg Infect (Larchmt) 22: 44-48. https://doi.org/10.1089/sur.2020.346

32. Edger-Lacoursière Z, Deziel E, Nedelec B (2023) Rehabilitation interventions after hand burn injury in adults: a systematic review. Burns 49: 516-553. https://doi.org/10.1016/j.burns.2022.05.005

33. Hsu KC (2023) Impact of long-term outcomes on the caregivers of burn survivors. Burns 49: 317-328. https://doi.org/10.1016/j.burns.2022.08.024

34. Lodha P, Shah B, Karia S, De Sousa A (2020) Post-traumatic stress disorder (PTSD) following burn injuries: a comprehensive clinical review. Ann Burns Fire Disasters 33: 276-287.

35. Kalidindi S (2024) The role of three-dimensional (3D) printing in plastic and reconstructive surgery: innovations and applications. Eur J Plast Surg 47: 96. https://doi.org/10.1007/s00238-024-02242-w

36. Understanding the Healing Stages of a Burn Wound. Phoenix Society. [https://phoenix-society.org/resources/understanding-the-healing-stages-of-a-burn-wound] [Accessed January 19, 2025].

37. Bogdanov SB, Gilevich IV, Melkonyan KI, Sotnichenko AS, Alekseenko SN, et al. (2021) Total full-thickness skin grafting for treating patients with extensive facial burn injury: a 10-year experience. Burns 47: 1389-1398. https://doi.org/10.1016/j.burns.2020.12.003

38. Alsaif A, Karam M, Hayre A, Abul A, Aldubaikhi A, et al. (2023) Full thickness skin graft versus split thickness skin graft in paediatric patients with hand burns: systematic review and meta-analysis. Burns 49: 1017-1027. https://doi.org/10.1016/j.burns.2022.09.010

39. Li Y, Jiang QL, Van der Merwe L, Lou DH, Lin C (2021) Preclinical efficacy of stem cell therapy for skin flap: a systematic review and meta-analysis. Stem Cell Res Ther 12: 1-12. https://doi.org/10.1186/s13287-020-02103-w

40. Ziegler B, Hundeshagen G, Will PA, Bickert B, Kneser U, et al. (2020) Role, management, and outcome of free flap reconstruction for acute full-thickness burns in hands. Ann Plast Surg 85: 115-121. https://doi.org/10.1097/sap.0000000000002412

41. Hendriks TCC, Botman M, Binnerts JJ, Mtui GS, Nuwass EQ, et al. (2022) The development of burn scar contractures and impact on joint function, disability and quality of life in low- and middle-income countries: a prospective cohort study with one-year follow-up. Burns 48: 215-227. https://doi.org/10.1016/j.burns.2021.04.024

42. Parikh UM, Mentz J, Collier I, Davis MJ, Abu-Ghname A, et al. (2022) Strategies to minimize surgical scarring: translation of lessons learned from bedside to bench and back. Adv Wound Care (New Rochelle) 11: 311-329. https://doi.org/10.1089/wound.2021.0010

43. Ioannidis CA (2023) Burns of the scalp, face, and neck. In Soft Tissue Injuries of the Head and Neck. Springer International Publishing, pp 119-154.

44. Njoroge MW, Hassan B, Bhagwat AM, Gornitsky J, Heron MJ, et al. (2024) Complications following tissue expander-based reconstruction in pediatric burn injuries: a retrospective analysis. Ann Plast Surg 92: S161-S166. https://doi.org/10.1097/sap.0000000000003928

45. Mahajan N, Soker S, Murphy SV (2024) Regenerative medicine approaches for skin wound healing: from allografts to engineered skin substitutes. Curr Transplant Rep 11: 1-15. https://doi.org/10.1007/s40472-024-00453-5

46. van den Bosch AS, Verwilligen RA, Pijpe A, Bosma E, van der Vlies CH, et al. (2024) Outcomes of dermal substitutes in burns and burn scar reconstruction: a systematic review and meta-analysis. Wound Repair Regen 32: 960-978. https://doi.org/10.1111/wrr.13226

47. Loehr VG, Goette WF, Roaten K (2022) Screening and assessment for psychological distress among burn survivors. Eur Burn J 3: 57-88. https://doi.org/10.3390/ebj3010008

48. Drake VE, Moyer JS (2023) The measure of a scar: patient perceptions and scar optimization after skin cancer reconstruction. Facial Plast Surg 39: 501-507. https://doi.org/10.1055/s-0043-1769807

49. Anand M, Bhagania M, Kaur K (2023) Tissue engineering in plastic and reconstructive surgery: fostering advances in the 21st century via an understanding of the present state of the art and future possibilities. Arch Aesthet Plast Surg 29: 64-75. https://doi.org/10.14730/aaps.2022.00710

50. Vidal L, Kampleitner C, Brennan MA, Hoornaert A, Layrolle P (2020) Reconstruction of large skeletal defects: current clinical therapeutic strategies and future directions using 3D printing. Front Bioeng Biotechnol 8: 1-11. https://doi.org/10.3389/fbioe.2020.00061

51. Taylor-Bennett J, Capobianco L, Wisely J, Wells A (2024) Qualitative analysis of emotional distress in burns, plastic and reconstructive surgery patients from the perspectives of cognitive and metacognitive models. Front Psychiatry 15: 1-13. https://doi.org/10.3389/fpsyt.2024.1461387

52. Markiewicz-Gospodarek A, Kozioł M, Tobiasz M, Baj J, Radzikowska-Büchner E, et al. (2022) Burn wound healing: clinical complications, medical care, treatment, and dressing types: the current state of knowledge for clinical practice. Int J Environ Res Public Health 19: 1338. https://doi.org/10.3390/ijerph19031338

53. Greenhalgh DG (2024) Basic techniques for optimizing burn wound healing: insights from clinical practice. Plast Aesthet Res 11: 1-13. https://doi.org/10.20517/2347-9264.2024.43

54. Killey J, Simons M, Tyack Z (2021) Effectiveness of interventions for optimising adherence to treatments for the prevention and management of scars: a systematic review. Clin Rehabil 35: 656-668. https://doi.org/10.1177/0269215520978528

55. Šuca H, Čoma M, Tomšů J, Sabová J, Zajíček R, et al. (2024) Current approaches to wound repair in burns: how far have we come from cover to close? a narrative review. J Surg Res 296: 383-403. https://doi.org/10.1016/j.jss.2023.12.043

56. Jang YC (2024) Split-thickness skin grafting. In The Art of Skin Graft: Advanced Graft Technique. Springer Nature, Singapore, pp 1-50.

57. Keenan CS, Cooper L, Nuutila K, Chapa J, Christy S, et al. (2023) Full-thickness skin columns: a method to reduce healing time and donor site morbidity in deep partial-thickness burns. Wound Repair Regen 31: 586-596. https://doi.org/10.1111/wrr.13114

58. Rogoń I, Rogoń A, Kaczmarek M, Bujnowski A, Wtorek J, et al. (2024) Flap monitoring techniques: a review. J Clin Med 13: 5467. https://doi.org/10.3390/jcm13185467

59. Sabapathy SR, Shanmugakrishnan RR, Ramkumar S, Muthukumar V, Senthilkumaran M, et al. (2022) Postburn reconstruction of the face and neck. Plast Reconstr Surg 150: 1326e-1339e. https://doi.org/10.1097/prs.0000000000009690

60. Masanovic MG, Téot L (2020) Scar contractures. In Téot L, Mustoe TA, Middelkoop E, Gauglitz GG (eds) Textbook on Scar Management. Springer, Cham, pp 117-122.

61. Hifny MA, Abdelmegeed AG (2024) Clinical comparison study of square flap method and five-flap Z-plasty technique for correction of post-burn axillary contractures: analysis of length gain and evaluation of functional outcome. Burns 50: 107246. https://doi.org/10.1016/j.burns.2024.08.012

62. Stashak TS, Schumacher J (2016) Principles and techniques for reconstructive surgery. In Equine Wound Management.

63. Hultman CS, Edkins RE, Lee CN, Calvert CT, Cairns BA (2012) Shine on: review of laser- and light-based therapies for the treatment of burn scars. Dermatol Res Pract 2012: 1-9. https://doi.org/10.1155/2012/243651

64. Haykal D, Cartier H, Goldberg D, Gold M (2024) Advancements in laser technologies for skin rejuvenation: a comprehensive review of efficacy and safety. J Cosmet Dermatol 23: 3078-3089. https://doi.org/10.1111/jocd.16514

65. Carney BC, Bailey JK, Powell HM, Supp DM, Travis TE (2023) Scar management and dyschromia: a summary report from the 2021 American Burn Association State of the Science Meeting. J Burn Care Res 44: 535-545. https://doi.org/10.1093/jbcr/irad017

66. Dai C, Shih S, Khachemoune A (2020) Skin substitutes for acute and chronic wound healing: an updated review. J Dermatol Treat 31: 639-648. https://doi.org/10.1080/09546634.2018.1530443

67. La Padula S, Pensato R, Pizza C, Coiante E, Roccaro G, et al. (2022) Face transplant: indications, outcomes, and ethical issues-where do we stand? J Clin Med 11: 5750. https://doi.org/10.3390/jcm11195750

68. Burgess M, Valdera F, Varon D, Kankuri E, Nuutila K (2022) The immune and regenerative response to burn injury. Cells 11: 3073. https://doi.org/10.3390/cells11193073

69. Chen J, Qu Q, Ye K, Fan Z, Wang J, et al. (2022) Natural reconstruction: a comprehensive standardized operating procedure for restoring eyebrow loss due to scarring. Plast Reconstr Surg 150: 877-886. https://doi.org/10.1097/prs.0000000000009564

70. Manek YB, Jajoo S, Mahakalkar C (2024) A comprehensive review of evaluating donor site morbidity and scar outcomes in skin transfer techniques. Cureus 16: e53433. https://doi.org/10.7759/cureus.53433

71. Toia F, Rosatti F, Cordova A (2022) Wound healing: physiology and pathology.

In Textbook of Plastic and Reconstructive Surgery: Basic Principles and New Perspectives. Springer, Cham, pp 15-25.

72. Bbaale D, Mohr C, Lindert J, Allorto N, Mabanza T, et al. (2024) Barriers and prospects for skin grafting in burn treatment across African countries. Burns 50: 1150-1159. https://doi.org/10.1016/j.burns.2024.02.012

73. Kim BK, Kong DS, Nam DH, Hong SD (2022) Comparison of graft materials in multilayer reconstruction with nasoseptal flap for high-flow CSF leak during endoscopic skull base surgery. J Clin Med 11: 6711. https://doi.org/10.3390/jcm11226711

74. Miroshnychenko A, Kim K, Rochwerg B, Voineskos S (2021) Comparison of early surgical intervention to delayed surgical intervention for treatment of thermal burns in adults: a systematic review and meta-analysis. Burns Open 5: 67-77. https://doi.org/10.1016/j.burnso.2021.02.003

75. Vosinakis C, Ippoliti S, Samoladas E, Haidich AB, Gamatsi IE, et al. (2024) Effectiveness of hand reconstruction techniques for the treatment of postburn contractures of the hand: a systematic review. Burns 50: 107281. https://doi.org/10.1016/j.burns.2024.10.002

76. Sarwer DB, Siminoff LA, Gardiner HM, Spitzer JC (2022) The psychosocial burden of visible disfigurement following traumatic injury. Front Psychol 13: 1-11. https://doi.org/10.3389/fpsyg.2022.979574

77. Woolard A, Bullman I, Allahham A, Long T, Milroy H, et al. (2022) Resilience and posttraumatic growth after burn: a review of barriers, enablers, and interventions to improve psychological recovery. Eur Burn J 3: 89-121. https://doi.org/10.3390/ebj3010009

78. Das P, Pal D, Roy S, Chaudhuri S, Kesh SS, et al. (2024) Unveiling advanced strategies for therapeutic stem cell interventions in severe burn injuries: a comprehensive review. Int J Surg 110: 6382-6401. https://doi.org/10.1097/js9.0000000000001812

79. Mirshafiei M, Rashedi H, Yazdian F, Rahdar A, Baino F (2024) Advancements in tissue and organ 3D bioprinting: current techniques, applications, and future perspectives. Mater Des 240: 112853. https://doi.org/10.1016/j.matdes.2024.112853

80. Karimzadeh F, Fard ES, Nadi A, Malekzadeh R, Elahian F, et al. (2024) Advances in skin gene therapy: utilizing innovative dressing scaffolds for wound healing, a comprehensive review. J Mater Chem B 12: 6033-6062. https://doi.org/10.1039/d4tb00966e

81. Balavigneswaran CK, Selvaraj S, Vasudha TK, Iniyan S, Muthuvijayan V (2023) Tissue-engineered skin substitutes: a comprehensive review of basic design, fabrication using 3D printing, recent advances and challenges. Biomater Adv 153: 213570. https://doi.org/10.1016/j.bioadv.2023.213570

82. Lukomskyj AO, Rao N, Yan L, Pye JS, Li H, et al. (2022) Stem cell-based tissue engineering for the treatment of burn wounds: a systematic review of preclinical studies. Stem Cell Rev Rep 18: 1926-1955. https://doi.org/10.1007/s12015-022-10341-z

83. Saccu G, Menchise V, Giordano C, Castelli DD, Dastrù W, et al. (2021) Regenerative approaches and future trends for the treatment of corneal burn injuries. J Clin Med 10: 317. https://doi.org/10.3390/jcm10020317

84. Rowe G, Allahham A, Edgar DW, Rurak BK, Fear MW, et al. (2024) Functional brain changes following burn injury: a narrative review. Neurorehabil Neural Repair 38: 62-72. https://doi.org/10.1177/15459683231215331

85. McDermott L, Hotton M, Cartwright AV (2023) Understanding the barriers and enablers for seeking psychological support following a burn injury. Eur Burn J 4: 303-317. https://doi.org/10.3390/ebj4030028

86. Moura FS, Amin K, Ekwobi C (2021) Artificial intelligence in the management and treatment of burns: a systematic review. Burns Trauma 9: 1-21. https://doi.org/10.1093/burnst/tkab022