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ORIGINAL ARTICLE

Analysis of wound types and wound care methods after the 2023 Kahramanmaras earthquake

Serap Ulusoy, MD[1], İbrahim Kılınç, MD[1], Mustafa Oruç, MD[1], Buket Özdemir, MD[1], Hasan Murat Ergani, MD[2], Ömer Halit Keskin, MD[3], Güzelali Özdemir, MD[3]

[1]Department of General Surgery, Ankara Bilkent City Hospital, Ankara, Türkiye
[2]Department of Plastic Reconstructive and Aesthetic Surgery, University of Health Sciences, Ankara Bilkent City Hospital, Ankara, Türkiye
[3]Department of Orthopedics and Traumatology, Ankara Bilkent City Hospital, Ankara, Türkiye

ABSTRACT

Objectives: This study aims to investigate the types of wounds and wound care in earthquake victims rescued from collapsed buildings after the 2023 Kahramanmaras earthquake.

Patients and methods: Between February 8th, 2023 and March 1st, 2023, a total of 94 patients (46 males, 48 females; mean age: 40.2±15.5 years; range, 16 to 77 years) with earthquake-related wounds who were trapped under rubble were retrospectively analyzed. Data including age, sex, duration of being trapped under rubble, type and location of the wound, bacterial cultures from deep tissue, and wound care methods used were recorded.

Results: The mean duration of being trapped under rubble was 58±38.1 h. Wounds were most commonly located on the lower extremities, followed by the upper extremities. The most common type of wounds were abrasions, followed by necrotic wounds due to crushing. Wound and skin antiseptics, debridement and negative pressure wound therapy (NPWT) were the most common wound care methods used.

Conclusion: Various types of injuries and wounds may occur after natural disasters. Chronic wound care is as important as the management of life-threatening acute pathologies. Preparations should be made properly for the long-term treatment of patients after disasters. Methods such as NPWT, debridement creams containing collagenase, wound and skin antiseptics, and hyperbaric oxygen therapy can provide satisfactory short-term results. A broader and more intense application of these treatments is thought to be beneficial, particularly in crush injuries.

Keywords: Collapsed buildings, earthquake, musculoskeletal injury, wound care wound.

On February 6th, 2023, a magnitude of 7.7 (Mw) earthquake struck the Pazarcık district of Kahramanmaras, Türkiye at 04:17 A.M. local time, followed by another magnitude of 7.6 (Mw) earthquake in the Elbistan district of Kahramanmaras at 01:24 P.M. local time on the same day. A large area in Türkiye and Syria was affected by these successive earthquakes. Hundreds of thousands of individuals were injured and thousands lost their lives due to collapsed buildings. As a result of the destructive impact of the earthquake, millions of individuals were forced to migrate.

The injury patterns of those trapped under the rubble vary widely, ranging from severe organ injuries that lead to sudden death to non-fatal minor skin abrasions. While musculoskeletal injuries are the most common, the vast majority of these injuries are soft tissue injuries.[1] Having precise and accurate information regarding the wound profiles of patients would facilitate disaster preparedness and patient management in similar disasters in the future.[2]

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Correspondence: Serap Ulusoy, MD. Ankara Bilkent Şehir Hastanesi, Genel Cerrahi Kliniği, 06800 Çankaya, Ankara, Türkiye.

E-mail: serapulusoy13@gmail.com

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When earthquake victims are removed from under the rubble, they may have various types of wounds all over the body, particularly on the extremities. Surgeons may create wounds requiring special care, such as fasciotomy or amputation, in inpatients who do not have open wounds, where necessary.

There are case studies on post-earthquake wounds in the literature, but the number of in-depth researches on post-earthquake chronic wound cases is limited.[3] The primary objective of this study was to evaluate the wound areas and wound types of patients who survived the earthquake and to investigate the most common treatments applied to these patients in our clinic. The secondary objective was to highlight the significance of chronic wound care in the management of earthquake-related wounds.

PATIENTS AND METHODS

This single-center, descriptive, retrospective study was conducted at Ankara Bilkent City Hospital, Department of General Surgery Chronic Wound Unit, between February 8th, 2023 and March 1st, 2023. A total of 113 earthquake victims who were consulted for wounds on different parts of the body after acute treatment were screened. Patient records and wound follow-up forms were retrospectively reviewed. Thirteen patients with pre-existing chronic wounds such as diabetic foot, venous leg ulcers, and sacral pressure injuries who were referred from the earthquake area, but were not trapped under rubble, and six patients with incomplete data about wound care methods in their wound follow-up forms were excluded from the study. Finally, a total of 94 patients (46 males, 48 females; mean age: 40.2±15.5 years; range, 16 to 77 years) with earthquake-related wounds who were trapped under rubble were included. Age, sex, duration of being trapped under rubble, wound type, body part where the wound was located, bacteria cultured in deep tissue, and wound care methods were recorded. As the majority of patients in this study had multiple injuries in various body parts, all data were presented as the number of patients rather than the number of wounds, taking into account whether the patients had the relevant wound or were receiving the specified treatment. The existing wound types of the patients were classified as abrasion, laceration, contusion, soft tissue necrosis due to crushing, amputation stump-related wounds, fasciotomy wounds, frostbite, ischemic gangrene wounds, and necrotizing fasciitis. Accordingly, only injuries that are confined to the epidermis, in which tissue continuity is disrupted, and considered the simplest in terms of healing, were classified as abrasions. Lacerations were used to describe irregularly defined wounds that extended to all layers of the skin, with tissue bridges called devitalized vessels, nerves, muscles, and any type of soft tissue that did not separate in the separation area. Contusion was used to describe injuries characterized by hemorrhage, edema, and inflammation in tissue resulting from the action of trauma on venules, veins, and small arteries.[4,5]

In wound care, wound and skin antiseptics, topical antibiotic creams, surgical and enzymatic debridement, boric acid, wound care products, autologous graft, wound closure with sutures, hyperbaric oxygen therapy (HBOT) and negative pressure wound therapy (NPWT) were used.

Hypochlorous acid (HOCI) (Crystalin, NPH Pharmaceuticals Inc., Izmir, Türkiye) was used as a wound and skin antiseptic, and 0.2% of nitrofurazone (Furacin, Sanofi Pharmaceuticals Inc., Kırklareli, Türkiye) was used as topical antibiotic cream.

For all NPWT applications, the pressure and application mode were determined according to the patient's condition and the wound. All applications were performed intermittently with a hydrophobic, wide-pore (400-600 μm) polyurethane silver foam, at a maximum pressure of 100 to 125 mmHg, with intervals of 5 min on and 2 min off. The lowest pressure set in off mode was 50 mmHg. The first application, when exudate was high, was performed every 48 h, and subsequent applications were performed every 72 h.

The patients were consulted with undersea and hyperbaric medicine for HBOT, and treatment planning was multidisciplinary. The HBOT was applied at 2.4 ATA for 120 min with 15 min of compression, 15 min of decompression, and 90 min of treatment depth. The number of sessions was decided based on the general condition of the patient and the status of the wound.

Statistical analysis

Statistical analysis was performed using the IBM SPSS version 20.0 software (IBM Corp., Armonk, NY, USA). Descriptive data were expressed in mean ± standard deviation (SD) or number and frequency, where applicable.

RESULTS

The mean duration of being trapped under the rubble was 58±38.06 (range, 2 to 160) h. The wound areas

TABLE I
Patients with wounds to the body parts indicated

	Wound area (n=94)	
	n	%
Lower extremity	79	84
Upper extremity	32	34
Trunk, front	14	14.9
Trunk, back	8	8.5
Head and neck	9	9.6
Perineum	5	5.3

TABLE II
Wound types (n=94)

	n	%
Abrasion	47	50
Laceration	18	19.1
Contusion	15	16
Crush, dry-necrosis	44	46.8
Crush, infected necrosis	21	22.3
Frostbite	4	4.3
Necrotizing fasciitis	4	4.2
Stump necrosis	13	13.8
Stump ischemia	3	3.2
Stump infection	25	26.6
Ischemia, gangrene	2	2.1
Fasciotomy	13	13.8

of the patients are summarized in Table I. The most common area was lower extremities in 84% patients, followed by upper extremity injuries (34%).

The types of wounds of the patients are summarized in Table II. The majority of patients had abrasion-type wounds. Crush injuries, which are the most complicated among earthquake injuries, were seen in 55 patients (58.5%) (Figure 1).

In wound care, the most common practice was wound washing with wound and skin antiseptics. The HOCI was preferred. In abrasions, which was the most common type of wound, wounds were washed with a wound antiseptic mostly. In 10 patients who had deeper abrasions, topical antibiotic cream containing 0.2% of nitrofurazone was applied over the area and the wound was wrapped with dry gauze. This application was done once a day.

A total of 55 necrotic wounds were observed on the extremities and body due to crushing under the mold and high pressure. Thirty-four patients had only dry necrosis, while 11 patients had only infected necrosis. Both wound types were present in 10 patients and the full depth of the wounds could not be clinically determined. After surgical debridement of all infected necrotic wounds, NPWT was applied to 52.4% of these tissues. The remaining patients were followed with a silver wound care dressing (Aquacell® Ag, ConvaTec, Princeton, NJ, USA). In 15 patients, the necrosis progressed to the fascia and muscle tissue and required re-debridement. Surgical debridement was also performed in 19 (43.2%) of 44 clinically uninfected patients with superficial dry necrosis. Other patients were followed with wound care dressing (18.2%) and NPWT (15.9%). In 25 patients, collagenase-containing enzymatic debridement cream (Hyalo4Start, Fidia Farmaceutici, Abano Terme [PD], Italy) was applied, followed by a secondary application of a hydrocolloid dressing (Comfeel Plus, Coloplast Hungary KFT, Nyirbator, Hungary). The cream was applied in a thin layer once a day onto the necrotic tissue. The enzymatic debridement



FIGURE 1. Necrotic wound caused by crushing.

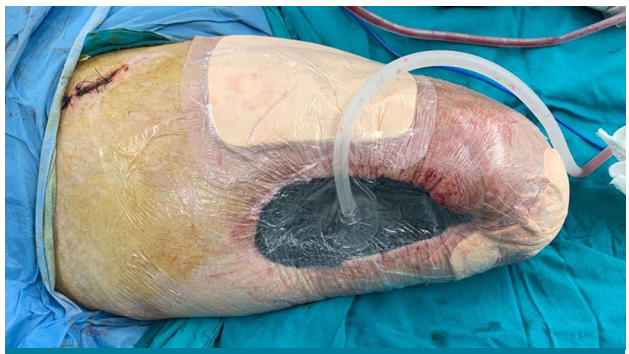


FIGURE 2. Negative pressure wound therapy with stump infection.

approach was used for the limited necrosis area in the amputation stump in one patient who underwent emergency forearm amputation in the earthquake zone, and the patient's wound was sutured primarily at the end of eight weeks.

In the included patients, stump necrosis, ischemia, or infection were detected alone or together. Surgical debridement was performed on 12 patients with stump necrosis. After debridement, the exposed pouch was partially or completely filled with silver-containing NPWT, either with or without partial closure. The amputation levels of the patients were maintained after the applied interventions (Figure 2).

In three patients with ischemia and infection in the stump, a hydrophilic, hydrofiber wound dressing (Aquacell®) made of silver sodium carboxymethyl cellulose was used (Table III). The hydrofiber wound dressing, which has a structure that directly absorbs liquid into its fibers and leaves minimal liquid on the skin/wound surface, was observed to improve ischemia, reduce tissue edema, eliminate the ischemic color on the stump skin, and minimize the need for extensive debridement.

Emergency fasciotomy was performed by other teams in the earthquake zone due to compartment syndrome in 13 patients. In fasciotomy-related wounds, washing with hypochlorous acid, surgical debridement, and NPWT with silver foam were applied. The HBOT was performed in one patient with recurrent necrosis. Two patients who became suitable with NPWT received autologous skin grafts, and primary closure was performed in three patients (Table III).

Four patients with foot ulcers due to frostbite were treated by washing the wounds with hypochlorous

TABLE III
Wound care methods used in patients with the relevant wound type

	Abrasion (n=47)		Laceration (n=18)		Contusion (n=15)		Crush, dry necrosis (n=44)		Crush, infected necrosis (n=21)		Frostbite (n=4)		Necrotizing fasciitis (n=4)		Stump necrosis (n=13)		Stump ischemia (n=3)		Stump infection (n=25)		Ischemic gangrene (n=2)		Fasciotomy (n=13)	
	n	%	n	%	n	%	n	%	n	%	n	%	n	%	n	%	n	%	n	%	n	%	n	%
Debridement	0	0	11	61.1	0	0	19	43.2	19	90.5	1	25	4	100	12	92.3	1	33.3	21	84	2	100	12	92.3
Wound antiseptic	37	78.7	13	72.2	12	80	37	84.1	17	81	4	100	4	100	7	53.8	3	100	15	60	2	100	10	76.9
Topical antibiotic	10	21.7	5	27.8	0	0	10	23.3	1	4.8	4	100	0	0	0	0	0	0	0	0	2	100	0	0
NPWT	0	0	3	16.7	0	0	7	15.9	11	52.4	0	0	4	100	11	84.6	0	0	15	60	0	0	6	46.2
Wound care dressing	12	25.5	7	38.9	2	13.3	8	18.2	9	42.9	1	25	0	0	5	38.5	3	100	15	60	0	0	8	61.5
Boric acid	1	2.1	2	11.1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Enzymatic debridement	0	0	0	0	1	6.7	25	56.8	5	23.8	0	0	0	0	1	7.6	1	33.3	1	4	0	0	2	15.4
HBOT	0	0	0	0	0	0	1	2.3	3	14.3	4	100	0	0	2	15.4	0	0	2	8	0	0	1	7.7
Graft	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	15.4
Primary closure	0	0	0	0	0	0	2	4.5	1	4.8	0	0	1	25	0	0	0	0	2	8	0	0	3	23.07

HBOT: Hyperbaric oxygen therapy; NPWT: Negative pressure wound therapy.

acid and applying topical antibiotic cream containing 0.2% of nitrofurazone. Cilostazol 100 mg twice daily was given peroral to promote vasodilation and low-molecular-weight heparin (4,000 Xa IU/0.4 mL once daily) was given as an anticoagulant. During follow-up, the damaged skin with gangrene peeled off on its own, and healthy tissue grew from under neath, without the need for amputation. Each patient received 20 to 30 sessions of HBOT and, during the writing of this article, HBOT treatments were ongoing. No amputations were observed in any of the patients during follow-up.

Boric acid-containing cream (Epidermos, Mosfarma A.Ş., Ankara, Türkiye) was used in two patients with widespread laceration and culture positive *Pseudomonas aeruginosa* growth. Four patients diagnosed with necrotizing fasciitis underwent surgical intervention including debridement, fasciotomy, and wound irrigation. After serial wound debridement, silver-containing NPWT was applied. Two patients with ischemia and gangrene in their toes due to trauma underwent toe debridement and amputation (Table III).

Bacterial growth was detected in the deep tissue culture of 62 patients. The most common bacteria was *Pseudomonas aeruginosa* (48%), followed by *Acinetobacter baumanii* (32%).

DISCUSSION

Patients trapped under debris during earthquakes may present with various types of injuries, ranging from small abrasions to various parts of the body to large wounds with tissue loss, affecting bones, muscles, major blood vessels, and nerves.

In disasters such as earthquakes, wound care can sometimes be overlooked as patient densities increase and life-threatening pathologies such as severe trauma, organ damage, and contusions occur in patients. Severe wound infections, wound-related sepsis, and tissue and limb loss may develop in patients who do not receive adequate wound care. Many different wound care methods are applied for the correct treatment of wounds. In wound care, the patient should be evaluated in a holistic manner, and the most appropriate wound care method should be used according to the wound and the patient's needs. Satisfactory results can be obtained in wound healing with the correct patient, treatment, and multidisciplinary approach in a shorter period. In the literature, there is no study reporting wound care and wound care methods used for earthquake patients.[6] We believe that our study would contribute to the literature on this subject.

The decision of which debridement method to use in wound care should be based on factors such as the condition of the wound and the patient, the clinician's experience, and the resources available at the facility. Surgical debridement is a preferred method, if the patient's overall condition is suitable and adequate results can be achieved, but caution should be taken regarding potential bleeding after surgical debridement.[7-9] In our series, we performed surgical debridement in 51 patients. Particularly in patients with major crushing injuries, there was much more necrosis in the muscles and fascia beneath the visible necrosis on the skin, and we observed that necrosis progressed as debridement was performed. We attributed the progressive necrosis to the prolonged compression of soft tissues under high pressure (Figure 3a-d). After providing viable tissue through surgical debridement, we continued treatment with different wound care methods. In addition to surgical debridement, other debridement methods such as autolytic, enzymatic, biological, and mechanical can be used. Each method has its advantages and disadvantages.[10] We used an enzymatic wound debridement ointment containing collagenase and selective collagen degradation in necrotic areas in superficial, clinically uninfected, dry necrosis (Figure 4) and in patients for whom surgical debridement is not suitable due to their overall condition. We found that the dry necrosis on the wound surface spontaneously separated from the underlying healthy granulation tissue and, in wounds that did not separate spontaneously, surgical debridement was easier, and there was less bleeding. A systematic review and meta-analysis by Patry and Blanchette[11] showed that the collagenase-containing enzymatic debridement ointment was used for the debridement of many chronic wounds and burns and, similar to our results, the ointment was found to be useful in terms of wound healing and its ability to remove necrotic, lifeless tissues.

Antiseptics are commonly used in wound care to prevent infection and support wound healing. One of the most used antiseptics in wound care is hypochlorous acid. Owing to its antimicrobial, anti-inflammatory, immunomodulatory, and wound-healing properties, HOCl has been included in topical formulations. It is effective against many Gram-positive and Gram-negative bacteria.[12-14] In earthquake-related wounds included in the study, HOCI was used for wound antiseptics and irrigation. Satisfactory results were obtained in terms of reducing wound exudate and odor and improving granulation, particularly in cavitated wounds.

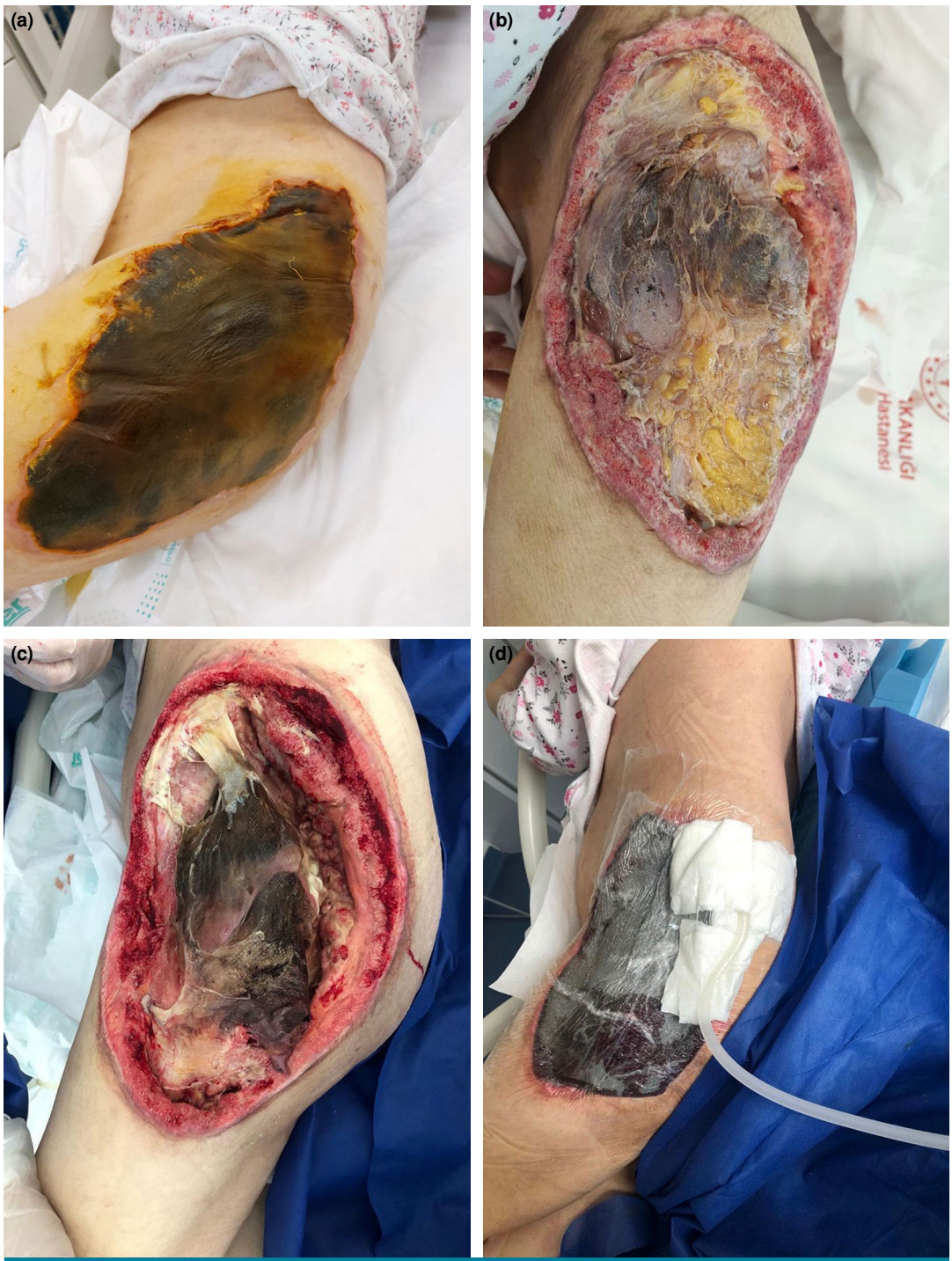


FIGURE 3. (a-c) Progressive necrosis to the prolonged compression of soft tissues under high pressure. **(d)** Negative pressure wound therapy after debridement.

Negative pressure wound therapy has been successfully used, particularly in difficult wound management since its introduction.[15,16] The method involves applying continuous or intermittent negative pressure to the wound, after it has been sterilely closed. The NPWT increases local blood flow, reduces edema and exudate, decreases bacterial load, promotes angiogenesis and granulation tissue formation, wound contraction, and epithelialization.[17-21] Foam impregnated with silver ion can be used as a filling material to take advantage of the antimicrobial effect of silver. Instillation can be applied with topical



FIGURE 4. Non-infected superficial dry necrosis.

negative pressure.[22] In our series, we used NPWT as the primary wound care method for tissue defects after necrotic tissue debridement, amputation stump pathologies, and fasciotomies. We observed a decrease in wound size, an increase in granulation tissue and vascularization, and no increase in amputation levels. There are numerous studies regarding NPWT in the literature.[23-25] The results of the study performed by Milcheski et al.[26] in acute traumatic wounds underlined that NPWT significantly reduced the wound healing time and acted as a bridge before primary closure. In the current study, we also observed similar benefits in our patients. Lalezari et al.[27] also reported an increase in tissue oxygenation and granulation after lower extremity fasciotomies performed after acute trauma with NPWT.[27]

The literature frequently reports the use of various forms of silver and positive results in infection control, particularly in infected wounds.[28,29] All of the NPWT applications in our series were performed with silver dressings. In particular, silver hydrofiber dressings were used in moderately to heavily exudative wounds. Wound exudate and edema significantly decreased with silver dressings, and satisfactory results were achieved in wound healing.

Since the Kahramanmaras earthquake occurred in February when the temperature in the region could drop below freezing, hypothermia and frostbite were observed (Figure 5), particularly in earthquake victims who were trapped under rubble for a long time. In our study, four patients with frostbite were examined. In the literature, early amputation is not recommended in patients with frostbite in addition to wound care, but HBOT, sympathectomy, thrombolytic therapy, and vasodilator agents such as iloprost, reserpine, pentoxifylline and buflomedil are recommended as adjunct therapies. There is no definitive information on the duration of HBOT that should be used. Iloprost is recommended as a vasodilator instead of cilostazol, which we gave to our patients.[30-33] Early amputation was not performed in our frostbite patients, as recommended in the



FIGURE 5. (a) The patient who stayed under the rubble for 144 h, showing a frostbite. **(b)** Appearance after 18 sessions of hyperbaric oxygen therapy.

literature. The treatments performed increased blood circulation in the frostbitten area, the damaged skin detached by itself with signs of gangrene, revealing healthy tissue underneath, and there was no loss of function in the patients.

The HBOT is a treatment based on intermittently administering 100% oxygen under pressures higher than normal atmospheric pressure of 1 ATA within a closed pressure chamber. Its main effect is increasing the partial pressure of oxygen, thereby achieving tissue hyper oxygenation.[34-36] The HBOT has been used in patients with crush injuries who had resistant muscle necrosis and fasciitis despite debridement. Patients with extensive and resistant muscle necrosis had chronic empyema which regressed with the HBOT treatment.

This study is one of the first studies related to the 2023 Kahramanmaras earthquake. It is also significant, as, to the best of our knowledge, it is the first study with a large series showing post-earthquake injuries from the perspective of chronic wound care. Nonetheless, there are some limitations to this study. Although there were a large number of injuries during the earthquakes, our sample size is relatively small. Due to the short time that elapsed since the earthquake, the long-term outcomes of the patients are unknown. Also, our study was conducted retrospectively based on the records of the chronic wound unit of our hospital and there is a need for further larger, prospective studies on wound care and long-term outcomes in earthquake victims.

In conclusion, various types of injuries and wounds may occur after natural disasters. Chronic wound care is as important as the management of life-threatening acute pathologies. Preparations should be made properly for the long-term treatment of patients after disasters. In wound care, the patient should be evaluated in a holistic manner, and the wound care method should be selected according to the wound and the patient's needs. Methods such as NPWT debridement creams containing collagenase, wound and skin antiseptics, and HBOT can provide satisfactory short-term results, if indicated. A broader and more intense application of these treatments is thought to be beneficial, particularly in crush injuries. However, further prospective studies are needed to evaluate the long-term results of these treatment methods.

Ethics Committee Approval: The study protocol was approved by the Ankara Bilkent City Hospital No. 2 Clinical Research Ethics Committee (date: 15.03.2023, no: E2-23-3628). The study was conducted in accordance with the principles of the Declaration of Helsinki.

Patient Consent for Publication: A written informed consent was obtained from each patient and/or parents or legal guardians of the patient.

Data Sharing Statement: The data that support the findings of this study are available from the corresponding author upon reasonable request.

Author Contributions: Idea/concept: S.U., M.O.; Design: S.U., İ.K.; Control/supervision, critical review: G.Ö.; Data collection and/or processing: İ.K., M.O.; Analysis and/or interpretation: M.O.; Literature review: H.M.E.; Writing the article: B.Ö., References and fundings: İ.K.; Materials: Ö.H.K.

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