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ORIGINAL PAPER

# Use of external fixators for damage-control orthopaedics in natural disasters like the 2005 Pakistan earthquake

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**Abstract**

*Purpose* In the 2005 Pakistan earthquake, the great many injured with multiple fractures and open wounds provided a unique opportunity to practice damage-control orthopaedics. External fixators remain a time-tested tools for operating surgeons on such occasions. The locally manufactured, readily available Naseer-Awais (NA) external fixator filled such needs of this disaster with good outcome.

*Methods* This is a retrospective descriptive study of 19,700 patients that presented over seven months to the two centres established by the lead author (SMA) in Muzaffarabad and Mansehra just one night after the 2005 earthquake. A series of local and foreign orthopaedic surgeon teams operated in succession. The computerised patient data collection of 1,145 operations was retrospectively analysed.

*Results* Of the 19,700 patients presenting to the SMA centres, 50 % had limb injuries. Total fracture fixations were 1,145, of which 295 were external fixations: 185 were applied on the lower limb and 90 on upper limb, the majority were applied on tibia.

*Conclusion* External fixators are valuable damage-control tools in natural disasters and warfare injuries. The locally manufactured NA external fixator served the needs of the many limb injuries during the 2005 Pakistan earthquake.

**Keywords** Pakistan · Earthquake · External fixation · Naseer-Awais external fixator

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## Introduction

> "The only thing you can definitely predict about earthquakes is, the further you are from the last one, the nearer you are to the next." Dr. Edgar K. Soper

On the morning of 5 October 2005 at 8.50 a.m. (Pakistan Standard Time), natures' fury shook the calm and tranquility of serene northeast Pakistan and western Kashmir, bringing anguish and woes to the lives of more than 3.5 million people [1]. The magnitude of the earthquake was 7.6 on the Richter scale, and its epicentre was in Muzaffarabad 90 km north of Islamabad. More than 73,000 lives were lost, and 3.5 million people were displaced [2, 3]. On that fateful day, an entire civilisation—people and infrastructure—were razed in a matter of seconds. The quake was followed by a string of aftershocks of magnitudes between 5.4 and 6 on the Richter scale. The tremors and constant landslides multiplied the shock and trauma, while the onslaught of a harsh winter jeopardised the lives of survivors. This was without argument the most fatal natural catastrophe in Pakistan's history; recuperating from it has already cost billions, and the process of healing continues to this day [1, 4]. The earthquake created a massive managerial task to aid the injured, from triage to rehabilitation [5]. The widespread effect destroyed countless cities and villages, and many hospitals were completely destroyed: 594 health units according to the Earthquake Reconstructive and Rehabilitation Authority (ERRA) report (Fig. 1). This greatly increased the task of health-care provision [6].

Extremity injuries associated with natural disasters and combat are typically from high-energy trauma, often open and routinely represent only part of the scope of injury to a polytrauma patient (Fig. 2). The early management of these injuries is normally performed in austere environments and relies heavily on the principles of damage-control orthopaedics (DCO), with external fixation of associated long-bone and juxta-articular fractures [7].

**Fig. 1** The vast destruction of the 2005 Pakistan earthquake in Mansehra and Muzaffarabad

The use of the external fixator in disasters for early damage control of the patient remains a vital tool. The less equipped and understaffed facilities with a great number of polytraumatised and patients with multiple fractures greatly benefit from such treatment. The features of low cost, less surgical time and health-care-professional expertise favour the use of external fixators [8, 9].

Damage control is a term of naval origin used to describe the procedures performed to keep a compromised ship afloat while at sea. In medicine, this term was first used by general surgeons to describe immediate life-saving procedures to control haemorrhage and minimise lengthy definitive procedures that may be deleterious to patients following such trauma. Only after the patient is adequately resuscitated and stabilised are definitive procedures performed [10]. The term DCO was first used by Scalea et al. [11] to describe a similar approach to musculoskeletal injuries. Temporising treatment measures such as external fixation are used on unstable or borderline patients to stabilise major orthopaedic injuries, halt ongoing musculoskeletal injury and control haemorrhage. These principles are very applicable to injuries sustained on the battlefield or in the wake of a disaster. Additionally, battlefield or disaster orthopaedics must take into account factors such as the number of patients needing treatment, available resources, fitness of patient for transport, weather conditions and availability of wound care [12].

The role of external fixation in DCO has been well described. In the civilian trauma setting, DCO refers predominantly to the use of expedient external fixation in the acute management of pelvic and long-bone fractures in the multitrauma patient. This provides early fracture stability while avoiding deterioration of the patient's physiologic condition as a result of either prolonged surgery or embolic phenomena related to the immediate definitive fixation of long-bone fractures. External fixation also allows the surgeon to provisionally manage periarticular fractures while awaiting the recovery of the soft-tissue envelope to the point where a formal surgical approach and internal fixation is safe with respect to wound-complication risks [13].

The technique of external fixation was popularised in the mid twentieth century when Hoffman introduced a device that used Steinman pins and bars to stabilise long-bone fractures. Charnley concomitantly impressed the orthopaedic community when he introduced an external fixator for knee arthrodesis. With a simple compression frame, he was able to

**Fig. 2** The spectrum of open-limb fractures presented in the 2005 earthquake

dramatically increase knee fusion rates and decrease consolidation time [14]. Behren described three basic concepts that govern the safe and effective application of external frames for bony trauma [15]: the pins and wires should avoid damage to vital structures, allow access to the area of injury and meet the mechanical demands of the patient and the injury. While the Western world was using external fixation sparingly, it was becoming a mainstay of orthopaedic treatment in Russia and later in northern Italy. In Kurgan, Siberia, Professor Ilizarov found external frames to be invaluable for a myriad of applications, including posttraumatic and congenital limb reconstruction, limb salvage, complex arthrodesis, management of osteomyelitis and bone defects and deformity correction. Using a circular fixation design with simple and versatile components, he was able to develop a method for osteogenesis that relied on a percutaneous approach with minimal trauma to the limb, closed anatomic fracture reduction and excellent bony stability that allowed early weight bearing [16].

The three basic types of external fixations used in practice today constitute either circular, unilateral or hybrid frames [15]. When considering unilateral frames, the two most common designs are the bulkier monobody designs (EBI, Parsippany, NJ, USA; Orthofix, Verona, Italy) and the trauma-type pin-to-bar fixators [16]. The local version of unilateral frames in Pakistan with a myriad of applications is the Naseer-Awais (NA) external fixator developed by Prof. Syed Muhammad Awais and named after his mentor Prof. Naseer Mehmood Akhtar. The NA external fixator was developed and used in the Department of Orthopaedic Surgery, King Edward Medical College and Mayo Hospital, Lahore, Pakistan, in early 1981. The mono-axial/mono-lateral frame has been successfully used for treatment of open and infected fractures, segmental fractures, leg lengthening and segmental bone defects [17–19]. The basic components of the NA external fixator are shown in Fig. 3. Following the 2005 earthquake, the readily available, low-priced, locally manufactured NA external fixator with additional benefits of easy and familiar application for local orthopaedic surgeons made it a valuable choice for fracture fixations.

The purpose of this article is to review the experience of the first author (SMA) in the damage control of musculoskeletal injuries managed with external fixators at local orthopaedic setups during the 2005 Pakistan earthquake.

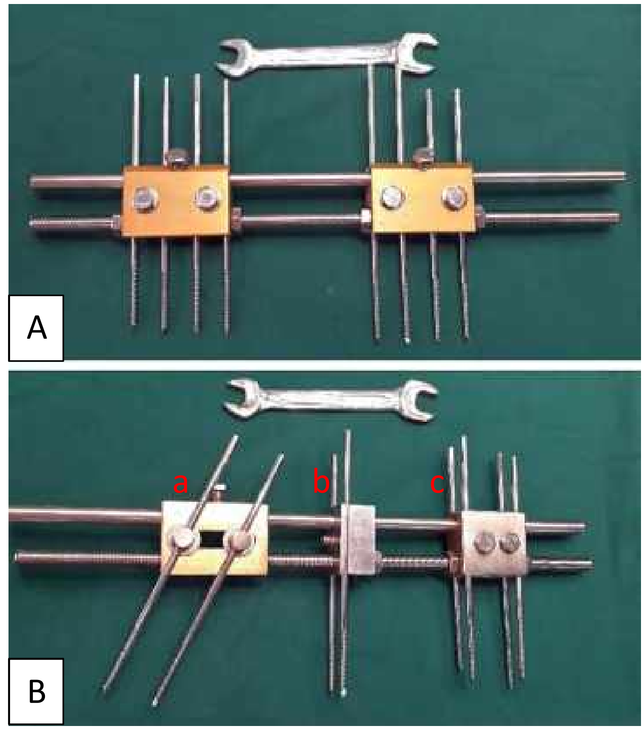


**Fig. 3** **a** Basic construct of a Naseer-Awais (NA) external fixator used for treatment of open fractures with mechanical advantage of self-locking Schanz screw and controlled compression and limb lengthening. **b** Three additional pin clamps that can be used with basic construct for different situations. *a* Clamp with rotatory pins to be used in the upper end of the femur and other angular bones; *b* horizontal pin clamp used for insertion into epiphysis for chondrodiastasis; *c* double Schanz screw clamp to be used in upper and lower ends of the femur and upper end of the tibia

## Materials and methods

SMA established two new level 1 orthopaedic surgery and rehabilitation centres through private philanthropy in existing public hospitals: one at the Abbas Institute of Medical Science (AIMS), Muzaffarabad, Kashmir, and the other in the DHQ Hospital, Mansehra, Khyber, Pakhtun Khuwa (KPK) Province. The aim was to immediately create a treatment facility for the injured within the earthquake-affected areas. The hospitals were taken over on 8 October 2005 and continued working under his direct supervision until September 2010. With generous help and aid from the Société Internationale de Chirurgie Orthopédique et de Traumatologie (SICOT), the World Health Organisation (WHO), the United Nations Children's Fund (UNICEF), Doctors Without Borders, the Arbeitsgemeinschaft für Osteosynthesefragen (AO) Foundation and local philanthropy, well-equipped orthopaedic centres were established at public hospitals in Mansehra and Muzaffarabad that endured the quake. International volunteers from Cuba, Holland, Turkey, USA, Canada, Bangladesh, UK, France, Singapore and Bosnia joined the team of local orthopaedic surgeons from time to time.

### Technique for external fixation employed in the disaster environment

The specific techniques employed for damage-control external fixation in the earthquake-struck areas vary greatly as a function of patient volume, associated injuries, open wounds and available equipment. The general principles, however, remain the same. First and foremost, standard external fixation

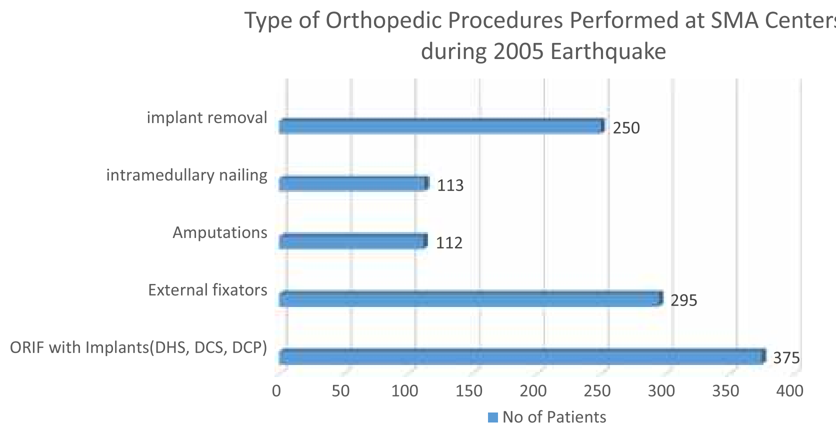


**Fig. 4** Type of orthopaedic procedures performed at SMA centres of Muzaffarabad and Mansehra during the 2005 earthquake

principles were applied, like optimising fracture reduction, cortical contact and increasing pin diameter to increase stability of the construct. Additionally, increasing the number of connecting rods, decreasing their distance from the bone, increasing the number of pins and optimising their spread and location relative to the fracture site also improved stability. These factors, however, were prioritised against competing interests, particularly with respect to the zone of soft-tissue injury. Whenever possible, it was considered to keep external fixation half pins out of open wounds. This simplifies wound management, particularly with respect to closure and soft-tissue coverage, and makes application of dressings substantially less complicated. It was also critical to consider the definitive management of fractures when applying the external fixator and take care not to obviate the optimal surgical exposure. When practicable, the half pins were kept out of the zone of both the surgical approach and the potential definitive implants.

In these centres, fluoroscopy, and even power drills and pin-driving equipment were not routinely available. Instead, pins were placed with hand drills and safely outside the area of fracture extension to ensure good bicortical purchase, to prevent propagation of fracture planes and prevent conversion to an open fracture by exposure of fracture ends and haematoma via the pin tract. Pin penetration was determined by feel of the near and far cortices in conjunction with a sense of how much the pin had advanced relative to the estimated thickness of the bone. Fracture reduction was achieved by regaining length through traction and by clinical assessment of limb alignment and reducing gross deformity (Fig. 4).

**Table 1** Percentage of total injuries presenting in SMA centres according to body parts injured

| Body part injured | No. of patients | Percentage |
|---|---|---|
| Lower limb | 9,850 | 50 |
| Upper limb | 5,516 | 28 |
| Pelvis | 1,970 | 10 |
| Spine | 985 | 5 |
| Head | 591 | 3 |
| Face | 394 | 2 |
| Abdomen | 197 | 1 |
| Chest | 98 | 0.5 |
| Eye | 99 | 0.5 |
| Total | 19,700 | 100 |

## Results

The two centres located in main cities, under the command and control of the lead author, were amongst the busiest in terms of patient turnover. A total of 19,700 patients were recorded between both centres over a period of seven months. On the first day 1,900 patients were received, 2,500 on the second day and on the third day 2,800 in Mansehra Centre alone. Treatment of earthquake survivors with musculoskeletal trauma included medical treatment, debridement, fasciotomy, closed reduction, open reduction and amputation.

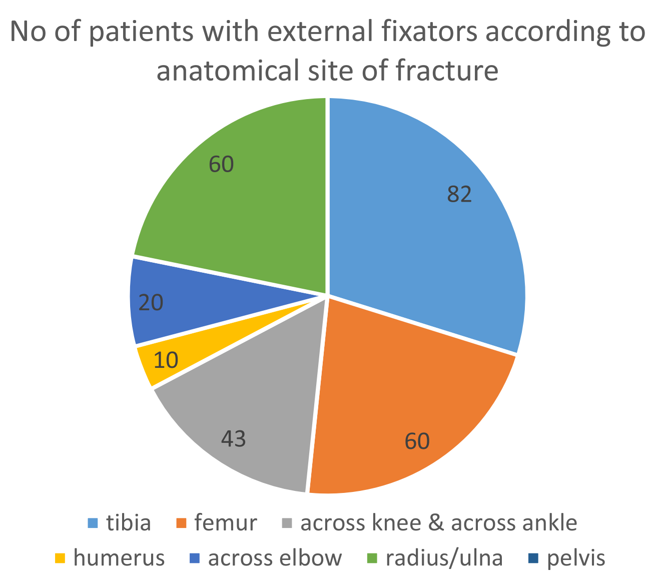


**Fig. 5** Number of external fixators applied according to anatomical site in SMA centres

The male to female ratio was 9,450 to 10,250. The paediatric population was ~15 %; 7 % of injuries were non-orthopaedic, and the remainder were musculoskeletal trauma (93 %). Most musculoskeletal injuries afflicted the lower limbs, accounting for 50 % of injuries, as shown in Table 1. Injuries to the upper limb and pelvis were 28 % and 10 %, respectively. A rough estimation of 5,500–6,000 patients with fractures were treated in both centres combined. Most fractures were managed conservatively in plaster and traction. Amongst fracture fixations, those that presented initially were mostly multiple fractures and polytrauma with open fractures and needed damage-control measures. Total fracture fixations were 1,440 in both centres' combined, with 1,145 internal fixations and 295 external fixations.

External fixations for lower limbs were 185, of which 82 were tibial, 60 femoral and 43 across the knee and ankle. Total fixators applied on upper limbs were 90: 60 on the radius/ulna and hand, 20 across the elbow and ten on the humerus (Fig. 5).

## Discussion

In the austere environment such as that following the 2005 natural calamity in Pakistan, a great many injured people with open fractures are received in the initial few days [20]. The challenge of triage in Pakistan was answered with damage control. External fixators are time-tested best tools for DCO [21]. For the same reason, many external fixations were done at Mansehra and Muzaffarabad medical treatment camps, as evident by the retrospective computerised data analysis of their 19,700 patients [4]. The greatest number of external fixators were applied to the tibia and forearm bones. Uniplanar fixators were used most often, primarily due to the availability of inexpensive, locally designed models like the NA external fixator. A significant number of fixators were applied on the pelvis as well (20 of 295).

Most patients were lost to follow-up, so exact results could not be properly evaluated and documented. Many fixators were used as definitive treatment for a particular fracture and soft-tissue injury, with successful outcomes regarding union and soft-tissue healing. The commonest complication was pin-tract infection and pin loosening. This was followed by malalignment, as most fixations were done without fluoroscopy. Fracture from the Schanz screw was also observed in several cases. In the long term, patients with nonunion and delayed union were followed up. Neurovascular, muscle and tendon impalement were also seen in a fraction of patients.

Among all human tragedies and injustices, specific circumstances, such as natural disasters, require immediate worldwide aid mobilisation due to their rarity, damage intensity and human resources and logistics needed [22]. More than 500,000 earthquakes are reported each year worldwide, with three million lives claimed over the past 20 years. However, the majority are minor events, with only a handful resulting in significant morbidity and mortality. In terms of the impact on human life and the logistical scale of relief coordination, the Pakistani earthquake is recognised as one of the biggest natural disasters of the past decade [23]. The poor facilities, harsh terrain and limited human resources made orthopaedic procedures difficult to perform. Under these circumstances external fixators were the standard tools used by local orthopaedic surgeons to repair extremity fractures [24].

In the austere environment typically associated with extremity injuries in combat, natural disasters and mass casualties, the need for damage control using acute external fixation is enormous. In addition to limiting damage to the extremity and maintaining as far as possible the overall well-being of the patient, external fixation represents the primary, and sometimes the only, mode of instrumented fracture fixation available to the surgeon [25]. External fixation provides a rapid means of relative fracture stability in preparation for patient transportation to a higher level of care for continued management. It is also a fast, temporary treatment for a large number of patients in such settings [8, 26].

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