ARTICLE

Our Experiences in Using a Dermal Substitute in Deep Burns of Various Etiologies

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ABSTRACT

OBJECTIVES: The gold standard treatment of burn injury involves early excision of the burned area and reconstruction using split-thickness skin grafts. Alternative methods can be used when traditional skin grafting may not be viable or donor skin is limited. We aimed to review the use and outcomes of dermal substitute combined with split-thickness skin graft for deep partial thickness burn wounds and full thickness burn wounds.

MATERIALS AND METHODS: We included 10 patients (9 males and 1 female; age range, 8-69 years with mean age of 34.5) who were treated in Gulhane Training and research hospital burn center between February 2023 and September 2023. Our protocol relied on clinical assessments, wound examinations, tissue cultures, and photographic documentation.

RESULTS: The burn area was generally located on the extremities. In 8 cases, bone, tendon, or cartilage were exposed. The percentage of total body surface area ranged from 1% to 18% (mean 5.5%). Four patients presented during the chronic period (21 days or more).

CONCLUSIONS: The use of dermal skin substitutes combined with split-thickness skin graft offers a promising alternative for deep burn wounds independent of patient age, burn etiology, or timing of the treatment.

KEY WORDS: ***MatriDerm, Split-thickness skin grafting, Wound, Wound care, Wound dressing, Wound healing***

INTRODUCTION

The global mortality resulting from burn injuries is consistently decreasing, underscoring the increasing importance of achieving satisfactory functional outcomes and acceptable aesthetic appearance.[1] In the initial phase after a significant burn injury, the optimal treatment involves early excision of the burn area and reconstruction with split-thickness skin grafts (STSG), which is considered as the gold standard.[2,3] Although an autograft is commonly regarded as the initial step in the reconstructive ladder, alternative treatment options like local or free flaps, dermal or epidermal substitutes, and stem cell therapy can also be considered for managing burn wounds, especially where traditional skin grafting may not be viable, such as in areas involving bone without periosteum and tendon without paratenon or donor skin is limited.[4-6] Dermal substitutes act as a scaffold for skin reconstruction and play a role in regulating the formation of scar tissue, particularly in scenarios involving acute burn excision, skin cancer, trauma, or scar resurfacing.[5,7] As a result, a variety of artificial dermal substitutes have been increasingly used to improve scar quality, yielding positive functional and aesthetic outcomes by offering an alternative wound cover.[2,8-11]

Several dermal substitutes, with different methods of application and for use for treatment procedure, are available, including MatriDerm (Dr. Otto Suwelack Skin & Health Care AG), Integra (Integra LifeSciences Corporation), Pelnac (Gunze), and NovoSorb Biodegradable Temporizing Matrix (Polynovo). Except for MatriDerm, all dermal substitutes are typically bilayered, incorporating a temporary silicon layer. This layer serves the dual purpose of shielding the dermal substitute from fluid loss and from infection, allowing for matrix vascularization and formation of neodermis. Once the wound bed integration is complete, the silicon layer is replaced with STSG, as a 2-stage reconstruction procedure.[7,10,12-14] Conversely, the novel concept involves the immediate application of skin graft over MatriDerm during the same session.[7]

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The matrix can act as a barrier for vascularization and may lead to skin graft desiccation and failure. A delay in revascularization of the skin graft due to the presence of dermal substitute has not been observed in high-resolution episcopic microscopy, suggesting that nutritional support of the skin graft is provided through diffusion, preventing graft desiccation.[15] A dermal substitute mitigates the risk of hematoma formation following skin grafting by virtue of its hemostatic properties.[2,6]

Negative-pressure wound therapy (NPWT) can play an important role in preconditioning deep wounds by enhancing perfusion within the wound, expediting the formation of granulation tissue, and reducing edema and bioburden, enabling closure through dermal substitute-augmented skin grafting.[5,6] Applying NPWT on grafts also has benefits such as reducing graft desquamation and infection.[5]

Successful engraftment has been repeatedly shown through 1-step or 2-step procedures that use a dermal substitute in deep tissue defects resulting from various causes.[6] We aimed to review the use and outcomes of dermal substitutes for patients with deep partial-thickness and full-thickness burns treated in our burn center.

MATERIALS AND METHODS

We included patients who were treated surgically at the Gulhane Training and Research Hospital Burn Center (Ankara, Turkey) between February 2023 and September 2023 for deep partial-thickness burn wounds and full-thickness burn wounds with exposed structures, such as tendons, ligaments, or bone, with autologous STSG in combination with the application of the dermal substitute and NPWT. We obtained pertinent data for these cases from electronic medical records and hospital archives. We included 10 patients (9 males,1 female) who underwent dermal substitution. Burn etiology, burn percentage, localization, and depth were evaluated. We conducted a retrospective review of both surgical photographs and medical records of the selected patients. The survival rate of the skin graft was determined by calculating the percentage of the entire graft that exhibited stability and proper adherence to the wound bed within 5 to 7 days after the surgery. The transplant was deemed successful if 90% of the grafted surface area exhibited stability. In all patients, the suitability of the wound bed; the presence of exposed tendons, cartilage, and bone; and the depth of the burn were assessed by the responsible surgeon, who decided whether to use a 1-step or 2-step approach.

We used MatriDerm, a disposable 3-dimensional collagen-elastin dermal matrix derived from bovine dermis provided by our hospital, in all patients.

Surgical procedure

The burn wound was debrided, and hemostasis was subsequently achieved. The dermal substitute was applied as a single-step procedure, directly positioned in the dry condition within the wound base of the defect, and subsequently moistened in situ with distilled water. In the 1-step approach, STSG measuring 1 mm in thickness was placed directly on the dermal substitute during the same procedure.

In the 2-step procedure, the dermal substitute was positioned on the wound base, covered with a nonadherent contact layer, and NPWT, or pressure dressing, was applied for 5 days. Skin grafts were applied when a satisfactory amount of granulation tissue had developed around the exposed bone or ligament. Application of STSG for coverage was conducted in a subsequent surgical step, frequently within 5 to 14 days. The STSG was customized to match the size of the wound and applied to the defect zone. The skin graft was utilized in either a mesh form (at a 1:1.5 ratio) or as a sheet. After placement of a nonadherent contact layer over the STSG, either a conventional wound dressing or NPWT device with a pressure setting of 80 mm Hg was applied. A dermal substitute layer measuring 1.0 mm in thickness was meticulously trimmed to align with the dimensions of the defect, with careful attention to avoid excessive size. The initial dressing change was routinely conducted on day 5 postsurgery, and the NPWT device was removed. The area from which the skin graft was procured was covered with a nonadherent contact layer and gauze, which remained in place for approximately 14 days until epithelialization was achieved.

Statistical analyses

Obtained data were gathered in the form of a consecutive case series from the investigators' standard patient population and documented in an Excel data sheet (Excel 2018, Microsoft Corp).

RESULTS

Of the 10 patients included in the study, 4 had electrical burns, 3 had contact burns, 2 had cold burns, and 1 had a chemical burn (Table 1). With the exception of the chemical burn patient and 1 cold burn patient, who had burn wounds in the face, defects were found in the lower and upper extremities. In 8 of 10 patients, bone, tendon, or cartilage was exposed. Six patients were admitted to our clinic in the acute period, with 4 admitted about the first month. The percentage of total body surface area ranged from 1% to 18% (mean of 5.5%). The average time of hospital admission was 14.2 days. Four patients presented during the chronic period (21 days or more). In a 69-year-old patient, there was sensory loss in both feet because of

diabetes; there were no other comorbidities in the remaining patients.

A 1-step approach was applied to 4 patients (Table 2). One of the 4 patients, who had a cold burn defect located in the lumbar region and knee and had previously undergone a session of dermal substitute and pressure dressing followed by partial-thickness grafting 5 days later, presented with graft lysis. In response to this, a 1-step approach was applied, but total graft lysis subsequently occurred again. Tissue culture obtained during the 1-step approach showed growth of *Acinetobacter baumannii*, and antibiotic treatment was initiated. After a decrease in acute-phase reactants through serial debridement occurred, a regional flap was performed (Figure 1). Application of dermal substitute and STSG to the multiple defects in the left crural region of the same patient resulted in successful outcomes (Figure 2).

A patient with a defect on the dorsum of the fingers of the right hand also underwent the 1-step approach. Subsequently, the patient had 10% graft lysis on the third finger, and this area was repaired with local flap (Table 2). Other than the third finger, graft adaptation was observed on the second, fourth, and fifth fingers (Figure 3).

In a 1-step approach applied to a patient with an electrical burn on the dorsum of the left foot, graft lysis was <10%. Successful results were then achieved with a 2-step approach (Figure 4). In another patient with electrical burns on both lower extremities, who had previously undergone grafting for all burn areas, successful results were achieved with a 1-step approach after application of dermal substitute and NPWT twice to areas with exposed tendons (Table 2).

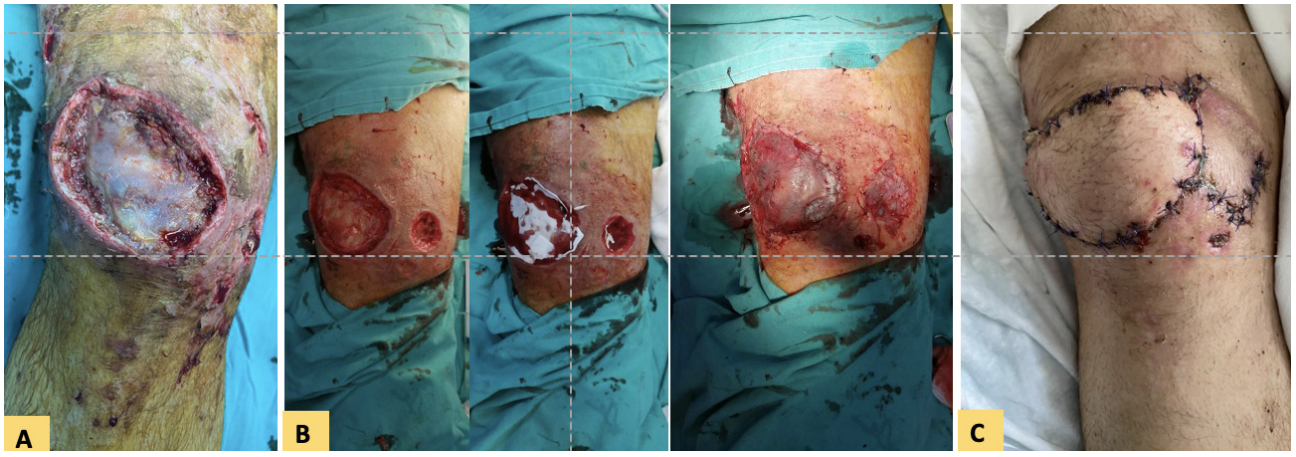
In patients that needed a 2-step approach, we applied different methods according to the current wound status of the patients. Initially, 5 patients had application of dermal substitution and NPWT (Table 2). Three of these patients received 2 to 4 sessions of NPWT alone, and, after observation of granulation tissue formation, STSG was applied. All grafts adapted successfully. The application of

TABLE 1. Patient Characteristics

No.	Age, y	Sex	Etiology	%TBSA	Localization	Exposed Tissue	Postburn Admission Day	LOS, days
1	27	M	Contact	2%	Right hand, dorsum of 2nd, 3rd, 4th, 5th digit, zone 2	Tendon, bone	Day 10	48
2	34	M	Cold	5%	Right knee, left lumber region, left anterior tibia	Bone	Day 6	67
3	8	F	Cold	2%	Left periorbital region, left eye, nose, left frontal area		Day 10	61
4	22	M	Electrical	3%	Left foot dorsum, left medial malleolus, left tibia lower 1/3	Tendon	Day 2	55
5	69	M	Contact	1%	4th, 5th digit of right foot, 1st digit of left foot	Bone, tendon	Day 29	58
6	26	M	Electrical	17%	Posterior neck, anterior thorax, bilateral leg	Tendon	Day 21	46
7	44	M	Electrical	5%	Bilateral lower extremities	Tendon	Day 0	57
8	53	M	Contact	1%	Right medial malleolus		Day 30	21
9	34	M	Chemical	18%	Bilateral hand, forearm, anterior thorax, bilateral leg, ear	Ear cartilage	Day 0	45
10	23	M	Electrical	1%	Left foot 1st digit	Bone, tendon	Day 34	39

Abbreviations: F, female; LOS, length of stay; M, male; TBSA, total body surface area

FIGURE 1. Patient 2, Knee Area



A, Postburn day 10. **B,** 1-step approach application, day 23. **C,** Regional flap, day 32.

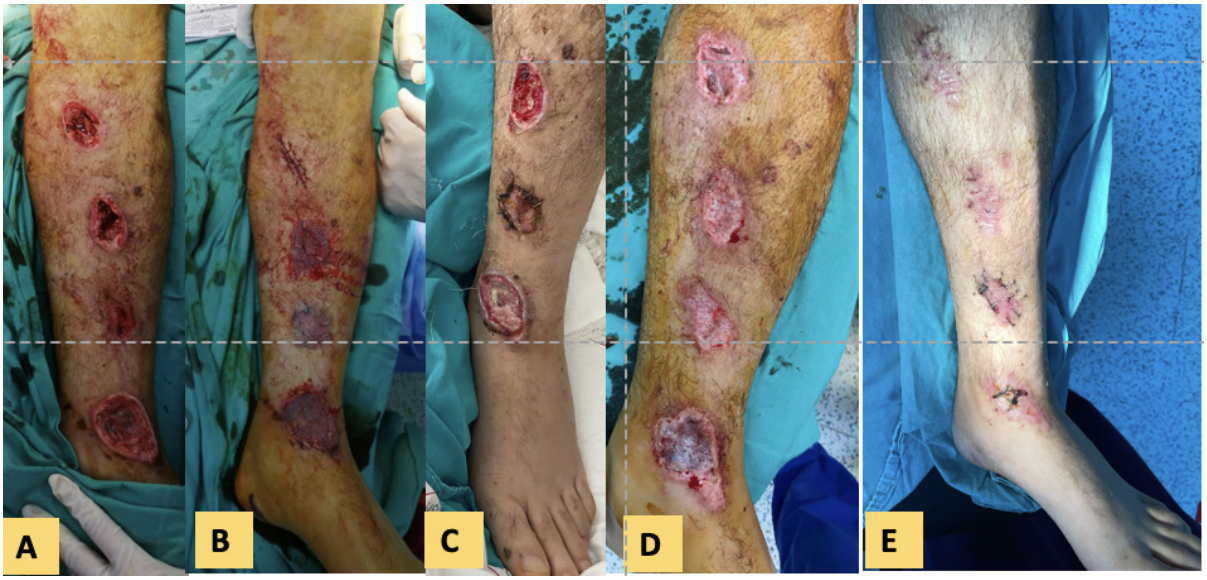
dermal substitute and NPWT was performed, on average, on day 40. Four of the 5 patients with the 2-step approach had exposed tendons without paratenon, bones without periosteum, or cartilage without perichondrium. In 1 of these patients, tissue cultures obtained during both sessions showed the growth of *Acinetobacter baumannii* and

TABLE 2. Operation Day and Application Type

Patient No.	Dermal Substitute Application Type
1	Day 12 dermal substitute + pressure dressing; day 17 STSG; day 23 dermal substitute + STSG + NPWT/flap
2	Day 17 dermal substitute + STSG + NPWT/regional flap
3	Day 24 and 30 dermal substitute + pressure dressing
4	Day 30 and 35 dermal substitute + NPWT; day 40 and 45 NPWT; day 56 STSG
5	Day 53 dermal substitute + NPWT; day 55 and 60 NPWT; day 71 STSG
6	Day 25, 29, and 36 NPWT; day 41 dermal substitute + STSG + NPWT; day 49 and 42 dermal substitute + pressure dressing; day 55 STSG
7	Day 43 and 49 dermal substitute + NPWT; day 51 dermal substitute + STSG + NPWT
8	Day 32 dermal substitute + NPWT; day 38 STSG
9	Day 20 dermal substitute + pressure dressing; day 32 STSG
10	Day 42 dermal substitute + NPWT; day 45, 50, 55, and 60 NPWT; day 65 STSG

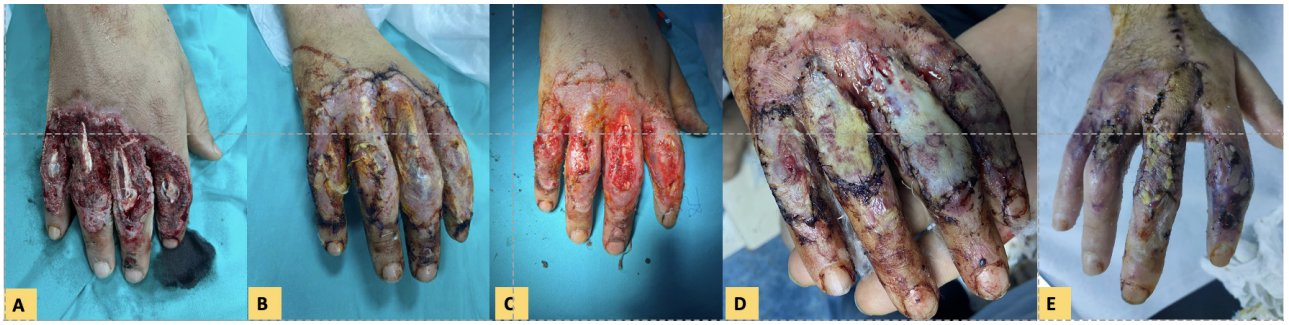
Abbreviations: NPWT, negative-pressure wound therapy; STSG, split-thickness skin graft

FIGURE 2. Patient 2, Left Crural Area



A, Postburn day 10. **B** and **C,** 1-step approach application, day 23. **D,** Before 2-step approach. **E,** After split-thickness skin graft application, day 65.

FIGURE 3. Patient 1



A, Postburn day 12. **B,** split-thickness skin graft after dermal substitute + pressure dressing. **C,** Lytic areas before one step approach. **D,** After 5 days of 1-step approach. **E,** Result after local flap applied to third digit.

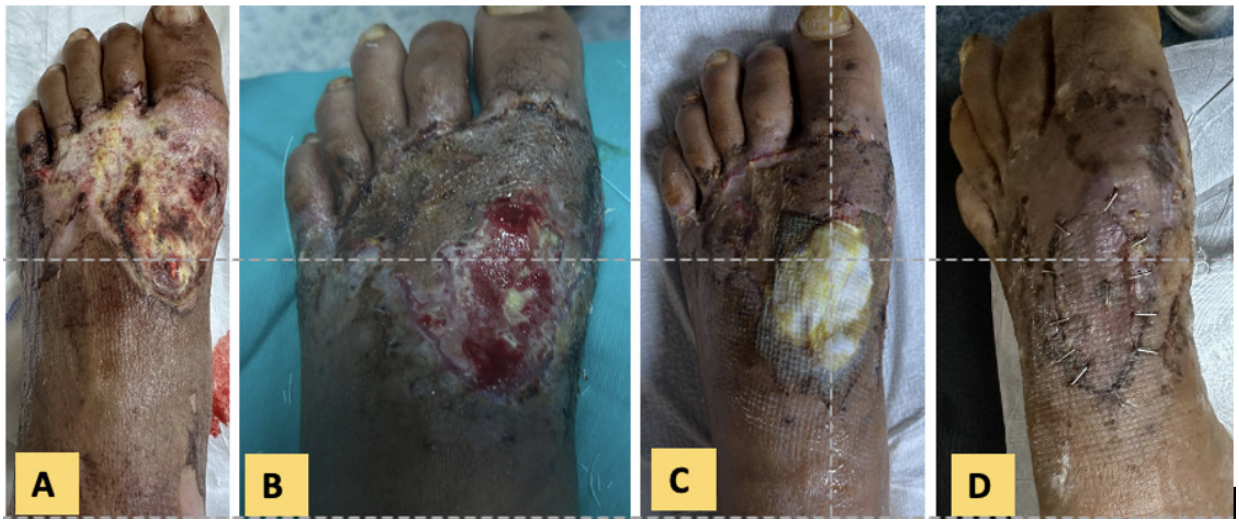
Pseudomonas aeruginosa. After a decrease in acute-phase reactants after application of antibiotic therapy and NPWT, STSG was applied.

The use of NPWT and dermal substitute in a patient with diabetes mellitus and contact burn on the left fifth digit resulted in successful outcomes (Figure 5).

Dermal substitute and pressure dressing were applied as the initial approach in 3 patients. In 1 patient, following total lysis in the STSG applied after the dermal substitute and pressure dressing application procedure, treatment was continued with the 1-step approach and regional flap. In another patient, after application of dermal substitute and pressure dressing, secondary healing and treatment with full-thickness skin graft were applied, and graft adaptation was observed. In the same patient, enucleation to the left eye and release of the contracture located on the left upper eyelid were performed (Figure 6).

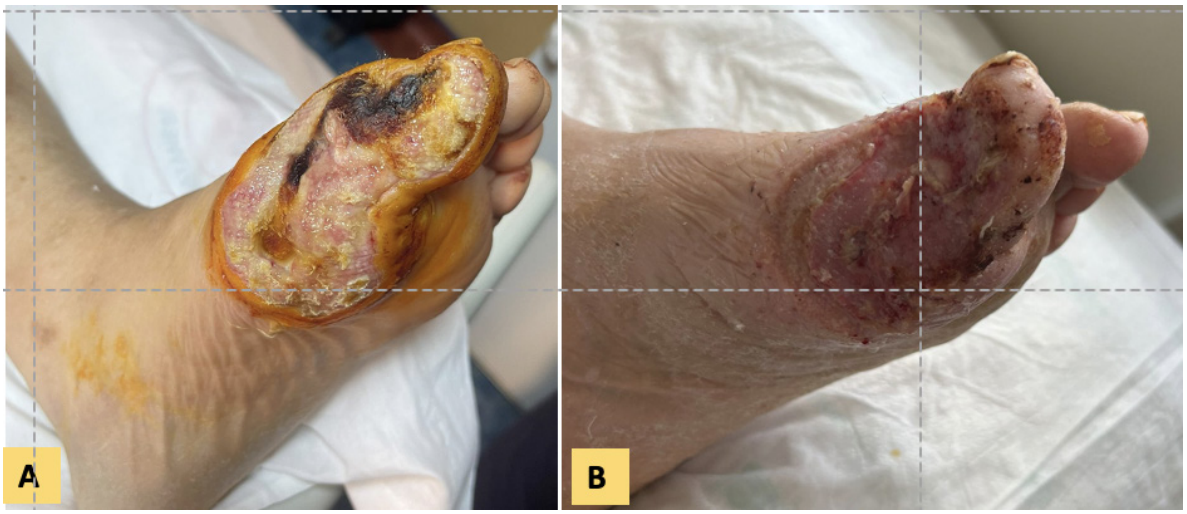
In another patient, who had STSG applied after 12 days of dermal substitute and pressure dressing, the graft was observed to be well adapted. The patient with a contact burn at the right medial malleolus level successfully healed with combined treatment using NPWT and STSG (Figure 7). After dermal substitute application, STSG application ranged from 5 to 26 days (mean of 13 days) .

FIGURE 4. Patient 6



A, Postburn day 20. **B,** Graft lysis after 1-step approach. **C,** Dermal substitute + pressure dressing. **D,** Day 5 after split-thickness skin graft.

FIGURE 5. Patient 5



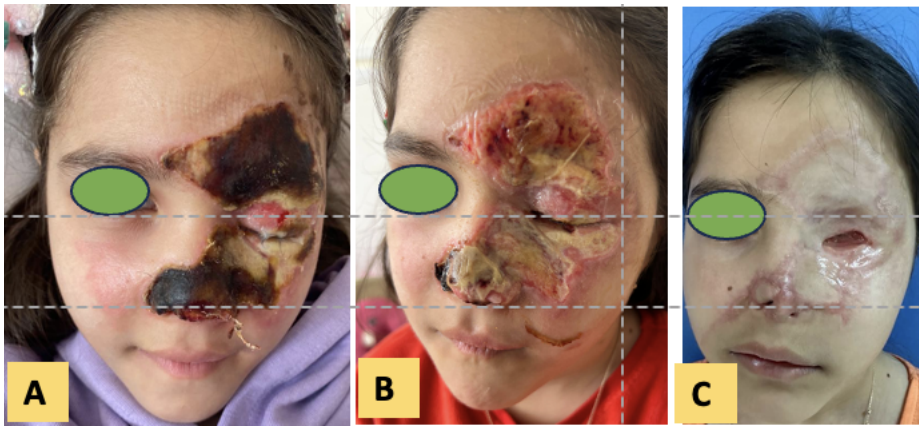
A, Postburn day 30. **B,** Postburn day 81, 10 days after split-thickness skin graft.

DISCUSSION

Based on the satisfactory clinical results shown in this study, the use of dermal skin substitutes combined with STSG offers a promising alternative for burn wounds with exposed bone without periosteum, tendon without paratenon, ligament, or cartilage without perichondrium independent of patient age, burn etiology, or timing of the treatment. In the past, treatment of these types of wounds involved preserving the eschar for granulation tissue formation, decorticating or drilling the bone cortex to establish a suitable foundation for skin grafts, and conducting limited local flap reconstruction. This type of treatment often resulted in long-term morbidity, such as persistent skin ulceration with the potential for malignant transformation, tendon loss, reduced tendon excursion, and joint fusion.[16] In our study, we showed that the combined use of dermal substitute with STSG can prevent these complications.

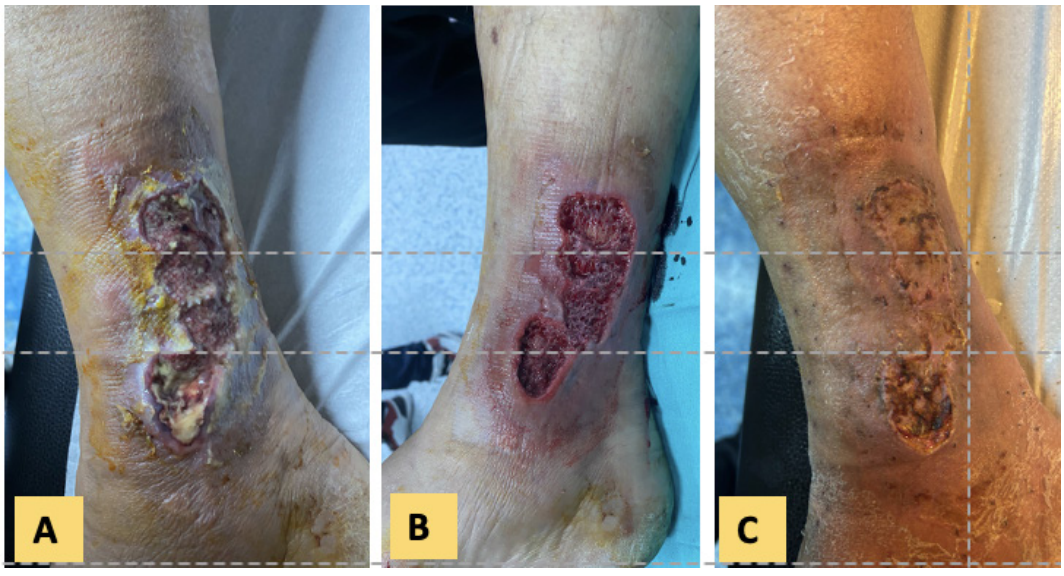
In previous studies, no substantial changes were observed in grafting frequency and graft take with the use of dermal substitutes, and the combined use of dermal substitute and STSG was reported as safe. The effect of the thickness of the dermal substitute on graft nutrition and how it influences graft take have been examined based on the increase in the distance between the graft and the wound bed. Studies showed that this distance did not have an effect on graft take.[2,17,18] In 1 of our patients who had reconstruction of knee region defect with a regional flap, the occurrence of graft lysis was presumed to be linked to the substantial depth of the wound and positive findings in the tissue culture. The deepening of the wound after debridement also led to the decision to implement a regional flap.

FIGURE 6. Patient 3



A, Postburn day 10. **B,** Postburn day 31, after debridement and dermal substitute + pressure dressing. **C,** Follow-up after 5 months.

FIGURE 7. Patient 8



A, Postburn day 30. **B,** Postburn day 38 after dermal substitute + negative-pressure wound therapy. **C,** Postburn day 50.

Options for reconstruction are based on the location and nature of the defect. Nevertheless, the objectives and principles of reconstruction stay consistent between the various options. Comprehensive debridement and the establishment of a clean, ideally well-vascularized wound site are essential prerequisites for any reconstruction. Advances in artificial dermal substitutes and NPWT have played an important role in achieving these goals.[5] Recent studies have shown a high success rate when a combined treatment approach involving dermal matrix and NPWT was applied before skin grafting.[5,19-21] As seen in our study, pretreatment reinforcement of the wound bed with NPWT, as well as the application of NPWT on STSG or dermal substitutes, facilitated adaptation of grafts to the wound bed.

In studies involving the use of dermal substitutes combined with STSG on hand defects, the importance of immobilization has been emphasized.[13,18] In the patient whose finger defect was repaired with a 1-step approach, the graft lysis was believed to be associated with inadequate immobilization of the hand, and this defect was subsequently repaired with a local flap.

Patients treated with dermal substitutes and STSG can have graft failure because of infections at the wound site.[22] In 2 of our patients who had the 1-step approach, we attributed graft lysis to infection. In the patient with <10% graft lysis on the dorsum of the left foot following the 1-step approach, tendon exposure and growth of *Pseudomonas aeruginosa* in the tissue culture were considered as potential causes for the lysis. Similar to other studies, the successful graft take in our study was defined as 90% adaptation of the graft. Therefore, with <10% graft lysis, this session was considered successful.[4]

Except for 2 patients, the absence of the need for local flaps indicated that complex cases with tendon and bone exposure can be managed with the assistance of dermal substitutes and NPWT.

Studies have shown that waiting for 2 to 4 weeks for the material to vascularize after dermal substitute application and applying grafts after this period can lead to more successful outcomes.[23-26] In addition, another study showed that a period of 2 weeks was sufficient, independent of NPWT application.[6] In our study, more effective results were achieved with the intermittent application of STSG and dermal substitute, similar to the 2-step approach. In our patients, STSG was applied for 5 to 26 days (mean 13 days) after the dermal substitute application, with successful graft take after this waiting period.

The main limitation of our study was its retrospective design, which relied on information documented in the patients' medical records. Additional prospective, multicenter studies are essential to assess functional and aesthetic outcomes following treatment with dermal substitutes and to compare these outcomes with patients managed solely with STSG.

CONCLUSIONS

The use of dermal skin substitutes combined with STSG offers a promising alternative for patients with burn wounds with exposed bone without periosteum, tendon without paratenon, ligament, or cartilage without perichondrium, independent of patient age, burn etiology, or timing of the treatment.

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