

Research Article

# The Provision of Orthopedic Surgery in the Gaza Conflict: A Literature Review

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## Abstract

**Background/objectives:** The Gaza–Israel conflict originally began in 1948. Since the Israel– Hamas conflict broke out on Oct 7, 2023, thousands have been killed or injured. Musculoskeletal trauma has historically represented a significant proportion of war injuries due to high-energy trauma from mines, gunshots, and bombs. This review aims to explore the role of orthopedic surgery in the Gaza conflict and the limitations of delivering orthopedic care.

**Methods:** A literature search of academic and grey literature on orthopedic surgery care in Gaza between Jan 1948 and May 2024 was conducted.

**Results:** Key themes identified were: 1) the breadth of orthopaedic surgery care in the Gaza strip; 2) injury demographics; 3) mechanisms of injury; 4) complications; 5) the delivery of orthopaedic surgery care in a multi-disciplinary setting; and 6) limitations of the delivery of orthopaedic surgery in Gaza.

**Conclusions:** Orthopedic surgeons have been vital to the management of war injuries in the Gaza Strip. However, the delivery of orthopedic care is limited by resources and personnel on the ground, highlighting a need for humanitarian aid and research or training partnerships with local healthcare providers and universities.

**Keywords:** War; Conflict; Trauma; Open fractures; Primary fixation; Orthopedic surgery; Orthopedics.

## Introduction

The Gaza Strip has a population of approximately 2.1 million people who live under a blockade that was imposed by Israel after Hamas took over the Gaza Strip in 2007 [1-3]. The Gaza–Israel conflict, however, began much earlier in 1948 when the First Arab–Israeli war took place after Israel was created and two-thirds of Palestinians were forcibly dispossessed and dispersed as refugees into neighbouring Arab countries [2,3]. The

most recent development in the region is the Israel–Hamas conflict which began on Oct 7 2023 after the terrorist group Hamas broke out of the enclave and killed 1,400 people in Israel and took over 240 people hostage [4]. In March 2024, five months into the Israel–Hamas war, 30,631 Palestinians were killed and over 72,000 Palestinians were injured [5].

Gaza’s medical facilities have not been spared during the conflict, suffering from approximately 135 strikes in Nov 2023

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[6]. For example, Al-Shifa Hospital, Gaza's largest hospital, struggles with restricted power and medical supplies and hindered evacuations [6], and years of being under siege have reduced it from a potentially modern university-like hospital to a makeshift field hospital [7]. As of May 2024, only 13 (36%) of Gaza's 36 hospitals are partly functional [8]. The United Nations (UN) further warns that Gaza's health system is on the brink of collapse due to air strikes, lack of fuel, increased numbers of patients suffering from war-related injuries, and severe shortages of essentials including anaesthetics, medicines, water, food, and electricity [4,8]. Outside of the Gaza Strip, Soroka University Medical Center in Be'er Sheva in the south of Israel, Barzilai Medical Center in Ashkelon and Rambam Health Care Campus in Haifa in northern Israel continue to handle many war injuries requiring advanced and complex prolonged surgeries [9].

Musculoskeletal trauma requiring orthopaedic surgery treatment has historically represented a significant proportion of the medical load in war zones due to the environment and modern weapons [10]. Developments in orthopaedic surgery have also been driven by surgeon experiences in combat such as in the First and Second World Wars [11,12]. However, a literature search found that there were no published reviews discussing the delivery of orthopaedic surgery care in Gaza despite the recency of the Gaza-Israel conflict. Therefore, we conducted a scoping review of studies related to orthopaedic injuries and orthopaedic surgical treatments in the Gaza Strip to describe how orthopaedic surgery has been utilized and summarise key themes that arose in the identified studies.

### Materials and methods

The question for this review was 'What information reported in the literature applies to the provision of orthopaedic surgery care in the management of those wounded in the Gaza-Israel conflict?'. We aimed to consolidate and synthesize information regarding how orthopaedic surgery care was provided in the context of the Gaza-Israel conflict, the breadth of care provided, and key themes from these studies.

A literature search of the following electronic databases was performed between 1 January 1948 and 20 May 2024: PubMed, Web of Science Core Collection, MEDLINE, Embase, Scopus, ScienceDirect, The Allied and Complementary Medicine Database (AMED), and the Cochrane Library. Grey literature articles were identified by searching the following databases with the same search strategy: the Virtual Health Library Regional Portal, OpenAire, OpenGrey and BASE (Bielefeld Academic Search Engine). The following key terms were used in the search (orthopaedics OR orthopedics OR orthopaedic surgery OR orthopedic surgery OR trauma surgery) AND (war) AND (Gaza). Boolean operators (AND, OR) were used to combine terms and narrow search results. Suitable articles underwent reference and citation screening for further relevant publications.

Studies were selected using a two-step process. Citations identified from the search criteria underwent a title and abstract screening for the following exclusion criteria: 1) non-English publications; 2) publications before 1948; 3) population outside Gaza; 4) publications not about orthopaedic surgery; and 5) publications of abstracts only. Subsequently, a full-text screening was carried out with the following inclusion criteria: 1) publications published or translated to English; 2) publica-

tions after 1948; population within Gaza; 4) publications about orthopaedic surgery; and 5) publications such as reviews, epidemiological studies, retrospective studies, cross-sectional studies, and descriptive studies. This process was carried out by two independent reviewers and discrepancies were resolved by discussion between the two reviewers.

### Results

The literature search provided 434 potentially relevant articles from BASE (n=256), ScienceDirect (n=109), Virtual Health Library (n=26), Embase (n=19), Web of Science Core Collection (n=10), MEDLINE (n=7), PubMed (n=4), Scopus (n=3), AMED (n=0), and the Cochrane Library (n=0). After excluding 102 duplicates, 332 records were available for title and abstract screening. 318 publications were removed after reviewing titles and abstracts. Of the residual corpus of literature, full-text reviews were performed. This identified seven peer-reviewed publications that met the inclusion criteria [13-19]. Key themes that were identified included: 1) the breadth of orthopaedic surgery care in the Gaza strip; 2) injury demographics, mechanisms and complications; 3) the delivery of orthopaedic surgery care in a multi-disciplinary setting; and 4) limitations of the delivery of orthopaedic surgery in Gaza. These are presented narratively below.

#### The breadth of orthopaedic surgery care provided in the gaza strip

Four articles described care for both upper and lower extremity injuries and three described cares for only the lower extremity. Four articles discussed fracture management [15,16,18,19], four discussed soft tissue management [15-17,19], four discussed amputations [13,14,16,18], two discussed reconstructive surgery [16,19], and two discussed post-surgery rehabilitation [13,16]. Regarding management, these included copious Irrigation and Debridement (I&D) [16,18,19], shrapnel removal [18], soft tissue management [18], nerve repair [17], vascular repair [16], fasciotomies for compartment release [16], bone grafting [19], and fracture management [15,16,18,19]. Management of fractures included both Open Reduction and Internal Fixation (ORIF) [15,19] and external fixators [16]. Oberlin and Rantissi (2011) reported 16 sciatic nerve trunk surgeries, 11 fibular nerve surgeries, four tibialis posterior nerve, one neurolysis of the sural nerve, and two neuroma resections in the lower extremity, and 19 ulnar nerve, three radial nerve surgeries, five nerve transfers, two medio-ulnar surgeries, one musculocutaneous nerve graft, and one plexus neurolysis in the upper extremity [17].

#### Injury demographics

Injuries varied according to patient background factors such as age, gender, and residency. The majority of the injured population were younger males. Oberlin and Rantissi (2011) did not specify the mean age and gender distribution of their patients but they reported that most patients were male and were between 18 and 25 years old [17]. Mosleh et al. (2018) also did not specify the mean age of their patients, instead reporting that 31.4% (95% CI: 26.6–36.2) were 0–19 years old, 49.5% (95% CI: 44.8–54.3) were 20–39 years old, 15.5% (95% CI: 12.4–19.8) were 40–59 years old, and 3.6% (95% CI: 2.1–5.5) were older than 60 years old. Regarding residency, Mosleh et al. (2018)

reported a significant difference in the severity of injury and disability according to patients' residency across the five Gaza governorates (North Gaza, Gaza governorate, Middle Gaza, Khan Younis, and Rafah) with most of the war injured residing in North Gaza and Gaza governorate [18]. Heszlein-Lossius et al. (2018) specified that 154 of 254 patients were refugees [13].

Types of injuries included fractures, soft tissue injuries, and amputations. Emile and Hashmonai (1998) reported that the upper and lower extremities were most commonly injured and that open fractures were accompanied by peripheral nerve injury of the radial and peroneal nerves while major artery injuries were uncommon [15]. Regarding nerve injuries, two common situations highlighted by Oberlin and Rantissi (2011) were medial high arm injuries requiring immediate vascular surgery of the severed brachial artery and secondary grafting of the severed median and ulnar nerves, and lateral lesions associated with multi-fragmental humerus fractures requiring either tendon transfers or nerve grafting to treat a radial nerve palsy [17]. Regarding amputation injuries, minor amputations often occurred in the upper extremities with the most common amputation being distal in the arm and hand [13], while major amputations often occurred in the lower limbs which could be categorized as unilateral or bilateral, above-knee or below-knee, or immediate or late [13,16]. Godwin et al. (2022) further described concurrent injuries such as fractures to bones such as the tibia and fibula, soft tissue injuries, and injuries to major vessels such as the popliteal artery [16].

### **Mechanism of injuries**

Regarding the mechanism of injuries, four articles discussed injuries that were due to blast or explosion-related injuries due to causes such as mines, missiles and bombs [13-15,18], and five discussed ballistic trauma such as gunshot injuries [15-19]. The oldest article, Emile and Hashmonai (1998), also discussed stabbing injuries and injuries from thrown projectiles such as striking stones [15]. Heszlein-Lossius et al. (2019) also specified drone strikes occurring during both periods of cease-fire and during declared military incursions as the cause of the majority of amputations in their study and that drone strikes caused more proximal amputation injuries that needed more surgeries than other explosive weapons [14]. Injuries also differed according to demographics. During the Palestinian uprising from Apr 1993 to Apr 1994, admitted Gaza citizens most commonly suffered from soft tissue injuries and fractures of the bones of the lower limbs due to firearm-related injuries compared to admitted Israeli soldiers and civilians who commonly suffered from soft tissue injuries of the face and neck due to striking stones [15].

### **Complications**

Complications varied according to the primary injury which ranged from fractures, soft tissue injuries, and amputations. Fractures were complicated by injuries to nerves such as the radial or peroneal nerves [15,17], vascular injuries [16], infections [16,19], bone shortening [19], and malalignment [19]. Regarding nerve injuries, Oberlin and Rantissi (2011) highlighted that pain is a major problem and that early nerve repair constitutes the best prevention of the corticalization of pain [17]. Godwin et al. (2022) reported a high failure rate (76%) for primary vascular repair. Patients with amputation injuries suffered from problems such as phantom pain, back pain, joint pain, insomnia, and depression [13,16], some even required over 10 surgeries after the initial amputation injury to treat surgical complications

or adjust amputation stumps [13,14]. These patients were provided with rehabilitation physiotherapy and individually fitted artificial limbs although the prostheses majority of patients in the study by Heszlein-Lossius et al. (2018) were not using their prostheses due to pain, discomfort, or that the prostheses limited their function [13]. Godwin et al. (2022) also found that the majority of patients in their study were not actively using their prostheses [16]. Farhat et al. (2024) found that among 244 patients with open tibial fractures, the median length of hospital stay was 25.5 days (IQR 10.0-49.8), 110(53%) experienced non-union, 8(3.4%) required a delayed amputation and 172(92.5%) suffered from an infection [19].

### **Delivery of orthopaedic surgery care in a multidisciplinary environment**

Two studies discussed the delivery of care via a Multidisciplinary Team (MDT) [16,19]. Godwin et al. (2022) utilized an MDT consisting of a prosthetist, orthopaedic surgeon, plastic surgeon, and physiotherapist [16]. Farhat et al. (2024) evaluated the differences in outcomes of open tibial fractures managed by orthopaedic surgeons alone, by orthopaedic surgeons and plastic surgeons separately (orthopaedic and plastic team), and by integrated orthopaedic-plastic surgery teams (ortho-plastic team). The ortho-plastic team managed most cases of severe muscle injury, large skin injuries, injuries with bone loss >1 cm and injuries with nerve or artery injuries. The severity of these injuries may have been a predictor for longer lengths of stay and higher incidences of non-union among patients treated by the ortho-plastic team.

### **Limitations of orthopaedic surgery in Gaza**

Two studies highlighted that conflict in the region creates several factors that limit the quality of care received by war-injured patients, leading to problems such as poor reduction, losses to follow-up, infection, malalignment and malunion [16,19]. These include a lack of resources such as adequately trained surgeons and medical personnel, medical records, X-rays, or implants, and an inability to provide the necessary care on time [16,19].

### **Discussion**

Our literature review identified several key themes regarding the need for orthopaedic surgery among those injured by war-related causes and problems faced by practitioners in these war zones. Articles showed that the causes of war-related injuries have evolved over several decades. Although the Gaza-Israel conflict began in 1948, the oldest paper identified in this review that discussed a form of orthopaedic surgery management in Gaza was only published in 1998 [15]. It was also the only paper to mention stabbing and throwing projectiles as a mechanism of injury. Blast injuries were identified in four studies [13-15,18] and gunshot wounds were identified in five studies [15-19]. Heszlein-Lossius et al. (2019) further identified that drone strikes caused the most traumatic amputations in surviving Palestinian citizens from 2006 to 2016 and inflicted more severe injuries in survivors than non-drone-delivered weapons did [14]. Drones were first used in close combat during the 1982 Israeli Bekaa Valley campaign and are often used against targets in low-income and middle-income countries [14]. The most recent study included in this review by Farhat et al. (2024) highlights how open tibial fractures during conflicts are more severe than open fractures in other low- or middle-income countries without conflicts and have a higher rate of non-union (53%) than



the estimated global range of non-union in open tibial fractures (10-30%) [19]. Eskeland et al. (2017) found that among 37 Gazan patients during the 2014 conflict, blast injuries were the main mechanism of injury which led to wounds in 30 patients and fractures in 28 patients [20]. This study was excluded from the review since only an abstract had been published. In other theatres of war, blast injuries caused the most child casualties in Afghanistan from 1997 to 2002 [21], in Iraq from 2003 to 2008 [22], and in Syria from 2011 to 2014 [23]. A study of 84 Gulf War casualties by Souka (1992) found 33 injuries (28%) to the upper extremities, 55 injuries (47%) to the lower extremities, and 10 injuries (9%) to the head and neck with 59 patients (70%) suffering from multiple injuries [24]. Causes of injury were fragments in 74 patients (88%), bullets in nine patients (11%) and both in one patient [24]. Another study of 1053 Gulf War injuries by Spalding et al. (1991) found that fragmentation weapons caused 24(47%) upper limb and 40(78%) lower limb injuries while bullets caused 4(33%) upper limb and 7(58%) lower limb injuries [25]. Both bullet injuries and blast injuries continue to cause serious damage to soft tissue and bones via direct impact of the bullet and fragments, and indirect trauma due to the transmission of the energy of the penetrating agent through surrounding soft tissues, referred to as 'shock wave cavitation' [17].

Studies included in this review identified that war injuries in Gaza often affected younger males. Furthermore, Gilbert and Skaik (2013) found that among 680 patients injured by bombing by drones, F-16 fighter planes, helicopters, or naval artillery during the Israeli 'Pillar of Defence' military attack on the Gaza Strip from 14–21 Nov 2012, 501(74%) were male, 74(11%) were younger than 18 years old, and 42(38%) required orthopaedic surgical operations [26]. This study was excluded from the review since only an abstract had been published. In the Middle East, a study of tibial injuries in 200 war-wounded patients by Fakhri et al. (2019) found that 86% were male and their mean age was 33.8±11 years. Alhammoud et al. (2019) found that among 955 patients with open long bone fractures injured during the Syrian war, 91.6% were males and the average age was 27.5±11 years old [27]. Regarding war injuries in general, Souka (1992) found that among 84 Gulf War casualties, their median age was 23 (range 18-43) years old [24]. Lafta et al. (2015) found that among 553 injuries that occurred over 11 years in Baghdad in the Iraq conflict, 356(64.4%) were male, and 125(22.6%) were younger than 19 years old [28].

Studies identified that the delivery of care in Gaza was often complicated or delayed by limited or inappropriate resources, suboptimal facilities, and inadequately trained personnel [19]. Gaza faces a lack of continuous medical supplies and local manufacturing facilities, hence relying on external supplies which are also restricted [29]. Difficulties in facilitating postgraduate medical education have also been previously identified as a problem in conflict zones [30]. Souka (1992) concluded that since patients fare better in fixed-base hospital facilities than the smaller mobile field hospitals that become more active after a ground attack starts, appropriate triage of casualties in frontline medical units and deployment of transportation and communication facilities are vital to optimising the use of healthcare resources and offsetting the time needed to evacuate the injured [24]. A study of tibial injuries in war-wounded patients in the Middle East by Fakhri et al. (2019) emphasized the importance of aggressive surgical debridement at the initial treatment and when managing subsequent bone infections, especially since the presence of a bone gap, not its size, was the

main factor affecting length of hospital stays and early complication rates [32]. Orthopaedic surgery in humanitarian aid and medical missions has been identified to be vital in the provision of care for war-injured patients [32]. In addition to missions, establishing and maintaining long-term bilateral partnerships with local healthcare providers and organizations in Gaza ensures consistent surgical care, collaborative research projects related to surgical care in conflict zones can help identify best practices and innovations, and teaching organised with local universities adapted towards local needs and addressed to students and surgeons enables local personnel to be adequately trained to deal with the problems they face in the war zone [32,33].

This literature review is not without limitations. Firstly, we chose to carry out a narrative literature review instead of a systematic review to provide a broad overview of the existing literature on this topic. Another limitation is that although the Gaza-Israel conflict originated in 1948, articles included in this review were only published between 1998 and 2024. Our review therefore provides limited historical context pre-1998. There was also some overlap between the delivery of orthopaedic surgery care and plastic surgery care in the combat zone so the decision was made to exclude certain studies that were written from a plastic surgery care perspective. Lastly, limiting the search to articles published in English or articles translated into English may have led to the exclusion of some relevant non-English articles.

## Conclusions

This literature review found that orthopaedic surgeons have been vital to the management of war injuries in the Gaza Strip, especially due to the severity of injuries caused by mechanisms such as explosives or ballistic weapons. However, the delivery of orthopaedic care is limited by resources and personnel on the ground, highlighting a need for humanitarian aid and research or training partnerships with local healthcare providers and universities.

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