Ring injuries of the finger: long-term follow-up

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Abstract

Purpose The purpose of this study was to report on the injury patterns and outcomes of a series of patients treated at our institution between the years 1983 and 2010 who were injured by rings worn on their finger. The series included typical ring avulsion injuries as well as all other injuries caused by rings.

Methods Retrospective chart review was conducted on 33 patients with ring injuries treated by the senior author and colleagues. Eight cases were classified as Urbaniak class I, 13 class II, and 12 class III.

Results Satisfactory finger motion occurred with salvage of fingers in which no damage occurred to the proximal phalanx or flexor digitorum sublimus or profundus tendons. All patients with flexor tendon injury or proximal phalangeal fracture or both had loss of PIPJ motion and total active motion as compared to class II injuries without tendon and bone involvement. Four class III injuries were treated with replantation. One failed requiring revision amputation at the metacarpalphalangeal joint level due to ischemia. The remaining eight were treated by primary amputation.

Conclusions As a guideline to digit salvage with ring injuries, the authors propose accurately documenting and basing

treatment on all injured structures. Particular attention should be given to fractures of the proximal phalanx and laceration of the flexor digitorum sublimus and profundus tendons, as injury to these structures led to significant loss in mobility of the finger in this series. While some current guidelines advise revascularization of class II ring avulsion injuries, our series suggests caution in anticipating good results with sublimus or profundus tendon laceration and proximal phalanx fracture. If the profundus tendon only is lacerated, particularly in zone I injuries, results of finger salvage may still be acceptable, but associated (distal interphalangeal joint) DIPJ injury may require K-wire stabilization and later fusion. Replantation in class III injuries, while possible, is warranted only in select situations (patient-specific and cultural factors).

Keywords Avulsion · Reconstruction · Ring

Introduction

Severe finger injuries occur when a ring, usually worn on the 4th or ring finger, is caught on an immobile object. These injuries result in a forceful proximal to distal stripping of the skin with subsequent damage to underlying tendons, bone, and neurovascular structures. Biomechanical analysis of this injury has been described in detail, and the severity of the injury is a function of the tilting of the ring on the digit [11]. Peak forces occur during skin traction and eventual avulsion followed by tendon and bone injury. The underlying neurovascular structures are often left undisturbed. Severity of injury increases as the ring maintains traction on the skin and strips the underlying tissues from the underlying skeleton. In severe injuries, the skin everts and allows the ring to slip distally. In a classic ring avulsion injury, the skin is stripped off the finger from proximal to distal beginning at the level of initial injury over the proximal phalanx and extending in some cases to the distal interphalangeal joint (DIPJ) which then

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dislocates often hinging on one collateral ligament or amputating the finger through the DIPJ. Occasionally, the ring does not strip the skin as far distal as the DIPJ, and in these instances, a proximal phalanx fracture with or without flexor digitorum profundus and or sublimus tendon laceration may occur.

As described by Carroll in 1973, these injuries are unique in that they involve only one finger in a violent injury, and this is usually the ring finger [6]. Injury may also occur when a heavy object directly strikes a ring with trauma to the structures directly beneath the ring with variable avulsion to the skin. A “ring injury” can also occur from less common means, such as thermal injury from an electrical charge to the ring or gradual eroding of a ring through the skin, as may occur in mentally unstable patients.

Since the advent of microvascular surgery, Urbaniak et al. proposed specific guidelines for classifying and treating ring avulsion injuries [16]. Other authors, including Kleinert et al. [10], Nissenbaum [13], Kay et al. [9], and Weil et al. [18], have proposed various modifications to the Urbaniak classification. Many basic principles continue to guide evaluation and treatment of ring avulsion injuries, but prior research varies in reported details of injury and outcome. Our study details subcategories of Urbaniak’s original classification and includes a specific evaluation of injured structures that may be associated with a worse prognosis.

Materials and Methods

Between the years 1983 and 2010, the senior authors treated 33 patients with injuries of the left ring finger. All patients were wearing a ring on the finger at the time of the injury with variable, yet always significant, degrees of skin avulsion. This group comprised 24 men and 9 women with an average age of 40 years, (range, 16–75). The study received Institutional Review Board approval.

Data was obtained from clinic and hospital records and included mechanism of injury (Tables 1, 2, and 3). The mean

follow-up was 30 months (range, 12–252). Final range of motion and secondary finger function were based on active range-of-motion of the proximal interphalangeal joint (PIP) and total active motion (TAM). Data on sensory return, patient satisfaction, cold intolerance, and survivorship were also gathered from patient charts.

Patients were classified by Urbaniak’s system with the following recommended treatments:

- Class I Circulation adequate: standard procedures for soft tissue injury are performed (Fig. 1).
- Class II Circulation inadequate: vessel repair (artery or vein) is necessary to preserve viability, thus permitting immediate or delayed procedures to the other tissues; variable injury to phalanges and tendons (Fig. 2).
- Class III Complete degloving or complete amputation: considerable judgment is required if any attempt is made at replantation. Viability may be restored; however, depending on the level of injury, the potential for function may be limited (Fig. 3).

Nissenbaum further subdivided Urbaniak’s class II injuries into patients with only arterial compromise (IIA) and those with injury to bone, tendon, or nerve as well as to the dorsal venous system (IIB). This modification was noted during early treatments to direct prognostic recommendations to our patients.

The purposes of this paper are to review the clinical outcomes of patients with ring avulsion injuries and to provide guidelines for treatment based on our results.

Results

Class I Ring Avulsion Injuries

Eight injuries were categorized as Urbaniak class I. Damage was limited to the skin of the finger. At final follow-up, the average PIP motion for class I injuries was 94.4° (SD±5°). All

Table 1 Class I ring avulsion injury patients

Patient no.	Age	Gender	Mechanism of injury	Final PIP motion (degrees)	TAM (degrees)	Outcomes
1	25	F	Caught on bath fixture	0–100	230	Normal sensation ^a
2	35	F	Car door	0–95	225	Normal sensation ^a
3	40	M	Electrical burn	0–90	220	Normal sensation ^a
4	51	M	Caught on garage door	0–85	215	Normal sensation ^a
5	43	M	Caught on trailer bolt	0–95	225	Normal sensation ^a
6	55	M	Fell from ladder	0–100	230	Normal sensation ^a
7	53	M	Between wheel and car jack	0–95	225	Normal sensation ^a
8	49	F	Caught on swing chain	0–95	225	Normal sensation ^a

TAM total active motion (sum MP, PIP, DIP Joints)

^a Normal sensation 5-mm 2-point discrimination

Table 2 Class II ring avulsion injury patients

Patient no.	Age	Gender	Mechanism of injury	Associated injuries	PIP motion (degrees)	TAM (degrees)	Other outcomes and complications
9	25	M	Caught on powerboat	DIP dislocation	0–100	240	Primary DIP fusion, protective sensation ^b
10	50	M	Caught on industrial drill		0–95	235	Protective sensation ^b
11	39	M	Caught on garage door		30–90	140	Protective sensation ^b
12	25	M	Caught on machinery bolt		10–100	190	Protective sensation ^b
13	31	M	Struck by sledge hammer	Proximal phalanx fracture, ulnar artery/nerve lacerations, extensor tendon laceration	45–45	120	Return to OR at 6 months for tenolysis and PIP contracture release. Normal sensation ^a
14	35	M	Entangled in logging chain	Proximal phalanx fracture, ulnar nerve laceration, partial extensor tendon laceration	50–90	140	Malrotation, adhesions. Neuroma, cold intolerance. Return to OR at 7 months for tenolysis. Protective sensation ^b
15	21	F	Caught on steering wheel	Proximal phalanx fracture	60–90	130	Normal sensation ^a
16	45	M	Caught on dump truck	Radial dorsal vein, small proximal phalanx intra-articular fracture	0–100	175	Return to OR at 3 weeks for full-thickness skin graft. 30° flexible mallet deformity
17	38	M	Caught on trailer	DIP dislocation	0–105	205	Full grip strength return. Normal sensation ^a
18	53	M	Caught on railing during fall	Dorsal vein injuries, DIP dislocation, extensor tendon laceration	0–70	164	Return to OR at 7 weeks for STSG. Cold intolerance. Protective sensation ^b
19	25	M	Caught on drill bit	Digital nerve lacerations, FDP laceration, PIP volar plate injury	0–80	175	Admit for IV antibiotics at 7 weeks postop. Cold intolerance. Protective sensation ^b
20	58	F	Caught on boat	Dorsal vein injury	20–100	235	Normal sensation ^a
21	49	M	Caught on drill	Both nerve lacerations, FDP laceration, extensor tendon laceration, dorsal veins	40–90	130	Return to OR at 6 months for tenolysis. Full grip strength return. Cold intolerance. Protective sensation ^b

TAM total active motion (sum MP, PIP, DIP Joints)

^a Normal sensation 5-mm 2-point discrimination

^b Protective sensation 7–10-mm 2-point discrimination

fingers survived, no cold intolerance was noted, and no limitations in sensory function were reported (Table 1).

Class II Ring Avulsion Injuries

Thirteen patients were Urbaniak class II. All patients in this group experienced compromised arterial and venous flow to the injured ring finger and variable damage to the extensor mechanism, flexor tendons, digital nerve(s) dorsal veins, proximal phalanx, or distal interphalangeal joint (Figs. 4 and 5).

Patients 9–12, 17, and 20 experienced arterial injury, and 9–12 had nerve injuries requiring direct repair. Patients 17 and 20 also had injury to the dorsal veins. Final average PIP motion was 88.3° (±16.3°), and total active motion (TAM) was 208° (±38.6°). No patients experienced loss of protective sensation, and all patients had 2-point discrimination ranging

from 5 to 10 mm. No cold intolerance was noted in this subgroup.

Patients 13–16, 18–19, and 21 also suffered combined injuries to both the underlying bone and tendons. Proximal phalangeal fractures were fixed with K-wires, and primary tendon repair was performed when necessary. Those with repair of a flexor tendon (patients 18, 19, 21) experienced reduced PIP motion average of 67° (±15.3°) and TAM of 156° (±23.5°). Even less range of motion was seen in patients with fracture of the proximal phalanx, ultimately obtaining 42.5° (±42°) of PIP motion and 141° (±23.9°) of TAM. Cold intolerance was reported in three patients within this subgroup (patients 18, 19, 21) (Table 2).

This study illustrates a unique Urbaniak II injury pattern in two patients in whom the ring strips soft tissues from proximal to distal to the level of the DIPJ, dislocating the DIPJ and hinging it on one of the collateral ligaments (patient no. 9 and

Table 3 Class III ring avulsion injury patients

Patient no.	Age	Gender	Mechanism of injury	Associated injuries	Final PIP motion (degrees)	Outcomes
22 ^a	35	M	Caught on snowplow		0–85	Replanted. Protective sensation ^c . DIPJ fusion 1 year postop
23 ^a	27	M	Caught on boat line		10–90	Replanted. Normal sensation ^b . Secondary DIP fusion at 6 months
24	75	F	Caught on trailer			Amputation revision
25	27	M	Industrial press			Amputation revision
26	40	F	Drill press			Amputation revision
27	16	F	Power takeoff			Amputation revision
28	51	M	Tow motor			Amputation revision
29	54	M	Caught on bulldozer			Amputation revision
30	44	M		All except FDP at PIP	0–100 MP	Amputation revision at proximal phalanx
31	46	M	Caught on rain gutter	All	0–85 MP	Amputation revision
32 ^a	41	F	Drill press	All	0–100 MP	Revision amputation
33 ^a	47	M	Bobcat hydraulic part	All except proximal phalanx. DIP dislocation	0–90 MP	Eventual amputation

^a Initial replantation^b Normal sensation 5-mm 2-point discrimination^c Protective sensation 7–10-mm 2-point discrimination

no. 16) (Figs. 4 and 5). In both patients, the digital arteries were avulsed as well with extensive intimal trauma from 5 mm proximal to the laceration to the level of the DIPJ. In each patient, the resulting avascular digit was salvaged by DIPJ stabilization with a K-wire and revascularization using long reversed forearm vein grafts from the origin of the radial digital artery in the distal palm to the distal stump of the ulnar digital artery just proximal to the DIPJ. Similarly, a long vein graft which is not reversed was required to restore venous

circulation. Patient no. 9 subsequently underwent DIPJ fusion for mallet deformity, no. 16 continues to work as a contractor with a 30°, flexible mallet deformity. A DIPJ fusion, however, is often indicated in this injury pattern if the terminal tendon does not heal well enough to maintain DIPJ extension.

Class III Ring Avulsion Injuries

Twelve patients were Urbaniak class III, with complete amputation or degloving. Eight had complete degloving injuries leaving an intact skeleton with the dorsal apparatus of the extensor tendon intact to the DIPJ and the flexor digitorum sublimis intact to its insertion in the base of the proximal phalanx. Each of these eight patients was treated with primary amputation at the metacarpophalangeal joint (MPJ) level. No reoperations were performed after the initial hospital stay.

Fig. 1 Class I ring avulsion injury to skin only **Fig. 2** Type II ring avulsion injury

Fig. 3 **a** Class III ring avulsion injury with complete amputation through the DIPJ. **b, c** Class III ring avulsion injury after successful replant

Patient no. 33 had complete soft tissue stripping of the digit with complete amputation through the DIPJ. Since he was healthy and relatively young, an attempt was made to replant the digit but failed, and amputation was performed at the MPJ.

Patient no. 22 sustained an identical ring avulsion injury with complete degloving and amputation through the DIPJ, and the finger was successfully replanted. Patient no. 23 suffered amputation through the DIPJ when his finger was caught on the bowline of an iceboat degloving the finger from the middle third of the middle phalanx and amputating the finger through the DIPJ. Replantation was successfully performed. Both patients regained excellent PIP motion and both required later DIPJ fusion. Patient no. 22 had a significant mallet deformity and no. 23 developed ulnar deviation secondary to an osteochondral defect. No patients with Urbaniak class III injuries experienced cold intolerance for more than 1 year. Protective sensation was reported in all patients with successfully replanted digits (Table 3).

Discussion

In 1963, Bevin and Chase noted that the only clear indication for amputation for a ring avulsion injury was irreversible loss of blood supply [3]. This approach reflects treatment options prior to the development of microsurgical techniques available today. Nevertheless, if the surgeon suspects that revascularization of a severely injured finger will not result in a functional, mobile finger, primary amputation should be performed.

An early classification system was recommended by Carroll in 1973 [6] and appears to be one of the first attempts to stratify outcomes based on anatomic structures involved in the injury. He described class I injuries as including variable mild skin injury (crush or laceration), bruising, and venous engorgement without neurovascular or tendinous impairment. Class II injuries included more extensive skin injury with damage to one neurovascular bundle but still no tendon and bone involvement. In both cases, the recommended treatment for these classes was soft tissue care ranging from simple ring removal to abdominal flap coverage. Class III injuries included tendon injury as well as both neurovascular bundles, and class IV adding joint dislocation or phalangeal fracture. His early recommendations suggest revision amputation for these injuries that include tendon laceration and phalangeal fracture or joint dislocation in addition to the neurovascular compromise.

In 1979, Flatt [8] noted that microsurgical techniques greatly improved the surgeon's ability to treat ring avulsion injuries but added no additional treatment recommendations. He also noted the utility of slotting a ring creating a stress riser resulting in the ring breaking prior to damaging the finger.

With the advent of microsurgery to repair digital vessels and nerves, Urbaniak et al. was among the first to develop a well-accepted classification scheme for ring avulsion injuries [16]. Subsequent to this original classification, Nissenbaum recognized the deleterious effects of damage to other underlying structures on outcomes [13]. His modification of Urbaniak's classification was based on results that showed improvements in patients with only arterial damage versus those with more extensive injuries to tendons and bone. His classification has proven useful to predict worse outcomes in patients with tendon laceration or phalangeal fractures.

Comtet et al. reported a unique type of ring injury resulting in radial and ulnar digital artery thrombosis, without skin laceration or damage to other structures [7]. In their report, revascularization by resection of the damaged vessel and repair or vein grafting may also yield an excellent result.

Kay et al. proposed a classification for ring avulsion injuries based more specifically on injury level and prognosis [9]. They modified the Urbaniak classification to include arterial only or venous only injuries in typical class II injuries without phalanx fracture or joint dislocation. Their class III injuries

Fig. 4 **a** Class II ring avulsion injury, which occurred when a 28-year-old male was climbing into a boat after water skiing. The patient's ring caught on a bolt on the transom of the boat and when the boat jerked forward, his finger was nearly amputated. The photo shows a circumferential laceration around the finger caused by his wedding ring. The ring has been removed and the finger is clearly nonviable. **b** Photo is taken in the operating room and shows the extent of the injury. The skin has been degloved to the level of the DIPJ. The DIPJ has been dislocated and is hinged on the ulnar collateral ligament. Both digital arteries and the radial digital nerve have been completely lacerated, while the ulnar digital nerve remained intact. The terminal tendon insertion of the dorsal apparatus has been lacerated, but the FDP remains intact. **c** Photo shows the hand 3 months later. **d** Full flexion and extension is noted at 3 months follow-up. **e** Photo shows the hand 25 years later in full flexion and **f** extension; DIPJ fusion was performed 1 year after the initial injury for a mallet deformity

included fracture or joint injury. Class IV was reserved for complete amputation. This study evaluated 52 patients. Approximately 36 % of their class II patients had complications requiring additional surgery compared to 83 % of class III patients.

In a similar study by Beris et al., finger function was much less compromised when trauma occurred distal to the flexor digitorum superficialis (FDS) insertion and at the distal interphalangeal joint [2].

Other studies, however, would dispute the notion that the level of phalangeal fracture affects outcome [15, 17]. More recently, other alternative treatments have been described that offer more options to salvage ring avulsion injuries [12]. One promising procedure for revascularization and soft tissue coverage is the use of a venous flow through flap from the volar forearm [4, 5]. This provides the finger with vascular supply as well as soft tissue coverage which is often necessary. Other

patient factors including health status, smoking history, and patient desire to return to work, which is also tied to economics, must also be taken into account.

Results of the current study support several interesting observations. As demonstrated by our results, class I injuries recover very well with soft tissue treatment alone. Conversely, type III injuries are often unsalvageable, and primary amputation is the best treatment. Although not a primary consideration, amputation is more cost-effective, minimizing OR time and allowing patients to return to work and day-to-day activities sooner. Replantation may be indicated when the patient is otherwise young and healthy and good proximal blood flow is present. Confirmation of adequate proximal flow may require debridement of the digital artery back to healthy-appearing intima. The success of a reverse vein graft also requires identification of a healthy distal digital vessel which may be on the

Fig. 5 A 44-year-old male jumped from his dump truck, catching his ring on a bolt protruding from the bed of the truck and lacerating his finger during the fall. Evaluation in the emergency department revealed dusky, cool fingertip with an open injury to the DIPJ (**a**). In the operating room, both digital arteries were found to be lacerated with extensive intimal damage. The dorsal venous circulation was disrupted as well. Both digital nerves appeared intact, confirming moderate sensation to light touch during preoperative evaluation. In order to restore arterial flow to the

finger, a reverse vein graft was taken from the ipsilateral wrist and sutured from the ulnar digital artery proximally to the radial digital artery distally (**b**). After final debridement, the wound was closed loosely. Leach treatment was used postoperatively for 24 h to alleviate venous congestion. He was taken back to the operating room 2 weeks later for full-thickness skin grafting of a relatively small, but persistent skin defect (1×1 cm). At 1 year follow-up, PIP motion was from 0° to 100° of flexion, and DIP motion was from 35° to 75° of flexion with intact sensation (**c**, **d**)

ipsilateral or contralateral side of the finger. In addition to venous flow through flaps [5], Adani et al. have had good results with revascularization by transferring the adjacent long finger digital artery to the nonviable ring finger [1]. While this technique has the advantage of supplying a normal artery to the injured finger, it has the obvious disadvantage of potential iatrogenic injury to the long finger.

Type II patients present a more challenging treatment consideration, particularly when there is a proximal phalanx fracture or a laceration of the profundus and sublimis tendons or a combination of proximal phalanx fracture and tendon laceration. The subgroups with laceration of the sublimis and profundus tendons and proximal phalanx fractures demonstrated poor motion and cold intolerance, although survival was uniformly good. If the proximal phalanx is not fractured and the sublimis and profundus tendons are intact, our findings suggest that adequate range of motion can be expected. When nerve repair was performed, all patients in this series demonstrated protective sensation or better.

Ozaksar et al. [14] present a series of 43 patients with complete amputations secondary to ring avulsion

injuries. Thirty-seven of the 43 patients underwent replantation of the ring avulsion injury. Twenty-one patients were salvaged with digital artery transfer from the adjacent digit; vein graft interposition was used in six patients and end-to-end repair in ten. Thirty-one of the 37 digits survived.

While our study is retrospective in nature, the authors believe that our study shows that the Urbaniak classification has withstood the test of time as the most practical classification for ring avulsion injuries. This retrospective review creates a lack of uniform and complete data that can be gathered from patient charts. We are also limited in the number of patients who experience this specific type of injury, which impacts statistical evaluation and consistent outcome patterns not only in this paper but also in previous research. Despite these limitations, when basic microsurgical principles are applied and secondary injuries such as proximal phalanx fractures and FDS and flexor digitorum profundus (FDP) lacerations are considered, the surgeon can decide to salvage the digit or not based on these findings using this simple straightforward classification of ring avulsion injuries.

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