Severe Hand Injuries From Fireworks: Injury Patterns, Outcomes, and Fireworks Types

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Purpose The purpose of this study was to characterize injury patterns and outcomes of fireworks-related hand injuries and determine if there was an association with certain fireworks types.

Methods A retrospective cohort study was conducted on patients treated at a trauma center between 2005 and 2015. A total of 105 patients sustaining operative hand injuries due to fireworks were identified. Medical records were reviewed to identify injury patterns, treatment outcomes, and fireworks types.

Results Eighty-eight patients (84%) sustained 92 thumb and/or first web space injuries. There were 12 thumb soft tissue only injuries (13%) and 80 thumb fractures/dislocations (87%). Of these, there were 52 thumb carpometacarpal (CMC) joint dislocations (57%) and 36 thumb fractures outside the thumb CMC joint (39%). Fifteen hands (16%) sustained both thumb CMC joint dislocations and additional thumb fractures. Twenty-three hands (25%) required thumb revision amputation. The number of surgeries for acute reconstruction ranged from 1 to 7, with 17 patients (19%) requiring 3 or more. Sixty-three hands had deep first web space injuries, and 11 (17%) required flaps acutely for first web space reconstruction. Six hands required secondary reconstruction of a first web space contracture. An external fixator was applied to 6 hands to maintain the first web space; none of these required secondary web reconstruction. Excluding isolated pin removals and dressing changes under anesthesia, 19 patients (22%) required later-stage surgeries. Shells/mortars (59%) were the most common fireworks type causing injury.

Conclusions Among operative hand injuries, fireworks most commonly fracture the thumb, destabilize the thumb CMC joint, and deeply damage the first web space. The first web space requires particular consideration because deep injury may result in adduction contracture and require secondary reconstruction if not prevented. (J Hand Surg Am. 2017;42(5):385.e1-e8.

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Type of study/level of evidence Therapeutic IV.

Key words Blast, fireworks, first web space, pattern, thumb.

When fireworks inflict injury, they most commonly injure the hands. Injuries have been reported with every fireworks type. The U.S. Consumer Product Safety Commission estimates about 10,500 people were treated in hospital emergency rooms for fireworks-related injuries in 2014.1 Of these, 36% were hand injuries.2 Previous studies have shown many of these injuries are superficial, treated as outpatients, and do not require surgery.1-4 However, some fireworks-related hand injuries are severe, require prolonged hospital stays with multistage reconstruction, and often result in amputations, stiffness, and long-term impairment.1,5,6

Although patterns of hand injury after blasts have been described, much of the information originates from studies assessing combat-related injuries or injuries due to a heterogeneous group of blast mechanisms including...
The purpose of this study was to characterize injury patterns and treatment outcomes among fireworks-related injuries and, if possible, identify fireworks types associated with specific injuries.

**MATERIALS AND METHODS**

Approval for this study was obtained from the institutional review board of our institution. The hospital trauma registry was queried to identify adult and pediatric patients with fireworks-related injuries. A retrospective cohort study was conducted on 105 patients who presented to our level 1 trauma/burn center between 2005 and 2015 with fireworks-related hand injuries requiring surgery. Medical records were reviewed to collect patient demographic information, fireworks type, injury characteristics, and operative details. Deep first web space injuries were defined as those in which the operative report specifically described a splayed-open first web space and debridement of necrotic muscle in that region. There were 102 males and 3 females, and the mean age was 28 years (range, 5–58 years). There were 16 pediatric patients (age, ≤17 years).

**RESULTS**

**Injury patterns**

Of the 105 patients with fireworks-related hand injuries requiring surgery, 12 patients (11%) did not have thumb or first web space injuries and 29 patients (28%) also had traumatic carpal injuries. Six patients (6%) underwent revision amputation of the hand through the wrist or forearm. Five of these 6 were excluded from the thumb/first web space subgroup. The sixth patient was included in the thumb/first web space subgroup owing to a contralateral thumb injury. Seventy-eight of the 105 patients (74%) sustained isolated hand and wrist injuries and 31 patients (26%) also had additional injuries to other body regions (globe, face, brain, arm, trunk, and/or leg) from the same blast. All injuries were from consumer or after-market modified consumer fireworks; none sustained injuries at professional fireworks displays. The distribution of revision amputations among 105 patients with operative hand injuries is displayed in Figure 1.

In the thumb and/or first web space injury group, 88 patients (84%) sustained 92 hand injuries (4 bilateral). Fractures, dislocations, amputations, and soft tissue injuries for this group are summarized in Table 1. Sixty-one patients (69%) sustained 63 deep first web space injuries. Figure 2 shows an example of a deep first web space injury.

**Thumb and first web space outcomes**

Among patients with thumb and/or first web space injuries, the number of surgeries for acute repair and reconstruction ranged from 1 to 7. Acutely, 58 of 88 patients (66%) required 1 surgery, 13 (15%) required 2 surgeries, and 17 (19%) required 3 or more surgeries. One thumb revascularization was performed; however, it failed in the perioperative period, and subsequent thumb reconstruction using a groin flap and second toe transfer was completed.

Eleven hands required flaps acutely for first web space reconstruction. Three fillet flaps, 4 reverse posterior interosseous artery flaps, 1 second dorsal metacarpal artery flap, 1 reverse radial forearm flap, and 2 groin flaps were used. Among these, a combination of Kirschner wires and/or external fixation devices stabilized the thumb carpometacarpal (CMC) joint and maintained the first web space. Of 63 hands with deep first web space injuries, 7 hands (11%) received no first web space operative immobilization, 50 hands (79%) were treated with Kirschner wires alone, and 6 hands (10%) were treated with an
external fixation device in addition to Kirschner wires. Of the 7 hands in which no first web space immobilization was applied, no secondary reconstructions of the first web space were required. Of the 50 hands treated with Kirschner wires alone, 6 (12%) required secondary reconstruction of a first web space contracture, 4 with local tissue flaps, 1 with a skin graft, and 1 with a free flap (medial sural artery flap). Two of these 6 had previously been treated during the acute stage with skin grafts to the first web space; the other 4 were closed primarily at the acute stage. Of the 6 hands in which an external fixation device was applied to maintain the first web space (Fig. 3), none required secondary reconstruction of a first web space contracture. Two of these 6 had previously been treated during the acute stage with first web space skin grafting and 3 had previously undergone flap reconstruction of the first web space at the acute stage.

Later-stage surgeries included pin removal (36 patients), flap debulking (1), tenolysis (3), osteotomy (3), nail ablation (2), stump revision (6), flap (2 groin flaps, 1 second toe transfer), neuroma excision (1), digital nerve reconstruction (1), capsulotomy (6), first web space deepening (6), and dressing changes in children (3). Excluding isolated pin removals and pediatric dressing changes under anesthesia, 19 patients (22%) required later-stage surgeries (range, 1–7).

The distribution of injury-causing fireworks is shown in Table 2, with shells/mortars comprising the largest category.

### DISCUSSION

In this retrospective study, we found that serious hand injuries from fireworks most commonly include thumb fractures, thumb CMC joint dislocations, and deep soft tissue damage to the first web space. The first web space requires particular consideration because deep injury may result in adduction contracture and require secondary reconstruction with tissue outside the zone of injury.

Previous studies investigating blast injuries reported multiple digit involvement, often with a radial to ulnar pattern, most commonly injuring the thumb, and frequently also injuring the index and middle fingers.5–9 Figure 4 shows a clinical example of this injury pattern. One group reported their most common injury pattern from firecrackers and bombs was dorsal dislocation of the thumb CMC joint with splitting of the first web space and varying degrees of thenar muscle injury, occasionally combined with index and middle metacarpal finger injury.9 This combination has been attributed to high-energy avulsion, hyperextension, and hyperabduction.5,7,9 Our study supports these findings in both children and adults.

Compared with Hazani et al’s study,5 our study found a higher rate of thumb injury (84% vs 48%).

### TABLE 1. Operative Thumb and First Web Space Injuries

<table>
<thead>
<tr>
<th>Injury Type</th>
<th>Hands (n = 92)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Thumb fracture/dislocation, n (%)</td>
<td>80 (87)</td>
</tr>
<tr>
<td>Thumb CMC joint dislocation, n (%)</td>
<td>52 (57)</td>
</tr>
<tr>
<td>Non-CMC joint thumb fracture(s), n (%)</td>
<td>36 (39)</td>
</tr>
<tr>
<td>Both thumb CMC joint dislocation + other thumb fracture(s), n (%)</td>
<td>15 (16)</td>
</tr>
<tr>
<td>Thumb revision amputation, n (%)</td>
<td>23 (25)</td>
</tr>
<tr>
<td>Additional non-thumb digit fracture(s), n (%)</td>
<td>42 (46)</td>
</tr>
<tr>
<td>Additional non-thumb digit revision amputation(s), n (%)</td>
<td>57 (62)</td>
</tr>
<tr>
<td>Deep first web space injury, n (%)</td>
<td>63 (68)</td>
</tr>
<tr>
<td>Without fracture/dislocation</td>
<td>9 (10)</td>
</tr>
<tr>
<td>With fracture/dislocation</td>
<td>54 (59)</td>
</tr>
</tbody>
</table>

*Excludes fractures treated with revision amputations.

**Figure 2:** First web space injury. Clinical photograph demonstrates thumb CMC joint dislocation with deep tissue avulsion and first web space injury."
When there was a thumb injury requiring surgical treatment, 25% of patients underwent some level of thumb amputation, 62% underwent at least 1 amputation in a digit other than the thumb, and 46% had at least 1 non-thumb digit fracture. The highest rates of revision amputations were in the index and middle fingers; specifically, ray amputation of the index finger, followed by ray amputation of the middle finger and revision amputation through the middle finger distal interphalangeal joint.

In addition, we found a high rate of carpal pathology. Excluding thumb CMC joint dislocations,
either an external fixation device. Although their injuries involved muscle, they were less severe and more superficial, as reflected in their treatment and lack of requirement for secondary reconstruction. Of patients with deep first web space injuries, 10% (6 of 63 patients) required secondary release of a first web space contracture. This compares favorably with the 16% (10 of 61 patients) previously reported.5 Whereas it is notable that all 6 of the patients in our study requiring secondary reconstruction of the first web space were treated with Kirschner wire fixation (multiple wires, pinning to the index metacarpal, or pinning to the distal carpal row) rather than external fixation devices, the numbers in each group were small and we do not have sufficient data to recommend one method over the other. When using either method, the thumb should be stabilized in palmar and radial abduction. In our experience, stabilization of the CMC joint with either an external fixation device or Kirschner wires is imperative to maintain the first web space and prevent thumb adduction contracture.  

Consistent with prior studies, revision amputations were common, and revascularizations were rarely indicated.5,6,9,11 Deep and extensive tissue destruction often necessitated serial debridement, staged reconstruction and later-stage surgeries, a finding supported by others.5,6,9,11–13 Similar to Logan et al12 reviewing their experience with gunshot and blast injuries in the hand, in our study, the average number of acute and later-stage reconstructive operations after fireworks-related injuries averaged between 1 and 2 for each. Kleinert and Williams11 and Hahn et al7 emphasized the importance of debridement of all nonviable tissue at the initial surgery, setting the stage for future surgeries and potentially minimizing the number of secondary reconstructive operations. We attribute the lack of infections in our study to aggressive sharp excisional debridement, leaving wounds open for serial evaluation until questionably viable tissue declared itself or was excised. Tissue coverage with local flaps is often limited, but multiple regional and distant flap options are frequently available.

Systematic, thorough patient evaluation and sound management principles after fireworks-related hand injuries have been outlined by Saucedo and Vedder14 and include sharp debridement of devitalized tissue, repair versus resection of parts with a focus on function, skeletal fixation, wound care, healing by secondary intention, repeat assessment, and stable tissue coverage followed by dedicated hand rehabilitation. We found that, among severe fireworks-related hand injuries in children and adults, the thumb and first web space are prone to specific injury patterns and outcomes. An understanding of these injury patterns and their associated sequelae will aid clinical decision making and patient counseling.

Among all fireworks-related injuries, burn injuries are the most common type (57%).1 However, injuries may include superficial or deep burns, penetrating injuries, tissue avulsions, fractures, and dislocations, or a combination thereof. In our study, among fireworks-related hand injuries requiring surgery, isolated burn injuries were relatively rare because most had a component of tissue avulsion or fracture/dislocation. Comprehensive examination for associated injuries to the airway, eyes, face, trunk, and other extremities is critical, and the American Burn Association has established burn center referral criteria that take into account body region(s) and surface area, burn depth, mechanism of burn, patient health, and age.15

Injuries have been reported with every fireworks type. Consumer fireworks regulations vary widely across the United States, and size limitations are specified within fireworks types. Fireworks are permitted under federal law but state and local authorities regulate

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**TABLE 2. Injuries by Type of Fireworks Device**

<table>
<thead>
<tr>
<th>Fireworks Type</th>
<th>Patients (n = 88)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sparklers, n (%)</td>
<td>0 (0)</td>
</tr>
<tr>
<td>Rockets, n (%)</td>
<td>1 (1)</td>
</tr>
<tr>
<td>Firecrackers, n (%)</td>
<td>8 (9)</td>
</tr>
<tr>
<td>Roman candles, n (%)</td>
<td>4 (5)</td>
</tr>
<tr>
<td>Shells/mortars, n (%)</td>
<td>52 (59)</td>
</tr>
<tr>
<td>Homemade, n (%)</td>
<td>16 (18)</td>
</tr>
<tr>
<td>Unknown/other, n (%)</td>
<td>7 (8)</td>
</tr>
</tbody>
</table>

28% of patients sustained at least 1 carpal bone fracture or dislocation. These ranged from isolated CMC joint dislocations to carpal dislocations.

This study also found a higher rate of deep first web space injury than Hazani et al5 (60% v 21%). However, Adhikari et al9 studied blast injuries in India and found an even higher rate, with greater than 98% of patients sustaining injury to the thenar muscles and first web space. In our study, the 7 hands (11%) with deep first web space injury that received no first web space immobilization and also needed no secondary reconstruction, in general, did not sustain the same degree of avulsion and tissue destruction as those treated with Kirschner wires and/or external fixation devices. Although their injuries involved muscle, they were less severe and more superficial, as reflected in their treatment and lack of requirement for secondary reconstruction. Of patients with deep first web space injuries, 10% (6 of 63 patients) required secondary release of a first web space contracture. This compares favorably with the 16% (10 of 61 patients) previously reported.5 Whereas it is notable that all 6 of the patients in our study requiring secondary reconstruction of the first web space were treated with Kirschner wire fixation (multiple wires, pinning to the index metacarpal, or pinning to the distal carpal row) rather than external fixation devices, the numbers in each group were small and we do not have sufficient data to recommend one method over the other. When using either method, the thumb should be stabilized in palmar and radial abduction.

In our experience, stabilization of the CMC joint with either an external fixation device or Kirschner wires is imperative to maintain the first web space and prevent thumb adduction contracture.
and may further restrict use. In the United States, 43 states plus the District of Columbia allow some or all types of federally legal consumer fireworks, 4 states (Illinois, Iowa, Ohio, and Vermont) allow only sparklers and other novelty items, and 3 states (Delaware, Massachusetts, and New Jersey) ban all consumer fireworks.\textsuperscript{16} Table 3 describes various fireworks types.\textsuperscript{17}

Our hospital in Washington state serves a wide catchment area, including 4 surrounding states (Wyoming, Alaska, Montana, and Idaho). In our state and one other catchment state, firecrackers and rockets are illegal (outside of Native American reservations); however, Roman candles and shells/mortars are permitted. Two other surrounding states have more lenient regulations, permitting most fireworks

TABLE 3. Description of Fireworks

<table>
<thead>
<tr>
<th>Fireworks Type</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sparklers</td>
<td>Sticks or wires coated with pyrotechnic composition that produce a shower of sparks upon ignition.</td>
</tr>
<tr>
<td>Rockets</td>
<td>Sky rockets (also known as bottle rockets) are tubes that utilize a wooden stick for guidance and stability. The stick is placed into a bottle, and once lit, the rocket rises into the air and explodes, producing a burst of color and/or noise at the height of flight. Missile-type rockets are similar in size, composition, and effect but use fins rather than a stick for guidance. Rockets may have a plastic cap.</td>
</tr>
<tr>
<td>Firecrackers</td>
<td>Small, paper-wrapped or cardboard tubes containing pyrotechnic composition; upon ignition, a noise and flash of light are produced. They are generally 0.25 × 1.4 inches and often come in packs. Many firecrackers strung together make repetitive “popping” sounds.</td>
</tr>
<tr>
<td>Roman candles</td>
<td>Heavy paper or cardboard tubes that expel up to 10 individual “stars” (pellets of preserved pyrotechnic composition) at several-second intervals.</td>
</tr>
<tr>
<td>Shells/mortars</td>
<td>Shells are aerial devices that are launched into the sky. Mortars are the tubes from which shells (and other aerial devices) can be fired; the tube remains on the ground. Mines contain multiple effects that are simultaneously ignited and propelled into the air (similar to a group of shells).</td>
</tr>
<tr>
<td>Homemade</td>
<td>Includes a variety of improvised explosive devices such as pipe bombs, tennis ball bombs, and altered consumer fireworks.</td>
</tr>
</tbody>
</table>

FIGURE 4: Multiple digit injury. A, B Clinical photographs demonstrate injury predominantly to the radial aspect of the hand. The patient underwent middle finger ray amputation in addition to revision amputations of the thumb at the interphalangeal joint, the index finger at the distal interphalangeal joint, and the ring finger at the proximal interphalangeal joint.
types, including firecrackers and rockets. In contrast, one adjacent state has quite conservative regulations, allowing only nonaerial fireworks.

It is notable that, in our study, the highest incidence of operative fireworks-related hand injuries resulted from shells/mortars, which are legal in our state. In contrast, we treated relatively few injuries from firecrackers and rockets, which are illegal in our state. Although injury pattern and severity may be related to volume of chemical composition within various fireworks, they may also be related to fireworks design and method of use (ie, hand-held, ground vs aerial device). Shells may have an increased propensity for hand injury because they are manually loaded into mortar tubes or thrown. One could also possibly attribute the trend to easier access to and, hence, increased utilization of legal (as opposed to illegal) fireworks. This finding is supported by the results of a matched case-control study performed in our state over 30 years ago, which found 75% of injuries were caused by legal fireworks.\(^5\) Our findings contrast with those of 2 other single-center studies that found firecrackers were the most common fireworks type among hand-injured patients.\(^4,5\) However, both of those studies have limitations. In one, the explosives encompassed a wide range of types (eg, fireworks, bombs, munition); in addition, firecrackers were 1 of only 2 fireworks types specified.\(^5\) In the other, adults were excluded, the injuries were less severe, patients were mostly treated in the outpatient setting, and hand injury patterns were not specifically examined.\(^5\) Multiple large national database reviews have not elucidated the relationship between fireworks types and specific hand injury patterns.\(^1–3,19\) This may stem from their trauma registry systems not reporting injury severity or outcome (aside from death); in addition, their diagnosis classification systems have questionable clinical relevance, often categorizing data as abrasions, contusions, lacerations, fractures, foreign bodies, and burns.\(^1–3,19\) Furthermore, inconsistent grouping of fireworks types and a large number of unknown types have made comparisons across studies difficult.\(^1–3,19\) In 2 smaller studies that did specifically focus on severe fireworks-related hand injury patterns, neither investigated association with fireworks types.\(^3,6\)

Our study supports the notion that shells and mortars cause serious hand injuries. One could speculate the large number of serious injuries in our study is the result of selection bias with non—level 1 trauma centers treating less-severe hand injuries; these less-severe injuries could be due to different types of fireworks, leading to underrepresentation of those fireworks types in our study. However, our goal was not to capture the true distribution of all fireworks types causing hand injuries, but rather to focus on those causing hand injuries that require surgical treatment. Our state prohibits what are considered the most dangerous types of consumer fireworks—firecrackers and rockets. Although shells and mortars are not currently on this list, restricting the availability of high-risk fireworks such as shells and mortars could potentially prevent injuries. Currently, 37 states plus the District of Columbia ban rockets, 25 states ban firecrackers, and 27 states ban shells and mortars.\(^16\) This study has potential limitations. It is based on the experience of a single center and thus regional variation in fireworks utilization and regulation limits generalizability to all patients in all settings. In addition, it is retrospective and has no control group. However, strengths include the large cohort of adults and children with fireworks-related hand injuries and comprehensive, clinically relevant injury descriptions.

**REFERENCES**


