

Effect of Zinc Supplementation on Healing of Patients with Burns in Sana'a City, Yemen: A Randomized Controlled Trial

Ahmed S. Hudna^{1,*}, Khawla B. Alkataa², Myar Y. Taleb³, Mariam A. Yassin³, Shaima'a A. Al-Ansei³, Ghaida F. Dahrog⁴, Hana'a M. Al-Ameri⁴, Malak M. Al-kolibi⁴, Elham M. Abo-Meskah⁴, Lamia A. Assada⁴.

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Abstract

Introduction: There are different modalities of burn treatment, including zinc supplementation to improve the outcome. Therefore, this study assessed the effect of zinc supplementation among burned patients.

Methods: A randomized controlled trial on zinc supplementation was conducted among 140 burned patients admitted to Al-Jomhuri Hospital, Sana'a from November 2020 to April 2021. Patients were randomly allocated into an intervention group (40) and a control group (100). A pre-designed checklist was used to collect demographic data, burn characteristics, laboratory parameters and burn outcomes. Data were analyzed, and differences and associations were considered significant at p -values <0.05 .

Results The majority of patients were males, aged <20 years, and with second-degree and flame-type burns. Most patients (57%) had burns affecting $>20\%$ of body surface area (BSA). There were no significant differences between both groups regarding age, gender, and degree of burns. However, the mean percentage of burns was significantly lower in the intervention group compared to the control group ($p = 0.015$). The percentage of BSA affected by $\geq 20\%$ was significantly lower in the intervention group ($p = 0.027$). There was a significant difference between both groups regarding the etiology of burns, with flame burns being significantly less frequent in the intervention group ($p = 0.001$). The mean length of hospital stay was significantly shorter in the intervention group ($p = 0.043$). In the intervention group, more patients were discharged with healing, and fewer patients died, but the differences were not significant. Zinc supplementation significantly increased the mean Hb level, WBC count and albumin concentration at discharge.

Conclusion: Zinc supplementation improves the burn outcome, increases the rate of discharge with healing, decreases mortality rate and shortens the length of hospital stay. It improves laboratory parameters. Further studies needed to investigate the role of zinc supplementation in burn treatment in Yemen.

Keywords: Burn, Outcome, Zinc supplementation, Yemen.

¹ Department of Pediatrics, Faculty of Medicine and Health Sciences, University of Science and Technology, Sana'a, Yemen

² Department of Nutrition, Al-Thawra Modern General Hospital, Sana'a, Yemen

³ Physiocenter of Nutrition and Dietetics, Sana'a, Yemen

⁴ Department of Nutrition, Al-Razi University, Sana'a, Yemen

Corresponding Author: Ahmed S. Hudna. E-mail: drahmedhudna@gmail.com

تأثير مكملات الزنك على مرضى الحروق في مدينة صنعاء، اليمن: تجربة سريرية

أحمد هدنة^{1*}، خولة القطاع²، ميار طالب³، مريم ياسين³، شيماء الأنسي³، غيداء دحروج⁴، هناء العامري⁴، ملاك الكليبي⁴، إلهام أبو مسكة⁴، لمياء السادة⁴

ملخص الدراسة

المقدمة: هناك طرق مختلفة لعلاج الحروق، بما في ذلك الزنك للعمل على تحسين العلاج، لذلك أقيمت هذه الدراسة لبيان تأثير الزنك على المصابين بالحروق.

الطريقة: أجريت هذه التجربة لدراسة استخدام الزنك على 140 شخصاً محروقاً تم إدخالهم إلى مستشفى الجمهوري، صنعاء من نوفمبر 2020 إلى أبريل 2021. تم تقسيم المرضى بشكل عشوائي إلى مجموعة تدخل (interventional group) (40) ومجموعة ضابطة (control group) (100). تم استخدام قائمة مصممة مسبقاً لجمع البيانات الديموغرافية وخصائص الحرق والفحوصات المخبرية ونتائج الحروق. تم تحليل البيانات، واعتبرت الاختلافات والارتباطات ذات دلالة إحصائية عند قيم p أقل من 0.05.

النتائج: كان غالبية المرضى من الذكور، تقل أعمارهم عن 20 عامًا، يعانون من حروق من الدرجة الثانية وحروق من نوع اللهب. يعاني معظم المرضى (57%) من حروق تؤثر على أكثر من 20% من مساحة سطح الجسم (BSA). لا توجد فروق ذات دلالة إحصائية بين المجموعتين فيما يتعلق بالعمر والجنس ودرجة الحروق. ومع ذلك، كان متوسط النسبة المئوية للحروق أقل بكثير في مجموعة التدخل مقارنة بمجموعة الضبط ($p = 0.015$). كانت النسبة المئوية لمساحة سطح الجسم المتأثرة بـ 20% أقل بكثير في مجموعة التدخل. وُجد فرق كبير بين المجموعتين فيما يتعلق بمسببات الحروق، حيث كانت حروق اللهب أقل بشكل ملحوظ في مجموعة التدخل ($p = 0.001$). كان متوسط مدة الإقامة في المستشفى أقل بشكل ملحوظ في مجموعة التدخل ($p = 0.043$). في مجموعة التدخل، غادر المستشفى عدد أكبر من المرضى بعد الشفاء، وتوفي عدد أقل من المرضى، لكن الاختلافات لم تكن ذات دلالة إحصائية. أدت إضافة الزنك إلى زيادة كبيرة في متوسط مستوى الهيموغلوبين، وعدد كرات الدم البيضاء وتركيز الألبومين عند مغادرة المستشفى.

الاستنتاج: تحسن مكملات الزنك الحروق، وتزيد من معدل الشفاء عند مغادرة المستشفى، وتقلل من معدل الوفيات وتقصّر مدة الإقامة في المستشفى ويحسن نتائج التحاليل المخبرية، لذلك يوصى بإجراء أبحاث أكثر لدراسة دور الزنك في علاج الحروق في اليمن.

الكلمات المفتاحية: الحروق، نتائج العلاج، مكملات الزنك، اليمن

1. قسم الأطفال- كلية الطب والعلوم الصحية-جامعة العلوم والتكنولوجيا - صنعاء-اليمن
 2. قسم التغذية- مستشفى الثورة العام الحديث- صنعاء-اليمن
 3. فيزيو سنتر للتغذية والحمية- صنعاء-اليمن
 4. قسم التغذية- جامعة الرازي- صنعاء- اليمن
- التواصل مع: أحمد هدنة - البريد: drahmedhudna@gmail.com

Introduction

Burns are traumatic injuries that can cause either a local tissue damage or a systemic mediator-induced response. Both local and systemic oxidant changes are manifested by the accumulation of free radicals and an increase in lipid peroxidation. Burn injuries can also significantly decrease the status of antioxidants and affect their roles. The accumulation of high concentrations of free radicals can result in an oxidative stress, and antioxidants may ameliorate and improve the burn outcome [1].

Zinc is the second essential trace mineral in the human body after iron. It is a cofactor of different enzymes in cell replication and protein synthesis following injury. At the cellular level, it is essential for cell survival, affecting signal transduction, transcription, and replication. Zinc plays an important role in protein synthesis, growth, fertility, immunity, vision, antioxidant defense, and wound healing [2,3].

High-protein diets are usually rich in zinc, whereas high-fiber diets, such as vegetables, are low in absorbable zinc [4]. Delayed wound healing is one of the clinical manifestations of zinc deficiency [2], and chronic zinc deficiency in children is associated with dwarfism, hypogonadism, dermatitis, and T-cell immunodeficiency [5].

The skin contains a relatively high amount of zinc, primarily within the epidermis. In burn patients, zinc deficiency negatively affects wound healing and burn outcomes [2,6].

Different studies had shown the role of zinc in the healing of wounds in patients with thermal injuries or exposure to surgical stress [7,9-11].

The escalating armed conflict and continuous deterioration of economic status have made burn incidence in Yemen more likely. In addition to casualties of bombarding, other causes include storage of fuel and flammable materials inside homes, lack of maintenance of cooking gas bottles, haphazard connection of electricity networks, using unsafe light methods like kerosene lamps, and lack of safety measures in general. Zinc supplementation for burned patients is one of the modalities that would enhance burn healing. This randomized controlled trial (RCT) aimed to investigate the effect of zinc supplementation on burn healing among Yemeni patients.

Methods

Study design, setting and population

A RCT was conducted at the Center of Burns & Plastic Surgery in Al-Jomhuri Hospital, Sana'a from November 2020 to April 2021. All burned patients admitted to the hospital during the study period were included if they were not severely ill, defined as foreseen imminent death, discharged or died nine days after admission, with chronic systemic diseases, or undergoing plastic surgery with skin resection.

Randomization and zinc supplementation

After assessment for eligibility (Figure 1), 141 out of 150 patients were allocated randomly into intervention and control groups, with an allocation ratio of 1:2.5. The

intervention group included 41 patients who were given zinc supplementation, while the control group included 100 patients who were not given zinc supplementation. One patient from the intervention group had an episode of diarrhea so family preferred to stop the participation in the study. Patients in both groups had been matched according to gender, age, burn area, and degree of burn.

The Center of Burns and Plastic Surgery comprised more than one ward, where the intervention group was managed at the fifth floor and the control group was managed at the seventh floor. Health care was provided for the two groups by different staff, but the patients of both groups were managed equally according to the center's policy, including daily wound dressing and usual antibiotics (intravenous ceftriaxone), except for

supplementing the intervention group with zinc during the daily morning shift by specialists of the center as a part of the usual therapy as ordered by the head of the center in cooperation with the researchers. The two forms of zinc used were zinc sulphate syrup (each 5 ml contains 3 mg elemental zinc) and zinc sulphate tablets (each tablet contains 13.6 mg elemental zinc). Daily zinc was given orally after meals during the follow-up period as follow: 3 mg (1 to 3 years) (5 ml of syrup once a day), 5 mg (4 to 8 years) (4 ml of syrup twice a day), 8 mg (9-13 years) (5ml of syrup three time per day) and 11mg (≥ 14 years) (one table once per day) (8). Supplementation was continued until complete healing. All other medical staff and patients at the seventh floor were not informed about the zinc supplementation to patients at the fifth floor.

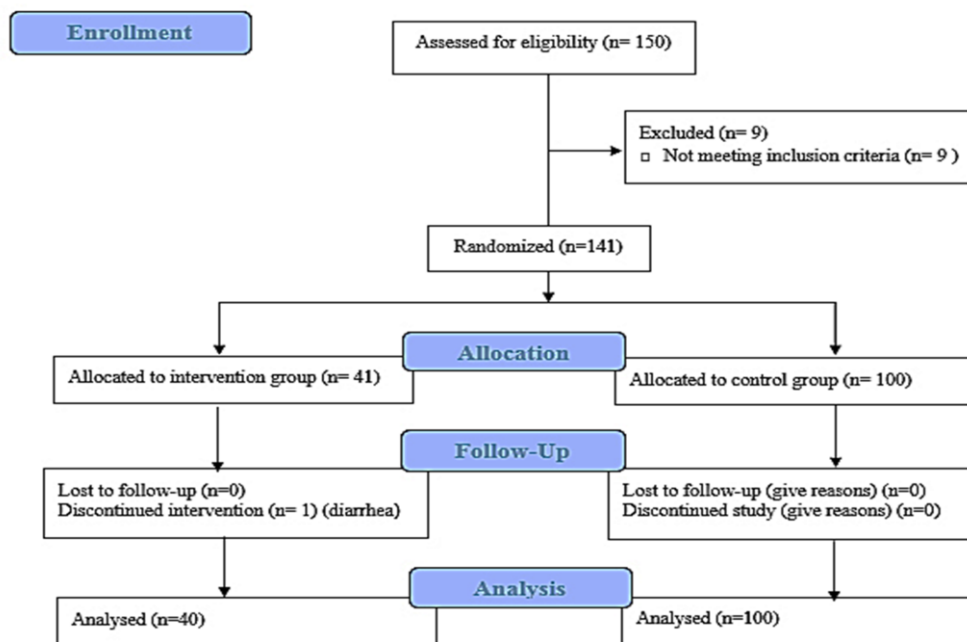


Figure 1: Flow Chart of the Clinical Trial on the Effect of Zinc Supplementation on Burn Healing, Center of Burns & Plastic Surgery, Al-Jomhuri Hospital, Sana'a

Data collection

A pre-designed checklist was used to collect data about demographic data, burn characteristics, hematological and biochemical parameters, as well as burn outcomes (discharge with healing, discharge without healing, or death). Evaluation of burn characteristics (degree, surface area, and healing) was done daily with the assistance of physicians of the center and recorded in the medical record of each patient every morning.

Data analysis

Data were analyzed using IBM SPSS Statistics, Version 26 (IBM Corp., Armonk, NY, USA). Qualitative variables were described as frequency and percentage, and quantitative variables were expressed as mean and standard deviation (SD). Chi-square and Fisher's exact tests were used to study the significance of association between qualitative variables. Independent and paired t-tests were used to compare the mean scores of quantitative variables between and within the groups, respectively. Statistical significance was considered at p -values <0.05 .

Ethical considerations

This study was approved by the Research Ethics Committee of the Faculty of Medicine and Health Sciences, University of Science and

Technology, Sana'a. Written informed consent was obtained from the participants or their caregivers.

Results

The mean age of patients recruited in this study was 20.6 ± 15.5 years and ranged between 4 months and 88 years, with males representing 69.3% of patients. Face and feet represented the most common burned body areas (76.7% and 52.7%, respectively), while perineal area burns were the least frequent (0.8%). Burns in all patients were thermal; either flame (83.6%) or scald (16.4%) burns. The majority of patients (92.1%) had second-degree burns, followed by third-degree (5.7%) and first-degree (2.1%) burns. Burn percentage ranged from 10 to 70% of body surface area (BSA) according to the rule of nines, with a mean percentage of 26.4 ± 11.1 . In the majority of patients (57.1%), burns affected more than 20% of BSA. The mean length of hospital stay was 23.0 ± 13.3 days (range: 9 – 110 days), and the majority of patients (76.4%) were discharged with healing while 9.3% of patients died (Table1).

Table 1: Characteristics of Burned Patients Admitted to the Center of Burns & Plastic Surgery, Al-Jomhuri Hospital, Sana'a (2020-2021)

Variable	No.	%
Group		
Intervention	40	28.6
Control	100	71.4
Age (years)		
Mean (SD): 20.6 (15.5)		
≤20	73	52.1
>20	67	47.9
Gender		
Male	97	69.3
Female	43	30.7
Site of burn		
Face	99	76.7
Feet	68	52.7
Hands	58	45.0
Neck	53	41.1
Upper limbs	37	28.7
Legs	26	20.2
Chest	25	19.4
Arms	20	15.5
Abdomen	19	14.7
Back	15	11.6
Shoulders	6	4.7
Lower limbs	5	3.9
Perineum	1	0.8
Degree of burn		
First degree	3	2.1
Second degree	129	92.1
Third degree	8	5.7
Burned BSA (%)		
Mean (SD): 26.4 (11.1)		
<20	60	42.9
≥20	80	57.1
Burn etiology		
Flame	117	83.6
Scald	23	16.4
Length of hospital stay (days)		
Mean (SD): 23.0 (13.3)		
Outcome		
Discharge with healing	107	76.4
Discharge without healing	20	14.3
Death	13	9.3

BSA, body surface area; SD, standard deviation

Association of demographic characteristics with burn outcome

Table 2 shows no statistically significant association between gender and burn outcomes, even though a higher proportion of discharge with healing and a lower proportion of deaths were observed among females than males, being 81.4% vs. 74.2% and 2.3% vs. 12.4%, respectively. In contrast, age was significantly associated with the burn

outcome ($p = 0.001$), with the proportion of discharge with healing was lower (64.2% vs. 87.7%) and discharge without healing was higher (17.9% vs. 10.9%) among patients older than 20 years compared to those aged 20 years or younger, respectively. On the other hand, more death happened among patients older than 20 years compared to their counterparts (17.8% vs. 1.4%, respectively).

Table 2. Association of Demographic Characteristics with Burn Outcome among Patients Admitted to the Center of Burns & Plastic Surgery, Al-Jomhuri Hospital, Sana'a (2020-2021)

Characteristic	N	Outcome of patients with burns						P
		Discharge with healing		Discharge without healing		Death		
		No.	%	No.	%	No.	%	
Gender								
Male	97	72	74.2	13	13.4	12	12.4	0.164
Female	43	35	81.4	7	16.3	1	2.3	
Age (years)								
≤ 20	73	64	87.7	8	10.9	1	1.4	0.001
>20	67	43	64.2	12	17.9	12	17.8	

Comparison between intervention and control groups of burn patients in relation to demographic and burn characteristics of patients, length of hospital-stay and burn outcome

Table 3 shows that there were no significant differences between patients in the intervention and control groups regarding age, gender and degree of burns. However, the mean percentage of burns was significantly lower in the intervention group supplemented with zinc compared to the control group (22.8% vs. 27.8% of BSA, respectively; $p = 0.015$). In addition, the percentage of BSA affected by $\geq 20\%$ was significantly lower in the intervention group compared to the control group (42.5% vs. 63.0%, respectively; p -value 0.027). There was a significant

difference between both groups regarding the main etiology of burns, with the proportion of flame burns being significantly higher in the interventional group compared to the control group (67.5% vs. 10% respectively), while the proportion of scaled burn was significantly higher in the control group compared to the interventional group (90.0% vs. 32.5%) with a p -value of 0.001.

Table 3 also shows that the mean length of hospital stay was significantly shorter in the intervention group compared to the control group (20.2 vs. 24.1 days, respectively; $p=0.043$). The proportion of patients discharged with healing was higher in the intervention group compared to the control group (87.5% vs. 72.0%, respectively), with

lower proportions of patients discharged without healing (7.5% vs. 17.0%, respectively) and of patients who died (5.0% vs. 11.0%,

respectively). However, the differences were not statistically significant.

Table 3: Comparison of Demographic and Burn Characteristics, Length of Hospital-Stay and Burn Outcomes between Intervention and Control Groups of Burns Patients, Center of Burns & Plastic Surgery, Al-Jomhuri Hospital, Sana'a (2020-2021)

Variable	Intervention group (N=40)		Control group (N=100)		p-value
	Mean (SD)	No. %	Mean (SD)	No. %	
Age (years)	17.9 (15.5)		21.7 (15.4)		0.422
≤ 20		23 57.5		50 50.0	0.114
> 20		17 42.4		50 50.0	
Gender					
Male		25 62.5		72 72.0	0.271
Female		15 37.5		28 28.0	
Degree of burn					
First degree		0 0.0		3 3.0	0.545
Second degree		37 92.5		92 92.0	
Third degree		3 7.5		5 5.0	
Percentage of burn	22.8 (9.6)		27.8 (11.3)		0.015
Burned BSA (%)					
<20%		23 57.5		37 37.0	0.027
≥20%		17 42.5		63 63.0	
Burn etiology					
Flame		27 67.5		10 10.0	0.001
Scald		13 32.5		90 90.0	
Length of hospital stay (days)	20.2 (7.7)		24.1 (14.8)		0.043
Burn outcome					
Discharge with healing		35 87.5		72 72.0	0.149
Discharge without healing		3 7.5		17 17.0	
Death		2 5.0		11 11.0	

Comparison between intervention and control groups of burn patients in relation to hematological and biochemical parameters at admission and discharge

Table 4 shows that there was no significant difference in the mean hemoglobin (Hb) level at admission between the intervention and control

groups (13.3 ± 3.8 vs. 13.7 ± 3.4 g/dl, respectively; $p=0.541$). However, zinc supplementation significantly increased the mean Hb level at discharge in the intervention group compared to the control group (14.6 ± 3.2 vs. 13.1 ± 3.6 g/dl, respectively; $p=0.022$). Regarding the total white blood cell (WBC), there was no

significant difference in the mean count at admission between the intervention and control groups (13.8 ± 4.3 vs. $13.7 \pm 4.5 \times 10^9/L$, respectively; $p=0.928$). However, zinc supplementation significantly increased the mean total WBC count in the intervention group compared to the control group (13.9 ± 5.4 vs. $11.7 \pm 5.3 \times 10^9/L$, respectively; $p=0.033$). In contrast, there were no significant differences between both groups at admission or discharge regarding the mean percentage of neutrophils, lymphocytes, platelet

count, the level of aspartate aminotransferase (AST), glutamate aminotransferase (ALT), total bilirubin, direct bilirubin, creatinine, urea, blood urea nitrogen (BUN), sodium, potassium and chloride between the intervention and control group, neither at admission nor at discharge. However, the mean albumin concentration significantly increased among patients of the intervention group compared to the control group at discharge (35.0 ± 6.1 vs. 28.2 ± 7.4 g/dl, respectively; $p < 0.001$).

Table 4: Comparison of Hematological and Biochemical Parameters at Admission and Discharge between Intervention and Control Groups of burn patients admitted to the Center of Burns & Plastic Surgery in Al-Jomhuri Hospital, Sana'a (2020-2021)

Variable	Timing of investigation	Intervention group	Control group	p-value
		Mean (SD)	Mean (SD)	
Hb (g/dl)	Admission	13.3 (3.8)	13.7 (3.4)	0.541
	Discharge	14.6 (3.2)	13.1 (3.6)	0.022
Total WBC count ($\times 10^9/L$)	Admission	13.8 (4.3)	13.7 (4.5)	0.928
	Discharge	13.9 (5.4)	11.7 (5.3)	0.030
Neutrophils (%)	Admission	69.6 (15.4)	74.6 (14.3)	0.073
	Discharge	77.5 (16.5)	72.8 (14.7)	0.101
Lymphocytes (%)	Admission	22.8 (13.8)	22 (14.1)	0.767
	Discharge	22.7 (12.3)	23 (12.6)	0.895
Platelet count ($\times 10^9/L$)	Admission	325.0 (216.3)	324.9 (177.7)	0.997
	Discharge	488.9 (207.3)	438.5 (220.1)	0.266
AST (U/L)	Admission	34.5 (17.8)	44.6 (34.2)	0.207
	Discharge	33.5 (31.6)	37.5 (28)	0.678
ALT (U/L)	Admission	35.6 (44.0)	38.7 (45.2)	0.812
	Discharge	26.2 (15.7)	43.6 (53.7)	0.278
Total bilirubin (mg/dl)	Admission	0.5 (0.2)	0.5 (0.2)	0.243
	Discharge	1.4 (2.2)	1.0 (1.5)	0.488
Direct bilirubin (mg/dl)	Admission	0.7 (2.4)	0.5 (1.9)	0.731
	Discharge	0.5 (0.7)	0.4 (0.6)	0.555
Albumin (g/L)	Admission	23.7 (9.3)	24.7 (5.5)	0.449
	Discharge	35.0 (6.1)	28.2 (7.4)	<0.001
Creatinine (mg/dl)	Admission	0.5 (0.2)	0.5 (0.2)	0.385
	Discharge	0.5 (0.2)	0.6 (0.4)	0.313

Urea (mg/dl)	Admission	31.5 (4.3)	25.5 (19.7)	0.094
	Discharge	25.3 (8.6)	19.8 (13.8)	0.225
BUN (mg/dl)	Admission	29.9 (49.2)	8.3 (3.4)	0.290
	Discharge	12.0 (5.0)	7.6 (1.9)	0.086
Sodium (mmol/L)	Admission	132.5 (3.9)	133.7 (6.0)	0.380
	Discharge	135.4 (5.1)	136 (6.4)	0.676
Potassium (mmol/L)	Admission	3.8 (0.6)	3.9 (0.7)	0.398
	Discharge	4.4 (0.8)	4.2 (0.6)	0.252
Chloride (mmol/L)	Admission	99.8 (6.2)	100.2 (6.5)	0.781
	Discharge	99.1 (6.7)	100.7 (5.6)	0.262

Discussion

Burn patients suffer from zinc deficiency due to exudative loss, increased urinary excretion, and decreased carrier proteins, leading to systemic dysfunctions including impaired wound healing. In addition, increased production of oxygen free radicals and the decrease in natural antioxidants may negatively affect wound healing and burn outcomes [9-11]. To the best of our knowledge, this is the first RCT to assess the effect of zinc supplementation on burn outcomes among Yemeni patients. The mean age of burned patients in this study (20.6 ± 15.5 years) is younger than that (35.6 ± 19.4 years) reported for Iraqi patients with burns [2] and that (41.6 ± 17.0 years) reported in burn centers across North America [11]. The gender ratio of burn patients in this study is consistent with those reported elsewhere [6,10], where males represented nearly two-thirds of patients. In contrast, lower proportions of males were previously reported for burn patients from Sana'a (58%) [12] and Hodeidah (54.1%) [13]. The higher burn rate in males could be attributed to their nature of work and occupational exposure.

The most affected site by burns among patients in this study was the face (76.7%), followed by feet, hands, neck, upper limbs, legs, and chest. However, the least affected sites were the arms (15.5%), abdomen (14.7%), back (11.6%), shoulders (4.7%), lower limbs (3.9%), and perineum (0.8%). Accordingly, the extremities (hands and other parts of upper limbs, feet, legs and remaining parts of lower limbs) were the most affected body sites. Similar findings were reported for Jordanian patients, with extremities being the most affected body sites (68.3%) [14].

In the present study, the majority of burns (92.1%) were of the second degree. This finding is consistent with that (84.5%) previously reported for burn patients in Sana'a [12]. This could be explained by the fact that patients with first-degree burns usually do not require admission to hospital in the majority of cases, and those with severe types of burns are admitted to the intensive care unit, and if imminent death was expected; they had been excluded from the present study.

In the present study, 10-70% of BSA was found to be burned according to the rule of nines, with more than 20% of BSA being affected for more than half of patients and 11-20% of BSA being affected for 39.3% of patients. This finding is consistent with that (15-70%) reported for Iraqi patients with burns [2]. However, a higher percentage of up to 93% was reported for burned BSA among burn patients in North America, with the majority (60.1%) having burns of more than 20% of BSA [11]. All burns among the patients in this study were thermal, either flame (83.6%) or scald (16.4%). This finding is in line with that reported for burn patients in Sana'a, where flame burns represented the majority (69.5%) of burns [12]. Likewise, the majority (77.5%) of burns among Iraqi patients were reported to be flame burns [2].

In the present study, zinc supplementation was found to significantly shorten the mean length of hospital stay to 20 days compared to 24 days for patients not supplemented with zinc. Likewise, zinc supplementation was found to significantly reduce the time of healing from 57 to 27.5 days among American patients with severe burns [6], from 20 to 10 days and from 9.2 to 8.6 days among Iraqi patients with burns [1,2]. Zinc supplementation was also found to reduce the length of hospital stay among Brazilian children with burns from 7.5 to 5.3 days [15]. Such findings support the role of zinc in protein synthesis and as an antioxidant to ameliorate wound healing. Despite the benefits of zinc for burned patients, it has been recommended that plasma zinc levels should be normalized to achieve its benefits, and large doses of zinc are therefore not necessary [6,15].

The proportion of burn patients discharged with healing was higher among patients supplemented with zinc compared to those not supplemented (87.5% vs. 76.4%, respectively), and only 5% of zinc-supplemented patients died compared to 11% of those not supplemented. This finding is comparable to that reported for Iraqi patients, where 3.3% of zinc-supplemented patients died compared to 20% of those not supplemented with zinc [1]. Similarly, death decreased from 11.1% to 9.1% and from 10% to 9% among American [6] and Swiss patients with burns, respectively [16].

In the present study, death was higher among males (12.4% vs. 2.3%), and older ages (17.9% vs. 1.4%). This finding is consistent with that reported for Jordanian patients with burns, where the mortality rate was higher among males (8.1% vs. 6.5%), and older patients (19.15% vs. 7.9%) [14]. Death was associated with burns of a larger BSA of $\geq 20\%$ (15% vs. 1.7%), but this association did not reach statistical significance. In contrast, a significant association was found between death and flame burns (10.3% in flame burns compared to 4.3% in scald burns). In line with this finding, mortality rate was found to be higher among Jordanian patients with flame burns compared to scald burns (20% vs. 4.6%, respectively) [14].

Regarding laboratory parameters in our study, Hb and total WBC count were significantly increased at discharge among patients supplemented with zinc compared to those not supplemented. All hematological parameters were within the normal range and did not significantly differ between both groups. Nevertheless, the

improvement of most parameters was better in the zinc-supplemented group. These changes in laboratory parameters are similar to what had been described among Swiss patients with burns [16]. Changes in hematological parameters among burn patients had been attributed to initial hemoconcentration of blood elements at admission due to fluid loss, followed by hemodilution related to fluid resuscitation [17]. The increase in hematological parameters among patients supplemented with zinc in our study is consistent with that described among Brazilian children with burns [15].

In the present study, patients of both groups showed normal liver function, where AST, ALT, total bilirubin and direct bilirubin were within normal ranges. This finding is in agreement with that reported among Iraqi patients by Al-Kaisi *et al.* [2]. Although Al-Jawad *et al.* [1] observed an initial mild increase in liver enzyme activity among Iraqi patients with burns, which reflects cellular damage due to burns, enzyme activity then returned to normal before patients were discharged [1]. On the other hand, the mean albumin levels were lower at admission in both groups, but albumin level was significantly higher at discharge among patients supplemented with zinc compared to their counterparts, which is consistent with that reported among Brazilian children with burns [15]. The initial decrease in albumin level could be attributed to bleeding and the acute inflammatory process generated by thermal trauma, but then improved at discharge [15]. Similar observations have been concluded in a double-blind, placebo-controlled trial [17].

Regarding renal function of burned patients, creatinine, urea, blood urea nitrogen (BUN) and electrolytes were within normal ranges in both groups, with no significant difference. This finding is consistent with that reported from patients with burns, where unchanged values of creatinine were found in patients after severe burn injury [2,15]. However, a significant increase in creatinine and BUN was observed for all Iraqi patients with burns at admission that gradually returned to normal levels at discharge [1].

Limitation of study

This study is limited by the small sample size, which is attributed to the low economic status of many patients that compelled to leave the hospital before completing the therapeutic plan. However, its design as an RCT provides insights into the usefulness of zinc supplementation to burn patients for the first time among Yemeni patients. Furthermore, the level of serum zinc was not assessed because of its high cost and the limited number of laboratories performing such a test .

Conclusion

Zinc supplementation improves the outcome of Yemeni patients with thermal burns, increasing the rate of discharge with healing and decreasing the mortality rate. In addition, this therapeutic modality shortens the lengths of hospital stay. It also improves hematological and biochemical parameters. Therefore, further studies needed to investigate the role of zinc supplementation in burn treatment in Yemen.

Competing interest

The authors declare that they have no competing interests.

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References

1. Al-Jawad FH, Sahib AS, Al-Kaisy AA. Role of antioxidants in the treatment of burn lesions. *Ann Burns Fire Disasters* 2008; 21(4):186–91.
2. Al-Kaisy AA, Salih Sahib A, Al-Biati HAHK. Effect of zinc supplement in the prognosis of burn patients in Iraq. *Ann Burns Fire Disasters* 2006; 19(3):115–22.
3. Lansdown ABG, Mirastschijski U, Stubbs N, Scanlon E, Ågren MS. Zinc in wound healing: Theoretical, experimental, and clinical aspects. *Wound Repair Regen*. 2007; 15(1):2–16.
4. Prasad AS. Zinc: an overview. *Nutrition* 1995; 11(1 Suppl): 93–9.
5. Kliegman RM. *Nelson Textbook of Pediatrics, Nutrition*. 20th ed. Elsevier; 2018.
6. Olson LM, Coffey R, Porter K, Thomas S, Bailey JK, Jones LM, *et al*. The impact of serum zinc normalization on clinical outcomes in severe burn patients. *Burns* 2020; 46(3): 589–95.
7. Lin PH, Sermersheim M, Li H, Lee PHU, Steinberg SM, Ma J. Zinc in wound healing modulation. *Nutrients* 2017; 10(1): 16.
8. National Institutes of Health. Zinc: Fact sheet for health professionals [Internet]. Bethesda, MD: NIH; 2022 [cited 2022 Sept 9]. Available from: <https://ods.od.nih.gov/factsheets/Zinc-HealthProfessional/>.
9. Khorasani G, Hosseinimehr SJ, Kaghazi Z. The alteration of plasma's zinc and copper levels in patients with burn injuries and the relationship to the time after burn injuries. *Singapore Med J* 2008; 49(8): 627–30.
10. Maret W, Sandstead HH. Zinc requirements and the risks and benefits of zinc supplementation. *J Trace Elem Med Biol* 2006; 20(1):3–18.
11. Caldis-Coutris N, Gawaziuk JP, Logsetty S. Zinc supplementation in burn patients. *J Burn Care Res* 2012; 33(5):678–82.
12. Alghalibi S, Humaid A, Alshaibani E, Alhamzy E. Microorganisms associated with burn wound infection in Sana'a, Yemen. *Egypt Acad J Biol Sci* 2011; 3(1):19–25.
13. Al-Kadassy AM, Suhail MA, Naji ARS, Alkadasi MNO, Zaid AA. Bacterial burn wound infections and susceptibility to antibiotics in Al-Thaowrah General Hospital, Hodeidah city, Yemen. *Proteus* 2014; 1:1–9.
14. El-Maaytah KA. Patterns and sequelae of burn injury at the Jordanian Royal Medical Services Rehabilitation Center in 2005-2017: a cross-sectional study. *Elect Physician* 2019; 11(2): 7552–7.

15. Barbosa E, Faintuch J, MacHado Moreira EA, Goncalves Da Silva VR, Lopes Pereira MJ, Martins Fagundes RL, et al. Supplementation of vitamin E, vitamin C, and zinc attenuates oxidative stress in burned children: A randomized, double-blind, placebo-controlled pilot study. *J Burn Care Res* 2009; 30(5):859–66.
16. Berger MM, Baines M, Raffoul W, Benathan M, Chioloro RL, Reeves C, et al. Trace element supplementation after major burns modulates antioxidant status and clinical course by way of increased tissue trace element concentrations. *Am J Clin Nutr* 2007; 85(5):1293–300.
17. Berger MM, Spertini F, Shenkin A, Wardle C, Wiesner L, Schindler C, et al. Trace element supplementation modulates pulmonary infection rates after major burns: a double-blind, placebo-controlled trial. *Am J Clin Nutr* 1998; 68(2):365–71.