Therapeutic management of burns affecting major joints of the limbs and the role of medical textiles in enhancing the rehabilitation process: 1 year retrospective study

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ABSTRACT – REZUMAT

Therapeutic management of burns affecting major joints of the limbs and the role of medical textiles in enhancing the rehabilitation process: 1 year retrospective study

Burn injuries rank among the most severe forms of trauma, posing a significant global public health challenge due to their high morbidity and mortality, even within specialised burn care facilities. Effective treatment for severe burns necessitates comprehensive critical care and early identification of complications, which can improve patient survival and functionality. A comprehensive set of criteria has been established for admitting burn patients to specialised burn centres, ensuring that those with extensive, complex, or specific types of burns receive appropriate multidisciplinary care. Burns involving major joints are particularly challenging due to risks of scarring, contractures and functional limitations that demand adequate surgical treatment and rigorous rehabilitative care. This one-year retrospective study analysed burn injuries to major joints in adult patients admitted to the Burn Unit at Clinical Emergency Hospital Bucharest in 2023. Inclusion criteria were the burns affecting the shoulder, elbow, wrist, hip, knee or ankle. Collected data included demographics, injury details and outcomes. Therapeutic management was also assessed, focusing on systemic support and treatment of complications, wound dressings and surgical treatment. Findings will aid in understanding the pathophysiology, etiology, and therapeutic strategies for burns involving major joints, emphasising the importance of early, targeted interventions to improve recovery and patient quality of life.

Keywords: *burns, major limb joints, dressings, surgical treatment, rehabilitation, medical textiles*

Managementul terapeutic al arsurilor ce afectează articulațiile majore și rolul textilelor medicale în procesul de recuperare: studiu retrospectiv pe 1 an

Arsurile se numără printre cele mai grave forme de traumatism, reprezentând o provocare semnificativă pentru sănătatea publică la nivel global din cauza ratei ridicate de morbiditate și mortalitate, chiar și în unitățile specializate de îngrijire a arșilor. Tratamentul eficient al arsurilor severe necesită îngrijire multidisciplinară, precum și identificarea timpurie a complicațiilor, ceea ce poate îmbunătăți supraviețuirea și funcționalitatea pacienților. A fost stabilit un set cuprinzător de criterii pentru admiterea pacienților cu arsuri în centre specializate, asigurându-se că acei pacienți cu arsuri extinse, complexe sau de etiologie mai rară beneficiază de îngrijire multidisciplinară adecvată. Arsurile care implică articulațiile majore sunt deosebit de provocatoare din cauza riscurilor de cicatrizare vicioasă, contracturi și limitări funcționale, necesitând tratament chirurgical adecvat și îngrijire riguroasă de recuperare.

Acest studiu retrospectiv pe un an a analizat leziunile de arsură ale articulațiilor majore la pacienții adulți internați în Secția Îngrijire a Arșilor Gravi a Spitalului Clinic de Urgență București în 2023. Criteriile de includere au fost reprezentate de prezența arsurilor ce afectează umărul, cotul, articulația radio-carpiană, șoldul, genunchiul sau glezna. Datele colectate au inclus informații demografice, detalii despre leziuni și rezultate. Managementul terapeutic a fost de asemenea evaluat, concentrându-se pe suportul sistemic și pe tratamentul complicațiilor, pansamentele utilizate pentru plăgi, precum și tratamentul chirurgical. Rezultatele vor ajuta la înțelegerea fiziopatologiei, etiologiei și strategiilor terapeutice pentru arsurile care implică articulațiile majore, subliniind importanța intervenției timpurii și direcționate pentru îmbunătățirea recuperării și calității vieții pacienților.

Cuvinte-cheie*: arsuri, articulațiile mari ale membrelor, pansamente, tratament chirurgical, recuperare, textile medicale*

INTRODUCTION

Burns represent one of the most severe types of trauma, imposing a substantial global public health burden due to their high morbidity and mortality rates, even in specialised burn centres. Effective management of severe burns requires comprehensive critical care and local treatment delivered by a multidisciplinary team. Early detection of complications is crucial, guiding precise treatment approaches that improve both survival and functional outcomes for patients. Survivors of major burns frequently face lasting physical and psychological challenges, requiring serial surgical procedures, ongoing physical therapy for functional disabilities, and long-term psychological support for lasting mental health impacts [1–5].

American Burn Association established the guidelines accepted worldwide for referral of burned patients to specialised Burn Centres based on the severity of the lesions. The following criteria impose hospitalisation in a burn centre: full-thickness burns on any surface, partial-thickness burns covering ≥10% of Total Body Surface Area (TBSA), deep partial or full-thickness burns affecting the functional areas (face, hands, genitalia, feet, perineum or areas over joints), patients with burns accompanied by other comorbidities or with concurrent traumatic injuries, inability to manage pain, inhalation injuries, pediatric burns, chemical and electrical injuries. Using these referral criteria for burn patients enhances outcomes by ensuring patients receive care aligned with the latest evidence-based practices and they benefit from the expertise of a properly trained team while still respecting the proper allocation of resources [6, 7].

One of the severity criteria established by ABA is the involvement of functional areas, which include the major joints. Burns on the joints present a unique challenge in clinical management due to their potential impact on mobility and function. The skin around joints is often thinner and more sensitive, making it more susceptible to deeper burns that can compromise underlying structures. When burns occur in these areas, they can lead to complications such as scarring, contractures, and limited range of motion, which may require extensive rehabilitation.

Contractures of the shoulder, elbow, hip, and knee joints are commonly seen after burn injuries. While burns affecting the limbs and joints can directly cause these deformities, improper positioning and insufficient physical exercise during recovery can worsen the condition. Effective treatment is essential, often involving advanced wound care techniques, pain management, and sometimes surgical interventions to promote healing and restore function [8–10].

This study aimed to analyse burns affecting the major joints of the limbs, which are a frequent encounter in burn patients. We sought to highlight the pathophysiology, etiology, and severity of these injuries – key aspects that guide therapeutic approaches and subsequent recovery. Involvement of joint areas can lead to severe functional deficits, some of which may be irreversible, significantly impacting patients' quality of life and their ability to reintegrate socially and professionally. Furthermore, the role of medical textiles in treating burn patients was thoroughly assessed as recent advances in this field provide optimal local care during all the evolutive phases of the burn lesions, from emergency settings to long-term rehabilitation.

MATERIAL AND METHOD

We performed a retrospective study including the patients admitted to the Burn Unit of the Clinical Emergency Hospital Bucharest for one year, from the 1st of January 2023 to the 31st of December 2023. The inclusion criteria were age ≥18 years and burns to the major joints of the limbs, such as the shoulder, elbow, wrist, hip area, knee and ankle joints. The exclusion criteria comprised the absence of burns at the joint level, incomplete medical records, and transfer to a different facility. The following data were obtained: age and gender of patients, mechanism of injury, burned surface area, presence of third-degree burns, localisation of affected joints, presence of inhalation injuries, length of stay (LOS), surgical and conservative treatment applied and outcome. The Abbreviated Burn Severity Index (ABSI) score was calculated to assess prognosis. The collected data were integrated into an Excel database for analysis and management.

This study received approval from the hospital's ethics committee and was conducted following all principles outlined in the Declaration of Helsinki.

RESULTS

Out of the total of 140 patients who were admitted between the 1st of January 2023 and the 31st of December 2023, 10 patients were transferred to another clinic, and 18 patients didn't present burns of the major joints and were excluded from the study. The remaining 112 patients were further analysed, and their characteristics are presented in table 1.

The majority of the patients were male, totalling 82 individuals (73.2% of the overall cohort). The mean age of the patients was 50.52 years old, while the mean total body surface area (TBSA) burned was 24.7%, with 36.6% of patients sustaining burns covering a maximum of 10% of body surface area and 26.8% of patients falling within the 11–20% range. Third-degree burns were present in 69 patients (61.6% of the total cases).

Concerning the mechanism of burn injury, 82 out of the 112 cases (73.2% of patients) were attributed to flame injuries, 23 (20.5%) were due to scalds, while 5 cases (4.5%) resulted from electrocution and 2 cases (1.8% of patients) were classified as chemical burns. Inhalation injury was present in 30 cases, representing 26.8% of the total. Tracheostomy was performed in 8 cases (7.1% of patients).

The ABSI score was calculated, with the distribution shown in figure 1. Among the 112 patients, 36 patients had an ABSI score of 4 or 5, corresponding to a probability of survival of 98%, 29 patients had a score of 6 or 7 (probability of survival of 80–90%); 19 patients had a score of 8 or 9 (probability of survival 50–70%), 12 patients had a score of 10 or 11 (probability of survival 20–40%), and 9 patients had a score equal or above 12, corresponding to a probability of survival equal or smaller than 10%. Mortality in the study group was 18.8%. The mean registered

Table 1

CHARACTERISTICS OF STUDY PATIENTS			
Variables	**Classification**	**Cases**	**Proportion (%)**
Sex	Male	82	73.2
	Female	30	26.8
Age	18–30	17	15.2
	31–40	17	15.2
	41–50	20	17.9
	51–60	22	19.6
	61–70	20	17.9
	71–80	13	11.6
	>80	3	2.7
Burn mechanism	Flame	82	73.2
	Scald	23	20.5
	Electrocution	5	4.5
	Chemical	2	1.8
%TBSA	1–10%	41	36.6
	11–20%	30	26.8
	21–30%	12	10.7
	31–40%	5	4.5
	41–50%	9	8
	51–60%	4	3.6
	61–70%	4	3.6
	71–80%	2	1.8
	81–90%	3	2.7
	91–100%	2	1.8
3rd-degree burns		69	61.6

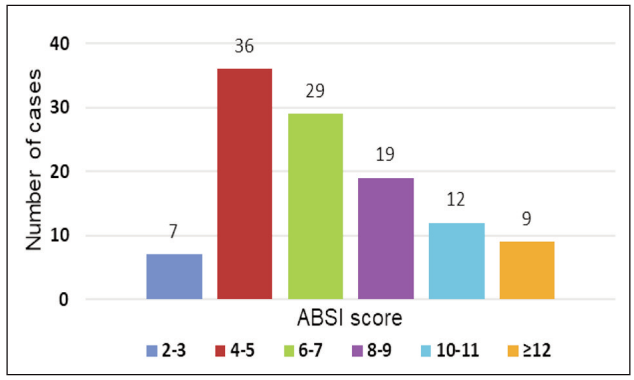

Fig. 1. Distribution of ABSI score in the study group

Table 2

THE NUMBER OF CASES PER JOINT AND THE TOTAL NUMBER OF CASES FOR EACH ANATOMICAL REGION				
Body segment	**Unilateral right side**	**Unilateral left side**	**Bilateral**	**Total**
Upper limb				146
Shoulder	10	5	15	30
Elbow	7	7	22	36
Wrist	13	13	54	80
Lower limb				78
Hip	2	6	13	21
Knee	10	2	12	24
Ankle	6	5	22	33

Length of Stay (LOS) of the patients was 22.9 days.

An analysis of burn localisation revealed involvement of 146 major joints in the upper extremity, with the wrist being the most affected (80 times), followed by the elbow (36 times) and shoulder (30 times). In the lower limbs, major joints were affected 78 times, with a higher incidence of burns also being reported for the distal joints – 33 times for the ankle and 24 and 21 times, respectively, in the case of the knees and the hips (table 2).

For all patients, dressing of the burn wounds was carried out regularly, employing suitable dressings according to the depth of the burns, the clinical presentation and the local progress, with notable examples depicted in figures 2 and 3.

In figure 2, the dressing has the ability to promote epithelisation while hydrating the burn lesion. Figure 2, *e* and *f* depict a case of a partial thickness burn lesion caused by a flame in the knee region epithelised with Epicite®. Figure 2, *g* and *h* present Aquacel® Ag for a temporary cover of a shoulder burn, absorbing the exudate while providing an antimicrobial effect. Figure 2, *i* illustrates a

Fig. 2. Dressing of the burn wounds: *a* to *d* – Epicite® used in a female patient with superficial burn lesions; *e* and *f* – burn lesion epithelioid with Epicite®; *g* and *h* – Aquacel® Ag used for a temporary cover; *i* – TenderWet Plus® used for absorbing the fluids; *j* and *k* – Mepilex Ag used for a wrist burn; *l* – Grassolind dressing

TenderWet Plus® used for absorbing the fluids in an elbow burn. Figure 2, *j* and *k* show the aspect of Mepilex Ag and its use in the case of a wrist burn, keeping the lesion moist while preventing bacterial contamination. Figure 2, *l* displays a Grassolind dressing, which has a greasy composition, thus promoting epithelisation.

The most severe cases with extensive burn lesions require daily lavage performed in a sterile manner with elaborate dressings to limit the liquid, protein and thermic losses while trying to repel any contamination of the burned wounds. Such type of dressing is exemplified in figure 3.

Fig. 3. Severe case with extensive burn lesions

Our standard protocol pays great attention to the local treatment of burn lesions. After thoroughly cleansing the wounds with antiseptic solutions, we always perform the dressings with Burnshield® in the initial phase. This type of dressing is used in the first 24 hours after burn injury, being a non-adherent, sterile, non-toxic, and non-irritant hydrogel. It has a soothing and cooling effect on the patient, reducing inflammation and providing pain relief while minimising the risk of infection. The burn lesions are assessed the next day. The initial depth and the evolution of the lesions dictate the type of dressings that we use in the following days.

In our Burn centre, burn care involves selecting appropriate treatments and dressings based on the depth of the burn and the stage of healing. For superficial partial-thickness burns, the primary goals were to promote epithelialisation, minimise fluid loss, and reduce the risk of infection. Dressings selected in these cases are non-adherent, protecting the fragile new epithelial layer and allowing painless removal, hydrating to maintain a moist environment that accelerates skin regeneration. Absorbent dressings were used to manage low to moderate levels of exudate while keeping the wound bed clean. These dressings aim to support rapid healing and also enhance patient comfort by reducing the need for frequent dressing changes. For deep partial-thickness burns, our focus was to maintain hydration, effectively manage exudate, and prevent infection to avoid complications. Moisture-retentive dressings help prevent tissue desiccation and support cellular activity essential for healing, while antimicrobial dressings reduce bacterial load and protect against infection. Dressings with high absorbency are used for managing moderate to heavy exudate, ensuring a balanced wound environment that promotes recovery. In cases of full-thickness burns, pre-surgical care aims to keep the wound clean and infection-free while preparing for surgical interventions like excision and grafting. Antimicrobial or barrier dressings were applied to create a bacteriostatic environment, and in complex cases where donor sites are insufficient, negative pressure wound therapy is taken into consideration to promote granulation tissue formation. Hydrophilic foam dressings may also be used to provide cushioning and absorb excess exudate from heavily draining wounds.

In the final phase of healing, scar remodelling was supported through silicone-based products that hydrate and soften scar tissue, compression garments that reduce collagen deposition and improve circulation, and emollient or vitamin-enriched products that maintain skin hydration and enhance texture. Throughout all stages of burn care in our Burn Centre, textile bandages play an essential role by securing primary dressings in place, providing gentle compression to manage edema or support scar remodelling, and adding padding to protect wounds from external mechanical forces. They are versatile and adaptable to various wound sizes and locations but should be carefully applied to avoid excessive pressure that could compromise circulation. Dressing choices and care strategies are regularly reassessed and tailored to the burn's depth, exudate levels, and healing phase to optimise outcomes.

Of the total lot of 112 patients, 79 patients (70.5%) required surgical treatment to cover the defects. Regarding the debridement of burns, 75 patients had a surgical excision performed either tangentially or in a fascial plane, depending on the severity of the lesion, while in 4 cases, enzymatic debridement using Bromelain was employed. After the debridement, these patients required permanent coverage with skin autografts. Out of the total cases, 7 patients had high-severity burns of the limbs, which required amputations. Defect covering using flaps was mostly reserved for the sequelae cases and consisted of 3 cases of Z-plasties, 1 random flap, 1 pedicled abdominal flap and 1 pedicled latissimus dorsi flap. Figures 4 and 5 exemplify the therapeutic strategy applied in two of our cases.

A 72-year-old female patient who had a full-thickness burn lesion of the arm, elbow, and forearm and a deep partial thickness burn of the distal third of the forearm is illustrated in figure 4, *a*. Figure 4, *b* depicts the aspect after the excision of the burn eschar in a fascial plane and a tangential excision in the distal aspect of the forearm and the wrist. The coverage of the resulting defect with a split-thickness skin graft (figure 4, *c*) and the evolution at 3 weeks (figure 4, *d*) with 90% of the graft integrated and healed, except for a small region near the elbow, which was successfully managed using negative pressure wound therapy (figure 4, *e*).

Figure 5 presents a 43-year-old patient with an axillary scar after a burn injury with significant retraction of the anterior axillary fold. Figure 5, *b* presented the immediate postoperative aspect: the contracture was managed by the release of the scar by Z plasties. Figure 5, *c* depicts the result with a significant functional improvement of the shoulder abduction.

According to the protocol in our clinic, all the patients in the study benefited from the systemic support of the vital functions, the local treatment of the burned lesions, thromboprophylaxis, and prevention of associated contractures of the joints by following a daily kinetotherapy program along with elevation of the affected limbs and means of anticontracture posture. After the complete healing of the burn wounds, patients were discharged with recommendations to wear compressive garments made from breathable, elastic materials that allow for comfort and flexibility while providing adequate compression (figure 6).

Figure 6 depicts a male who suffered burns by flame to the right upper limb and the lower limbs, which required coverage with skin grafts. This stage presents the healed grafts the patient wearing compressive garments to prevent the formation of vicious scars.

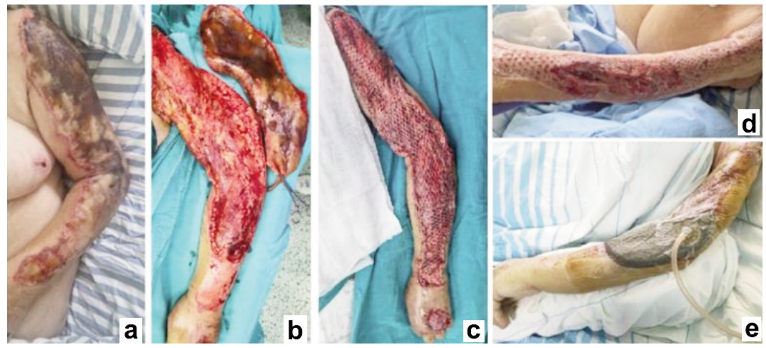

Fig. 4. 72-year-old female patient with: *a* – full-thickness burn lesion of the arm, elbow, and forearm; *b* – aspect after the excision of the burn eschar; *c* – split-thickness skin graft; *d* – evolution at 3 weeks; *e* – 90% of the graft integrated and healed

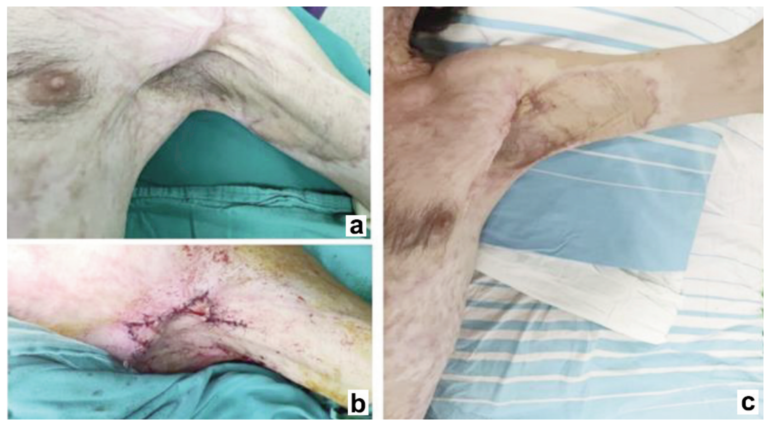

Fig. 5. 43-year-old patient with: *a* – axillary scar after burn injury; *b* – the scar by Z plasties; *c* – significant functional improvement of the shoulder abduction

Fig. 6. Male that suffered burns by flame to the right upper limb and the lower limbs

DISCUSSION

Assessment of burn severity

Burns represent a particularly severe form of trauma, with a high risk of mortality even in developed countries, having the potential to significantly impact the quality of life of survivors. The involvement of functional areas is one of the admission criteria in specialised burn centres, as it represents a severity factor that worsens the vital and functional prognosis of patients [1, 5].

In this study, we focused on burns affecting the major joints of the limbs, as their involvement poses unique challenges for specialised surgical treatment, both in the acute phase and throughout the patient's long-term recovery. Such cases demand an intensive, sustained rehabilitation program to restore quality of life and achieve an optimal functional outcome.

Out of the 140 total patients, only 112 met the eligibility criteria for this study, having burned joints. Male patients made up a significantly higher percentage, with 82 cases (73.2%), compared to only 30 female patients (26.8%), the percentage of male patients being similar to what other studies have described [11, 12]. The mean age was 50.52, with 17 patients being younger than 30 years of age, 17 in the 31–40 interval, 20 between 41–50, 22 between 51 and 60, 20 between 61 and 70 and 13 between 71 and 80 with only 3 cases older than 80.

Of critical importance in assessing the severity of the cases is the lesional mechanism that affects the prognosis of recovery. Extensive flame burns, which were the most frequent in this study (82 cases), affect multiple anatomical regions and cause inhalation injuries (27 of the total 30 inhalation injuries noted) while leading to severe systemic complications that will require prolonged health care by a multidisciplinary team [1]. The more infrequent etiologies are the chemical burns and the electrocutions. Chemical burns represent dynamic lesions caused by various substances, frequently determining deep burns that require excision and coverage by skin grafts. Electrocutions, in particular those caused by high voltage, lead to extensive tissue damage on the electric current passage with severe muscle destruction, rhabdomyolysis, nerve and artery destruction with ischemia events, compartment syndrome formation as well as potentially fatal systemic complications, such as acute kidney failure. Consequently, decompression fasciotomies and rapid excision of the devitalised tissues become mandatory [13]. Since the lesions may progress during the following days, serial debridements frequently become necessary. As such, this type of lesion produces complex defects involving the skin, musculotendinous system, neurovascular elements and even bone and joint involvement. Therapeutic strategies in these cases require elaborate reconstructive procedures.

One of the most important indicators was calculating the mean TBSA burned. A larger value is likely involving multiple joints, frequently accompanied by a longer hospital stay and leading to a significantly higher risk of developing contractures. In the same study performed by Tan et al., they found a higher incidence of contractures in the severely burned patients than in the less affected ones [11]. The mean TBSA calculated in this study was 24.7%, with the majority of patients having small burned surfaces, 41 patients (36.6%) having less than 10% burned surface, and another 30 patients (26.8%) had between 11 and 20% burned TBSA. Although the mean burned TBSA was not particularly high, the severity of the lesions was increased by the depth of the lesion. Hence, the percentage of 3rd-degree burns was noted in 61.6% of the cases having severe burns, while another 95 cases (84.8%) also associated deep intermediate burns. Another severity factor studied was the presence of inhalation injuries, as it increases the risk of mortality ranging from 45% to 78% [14, 15]. In our study group, 30 of the total cases (26.8%) had inhalation injuries, 8 of which also required tracheostomy.

Prognostic scores are an important tool for predicting the evolution of burn patients. One of the most widely used prognostic scores is the ABSI score, which assesses burn severity and estimates mortality risk, including total body surface area burned, burn depth, age, sex, and the presence of inhalation injuries [16]. According to the ABSI score, 21 out of the 112 patients (18.8%) faced a severe (score of 10–11) or a maximum (score ≥12) threat to life, statistically giving them the lowest chances of survival. This aligns with the 21 patients who did not survive, representing 18.8% of the total patient group.

Out of the total patient group, 59 had additional health issues. Due to the elevated risk of low adherence to treatment recommendations with some of these issues, it was important to highlight the ones most likely to impact the evolution: 18 patients had cardiac conditions such as heart failure or valvular disease, 3 had cancer, 29 had HBP (high blood pressure), 12 were diabetic and 20 obese. The greatest adherence challenges were observed among psychiatric patients (23 cases) or with those with chronic alcohol abuse (15 cases), totalling 38 patients (33.9%). Studies approximate that half of the patients with a psychiatric disorder do not adhere to the treatment recommendations [17–19].

Despite significant advances in therapeutic modalities, burns often lead to a range of complications, which can be broadly categorised into systemic and burn wound-specific issues. Systemic complications may involve multiple organs and systems and may include multisystem organ dysfunction, specific organ failures such as acute kidney injury with acute tubular necrosis, pulmonary failure, cardiac and hepatic failure, gastrointestinal system failure, hematologic complications (including anemia, thrombocytopenia, increased thromboembolic risk), central nervous system impairment and severe infectious complications (highly aggressive, multi-drug-resistant pathogens are frequently involved, including the ESKAPE group). Systemic dysfunctions can complicate the patient's recovery and increase mortality risk [4, 20–23].

Patients also experience persistent hypermetabolism, which places a considerable burden on nutritional and energy reserves, requiring long-term intensive metabolic support to meet the increased demands for recovery [24]. In addition to systemic complications, burn lesion-related problems are common and can significantly impact long-term outcomes. Burn wound infections and sepsis are frequent and serious complications that require permanent monitoring and prompt therapeutic management [20, 25]. Furthermore, burns frequently lead to abnormal wound healing, resulting in hypertrophic scarring, keloid formation, and, in some cases, heterotopic ossification, with bone formation in soft tissue areas. These burn-specific complications can alter mobility, impact quality of life, and require additional surgical interventions [26, 27].

Burn wound local treatment: modern dressings including textile technologies and surgical strategies

For deep burns, early excision and grafting have been the standard of care since the 1970s, using autografts for coverage, but patients with more extensive burns may require temporary coverage with allografts, xenografts, and dermal substitutes. For patients with partial-thickness burns, numerous options are available for dressings, with the choice depending on the depth of the burns, the location and the amount of exudate of the burn wounds, the desired frequency of dressing changes, and associated costs [28].

Burn wounds present unique challenges in wound management, and the selection of appropriate dressings is critical for successful treatment. Due to the complexity of these lesions, there is no universal dressing that can effectively address all types and stages of wound healing. Choosing the most suitable dressing for a burn wound requires a thorough clinical assessment. Key characteristics of an ideal burn dressing include the ability to alleviate pain, absorb wound exudates, prevent infection, and protect the wound from microorganisms. Additionally, the dressing should maintain a moist healing environment, provide optimal gas exchange, regulate temperature and pH, and have the ability to be non-toxic [29, 30].

Modern advancements in wound dressing materials have led to the development of composite dressings, incorporating layers with specific properties like elasticity and antibacterial activity to manage burns effectively. These advanced dressings often include bioactive compounds, such as collagen, colloidal silver, and hyaluronic acid, which enhance healing by supporting fibroblast proliferation, angiogenesis, and infection control. Furthermore, ideal dressings for burn wounds are designed for flexibility, ease of application and comfort, as pain management is crucial. Further research is carried out in textile technology to optimise the properties of wound dressings [30, 31] by designing and creating tri-layered structures to obtain a varied range of possible special effects. The three-layered structure consists of outer layer I, which plays the role of carrier, insulator and protector of the underlying layers, being elastic, resistant and sub-micro-porous (to block the physical access of microorganisms to the lesion), (layer II) – intended management of liquid compositions in the lesion area, macroporous and compressible, with open pores with high tortuosity and layer III – impermeable substrate – non-adherent, biologically inert and microporous. Antimicrobial properties are frequently integrated into burn dressings to inhibit the growth of bacteria such as Staphylococcus aureus and Escherichia coli and fungi like Candida albicans, helping to prevent infection, which represents a significant risk in burn wounds. Additionally, the hemocompatibility of these materials is crucial, ensuring minimal damage to blood cells while providing compatibility with the patient’s tissues. Modern burn dressings are not only passive barriers; they are active, multifunctional materials that play an important role in facilitating wound healing and protecting patients from systemic complications [30, 32].

Textile dressings, being currently the most used type of local therapeutic strategy in burn care, offer several advantages, including widespread availability, ease of use by all healthcare workers, and affordability due to their low cost. Additionally, they allow for easy inspection of wound secretions, making them practical for monitoring wound healing progress [30, 33].

Traditional dressings serve essential functions, such as absorbing exudate, protecting the wound from contamination, and therefore supporting healing by keeping the wound environment clean. [31] While traditional dressings are still widely used, modern wound dressings represent an evolution in wound care technology; they are designed to create a moist healing environment, effectively manage wound exudate, support the body’s enzymes in breaking down damaged tissue through autolytic debridement, and encourage tissue regeneration [34, 35]. This category includes hydrocolloids, hydrogels, foams, films, and hydrofibers [33, 36]. Film dressings are transparent, flexible coverings that conform to any wound shape without needing additional dressing material, allowing for wound inspection without removal. They can absorb small amounts of exudate, maintaining an optimal moisture balance for healing. Medicated films can also be preloaded with drugs. Hydrocolloids are specialised wound dressings with a dual-layer structure consisting of an impermeable outer layer that serves as a protective barrier for the inner hydrocolloid layer [33]. Hydrocolloid dressings are transparent or translucent and suitable for wounds with minimal to moderate exudate. These dressings are biodegradable, non-toxic, and breathable but are not recommended for deeper wounds, wounds with heavy exudate, or those needing free oxygen flow for healing [37]. Hydrofibers are particularly suitable for wounds with moderate to high exudates thanks to their fibrous scaffold of synthetic polymers such as polycaprolactone, polylactic acid, or carboxymethyl cellulose. When they are exposed to wound fluid, hydrofibers transform into a gel-like matrix with effective absorption capacity for wound exudates, preventing dryness and promoting a clean healing environment [38, 39]. Foams have an outer layer of polyurethane sheet, which forms pores in response to moisture-regulating gas exchange and water evaporation [40]. The inner matrix consists of polyols or polyacrylates, which enhance moisture resistance and water absorption capabilities [32]. Hence, they are the preferred choice for surgical wounds with high exudate levels and diabetic foot ulcers, and they should be avoided in wounds with low exudation, dry scars or similar conditions [38–41]. Hydrogels are made from a three-dimensional polymeric network. These are composed of a cross-linked network of hydrophilic polymers capable of absorbing and retaining huge volumes of water or wound exudate [32].

Recent advancements in wound dressing materials have led to the development of composite dressings, incorporating layers with specific properties like elasticity and antibacterial activity to manage burns effectively. These advanced dressings often include bioactive compounds, such as collagen, colloidal silver, and hyaluronic acid, which enhance healing by supporting fibroblast proliferation, angiogenesis, and infection control. Furthermore, ideal dressings for burn wounds are designed for flexibility, ease of application and comfort, as pain management is crucial. Further research is carried out in textile technology to optimise the properties of wound dressings [30, 31] by designing and creating tri-layered structures to obtain a varied range of possible special effects. The three-layered structure consists of outer layer I, which plays the role of carrier, insulator and protector of the underlying layers, being elastic, resistant and sub-micro-porous (to block the physical access of microorganisms to the lesion), (layer II) – intended management of liquid compositions in the lesion area, macroporous and compressible, with open pores with high tortuosity and layer III – impermeable substrate – non-adherent, biologically inert and microporous. Antimicrobial properties are frequently integrated into burn dressings to inhibit the growth of bacteria such as *Staphylococcus aureus* and *Escherichia coli* and fungi like *Candida albicans*, helping to prevent infection, which represents a significant risk in burn wounds. Additionally, the hemocompatibility of these materials is crucial, ensuring minimal damage to blood cells while providing compatibility with the patient's tissues. Modern burn dressings are not only passive barriers; they are active, multifunctional materials that play an important role in facilitating wound healing and protecting patients from systemic complications [30, 32].

Advancements in various technological fields have highlighted the promising role of textile technologies in the medical sector. These technologies have been utilised in the development of a wide range of materials for complex reconstructive applications, including skin substitutes, vascular prostheses, implants, and nerve conduits. Textile-based materials are particularly advantageous due to their cost-effective production, versatile fabrication processes, and favourable structural and biomechanical properties, making them a valuable asset in modern medical applications [42–44].

Smart textiles are revolutionising wound care by integrating sensors, drug delivery systems, and responsive materials to actively monitor and enhance the healing process. These advanced fabrics can track key wound parameters such as moisture, pH, temperature, and infection, enabling real-time feedback and personalised treatment. Their ability to release therapeutic agents, maintain optimal conditions, and support tissue regeneration makes them highly effective for chronic and acute wounds. With cost-effective production, flexibility, and remote monitoring capabilities, smart textiles offer a promising solution to improve patient outcomes and reduce healthcare burdens [45, 46].

Nanostructured textiles, particularly those developed using electrospinning technology, offer significant potential in treating severe burn injuries by providing bio-responsive scaffolds that enhance cell adhesion, proliferation, and tissue regeneration. These advanced materials are biocompatible, biodegradable, and non-toxic, ensuring safe clinical use without inducing chronic inflammation. Their high porosity and permeability facilitate nutrient and oxygen exchange, promoting wound healing while reducing scar formation and tension. Electrospun mats improve handling and can be functionalised with growth factors or antibiotics, determining enhanced cell growth with less tension and smoother skin surface than traditional regenerative solutions. In addition, they also improve the scar quality and enhance angiogenesis in preclinical trials. Supported by textile re-industrialization efforts and funding programs, these materials are scalable and cost-effective, with ongoing clinical evaluations aiming to validate their efficacy further. Nanostructured textiles represent a promising innovation in burn care, offering personalised, efficient, and sustainable solutions for better rehabilitation of these complex patients [47–49].

In our study, a high incidence of full-thickness and deep partial-thickness burns was collected, most of which were on the joints or the limbs, with a majority of the patients requiring surgical treatment. In the acute setting, incisions and fasciotomies were carried out for compartment syndrome release in 27 cases. As the gold standard for the treatment of 3rd-degree burns remains that of the excision of the entirely affected region and closure with skin grafts, this practice has been shown to significantly reduce the mortality rates and the length of stay [1, 50]. Thus, this became the most commonly performed operation, being used in 50 patients once, 11 patients required 2 grafting sessions, while the more severe cases required 3 or 5 subsequent graftings in 3, respectively, one case. The severity of the trauma in 7 patients with fixed joints and non-contractile muscle mass in the setting of increasing vasopressor support imposed the necessity of amputating a limb in 5 cases, while 2 other patients required 2 simultaneous amputations. The sequelar stages were treated using local flaps such as Z plasties in 3 cases, 1 local random flap in another case, a pedicled abdominal flap and the use of a locoregional latissimus dorsi flap for the reconstruction of the elbow.

Negative pressure wound therapy (NPWT) is another therapeutic strategy that is also useful for burn injuries. NPWT typically includes an open-pore polyurethane ether foam sponge covered with an adhesive film to form a semi-occlusive dressing and a negative pressure source consisting of a fluid collection system and a suction pump that generates negative pressure and removes excess fluid. NPWT uses controlled suction to remove excess fluid from partial-thickness burn wounds, helping to accelerate healing and reduce further wound progression [51–53].

Particularities of major joints of the limbs involved in severe burns

The issue of joint involvement is a particular one in the burned patient as they can be directly involved by the injury – which was described in 112 of the total cases (80 of these having hand burns), or they can be involved as well in patients with extensive burns without a direct injury of these joints. A large burn injury typically requires an extended length of ICU stay, which, alone, is associated with a significant incidence of contracture [8, 54, 55].

The direct involvement of the joint frequently is treated by the aforementioned therapeutical principles using dressings and by surgical resolve. Of particular interest is the importance of prophylaxis of the contractures, which is achieved by using non-meshed good-quality skin grafts if the donor sites are sufficient. The use of dermal substitutes may prove useful in these cases when the donor sites are scarce. A meticulous operative technique that determines the adherence of the graft to the bed is essential, as well as the post-operative splinting, with all patients benefiting from a strict kinetotherapy program [56, 57]. Aside from the systemic management of these patients, in cases of joint involvement in patients with a high burned TBSA, it is crucial to conduct a correct assessment of the depth of the burned lesions, which may lead to the following therapeutic conduct. Superficial partial thickness may be managed conservatively by aiding the epithelisation using different dressings according to the lesional characteristics. Deep partial-thickness and full-thickness burns require excision and rapid coverage to avoid local complications and sequential functional deficit. The surgical excision can be performed either tangentially using the dermatome or may require excision down to the fascial plane, thus limiting the blood loss but determining more important functional sequelae. Alternative methods are represented by hydro-surgical debridement (Versajet®) or enzymatic debridement using Nexobrid® [58]. The decisive coverage is done with thick, non-meshed skin grafts to avoid scar contracture. Dermal substitutes such as Integra® and Alloderm® may be used to improve functionality but must also be covered with skin grafts [59].

The most severe lesions that lead to exposure of the articular surfaces or the bone will require complex reconstructive methods using flaps [60]. Most of these cases involve electrocution injuries, and therefore, these patients require flap coverage. In one case, a latissimus dorsi flap was used, while two other patients received coverage with random circulation flaps.

Burn contractures affect almost one-third of the total burn patients, leading to a major functional impairment and increasing costs while affecting the patient's physical function, pain and quality of life [61]. Therefore, the importance of effective prevention with treatment strategies aimed at decreasing morbidity and expenses as well as proper body positioning and splinting of the joint structures [62].

Recently, Raborn and Janis published a review paper analysing the latest available data on burn contractures. Despite the extensive number of articles reviewed, they concluded that the literature lacks robust evidence to support the development of an anatomically based algorithm for contracture management. Each anatomical site has its particularities with several reconstructive options but few comparisons between the options. However, they could derive some conclusions: flaps have better outcomes with a lower risk of re-contracture compared to grafts, acellular dermal matrices may decrease the risk of graft contracture, laser therapy mildly reduce contractures and several drugs have been proven to inhibit contracture formation [61]. When establishing a protocol for the surgical treatment of burn patients, prioritising functional zones such as the joints is essential.

A prolonged interval of physical inactivity, which is associated with the burn treatment and the contraction of the scar tissue surrounding the joint, is highly likely to impede joint mobility and recovery. Even though every joint in the body may suffer modifications, the most prone to the formation of contractural deformities are the shoulder, the elbow (most often), the hip and the knee [8]. Studies have shown the fact that wearing splints drastically reduces the incidence of contracture formation from 79% to 26% in the case of the axilla, respectively from 55% to 12% in the case of the elbow, with an even more drastic reduction in incidence if the splints were worn more than 6 months. Consequently, in their study, more than 90% of the 219 individuals who did not use splints necessitated reconstructive surgery, while the incidence of surgery in the lot who used decreased dramatically to 25% [63].

The management of joint contractures can be divided into three stages: acute, intermediate phase of the recovery and established contractural deformities. In the first phase, the main factors leading to contractural deformities are inadequate physical exercise as well as lack of joint splinting. In this setting, splinting of the joints and proper body positioning become necessary. The second phase spreads from the second to the fourth month following burn injury with a physiologically active cicatricial process having the highest collagen synthesis rate and an increase in the myofibroblast population thus being recommended the continuous use of splinting alongside pressure to support the joints and the burned sites [26]. Compression garments prevent the formation of hypertrophic scars if they have not formed yet [64]. The contractural deformities usually require surgical reconstruction, although there also are cases that can be treated by a nonoperative approach, usually after a long period of inactivity and less from scar contracture [8,65,66].

The classic recommendation is that surgical treatment for contractures should be undertaken after the active phase of healing has ceased, usually nearly 1 year when the scar is mature, supple and avascular. Operation on a still active scar, which is in the phase of contraction, may insult the traumatised tissues, leading to a further contraction, ignoring the fact that in this stage, physical therapy approaches may significantly improve the condition. There are some exceptions to this rule, on the subject at hand worth mentioning would be the crippling contractures of the hand, especially those leading to hyperextension of the metacarpophalangeal joints with permanent damage of the extensor mechanism and the contractures of the knees, affecting the upright human position as well as any incapacitating contracture which does not improve by physical therapy [64].

Summarising the aforementioned data, two primary causes of joint injury are highlighted: direct burns and articular contractures, both of which can lead to complex, progressive lesions that may impact various joint structures. Currently, there is no clear consensus on the optimal treatment for these lesions. As a result, prioritising preventive measures, early therapeutic intervention, and a continuous rehabilitation program are essential to reducing morbidity, minimising functional loss, and improving quality of life.

CONCLUSIONS

Burns are among the most severe types of trauma, with high mortality risks even in developed countries and a profound impact on the quality of life for survivors. When functional areas, such as major joints, are affected, these injuries are considered particularly severe, requiring specialised care due to their negative impact on acute recovery and long-term functional outcomes. This study focuses on burns involving major limb joints, which present unique challenges for specialised surgical treatment during the acute phase and throughout long-term recovery. Managing such cases requires intensive, sustained rehabilitation to restore functionality and enhance the patient's quality of life. Our findings emphasise the importance of early intervention and individualised therapeutic strategies for joint-involved burns. By implementing focused surgical and rehabilitative approaches, healthcare providers can address the complex pathophysiology of these injuries, reduce the risk of debilitating complications, and optimise recovery outcomes for burn survivors. The importance of the local treatment has been proven in the evolution of the burned patient, more so when treating the functional ones. Textile technologies represent a promising field for burn wound care in the acute setting as well as during patient rehabilitation.

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