Ring Avulsion Injuries: A Systematic Review

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Abstract

Background: Ring avulsion injuries can range from soft tissue injury to complete amputation. Grading systems have been developed to guide treatment, but there is controversy with high-grade injuries. Traditionally, advanced ring injuries have been treated with completion amputation, but there is evidence that severe ring injuries can be salvaged. The purpose of this systematic review was to pool the current published data on ring injuries. **Methods:** A systematic review of the English literature published from 1980 to 2015 in PubMed and MEDLINE databases was conducted to identify patients who underwent treatment for ring avulsion injuries. **Results:** Twenty studies of ring avulsion injuries met the inclusion criteria. There were a total of 572 patients reported with ring avulsion injuries. The Urbaniak class breakdown was class I (54 patients), class II (204 patients), and class III (314 patients). The average total arc of motion (TAM) for patients with a class I injury was 201.25 (n = 40). The average 2-point discrimination was 5.6 (n = 10). The average TAM for patients with a class II injury undergoing microsurgical revascularization was 187.0 (n = 114), and the average 2-point discrimination was 8.3 (n = 40). The average TAM for patients with a class III injury undergoing microsurgical revascularization was 168.2 (n = 170), and the average 2-point discrimination was 10.5 (n = 97). **Conclusions:** Ring avulsion injuries are commonly classified with the Urbaniak class system. Outcomes are superior for class I and II injuries, and there are select class III injuries that can be treated with replantation. Shared decision making with patients is imperative to determine whether replantation is appropriate.

Keywords: ring avulsion, replantation, avulsion injury, microsurgery, completion amputation

Introduction

Ring avulsion injuries have classically been a challenge for hand surgeons. There is a large spectrum of injury ranging from soft tissue injury to complete amputation. Prior to the advent of microsurgery, treatment options were limited to local soft tissue coverage and completion amputation.^{10,12,18,40} The age of microsurgery introduced the concepts of revascularization and replantation to ring avulsion injuries.^{16,43} The potential utilization of these techniques has initiated a debate on when to replant and when to amputate.

Multiple classification schemes have been published on ring avulsion injuries.^{23,32,43,47} The original classification was developed by Urbaniak et al.⁴³ The Urbaniak classification features 3 classes: Adequate Circulation (I), Inadequate Circulation (II), and Degloving/Complete Amputation (III). Kay et al²³ expanded the classification by dividing class II injuries by the presence of skeletal injury and creating a class IV injury (complete amputation). Adani et al¹ subdivided class IV injuries into IVd, amputation distal to the flexor digitorum superficialis (FDS) insertion; IVp, amputation

proximal to the FDS insertion; and IVi, complete degloving injuries with intact tendons. While Urbaniak's was the first classification system adopted, all of these classifications are seen in the literature.

Ring avulsion injuries are uncommon injuries despite the small forces needed to produce a complete amputation.²⁴ Hence, the literature on ring avulsions is limited to case reports and retrospective case series. The purpose of this study was to systematically review the existing literature on ring avulsion injuries. Pooling the available retrospective data on ring avulsion injuries gives more insight into treatment successes and failures than single studies alone.

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Evaluating successful techniques and patient selection for repair and replant will shed light on a challenging decision-making process.

Materials and Methods

We performed a literature search using MEDLINE in September 2015 to summarize outcomes after ring avulsion injuries. Ring avulsions were defined as an injury from a sudden pull on a finger ring which results in injury ranging from soft tissue laceration to complete amputation. We used the key words “ring avulsion,” “ring amputation,” or “finger avulsion,” combined with “amputation,” or “replantation” to identify studies. Studies were limited to those published in English.

Inclusion criteria required that studies meet the following:

1. Presentation of primary data
2. The study included at least 5 patients with a defined ring avulsion injury
3. The study presented amputation, microsurgical, and failure rates.

The following studies were excluded from the analysis:

1. Incomplete data
2. Studies that had patients with non-ring avulsion injuries
3. Outcomes of all patients were not reported.

All articles were reviewed by 2 independent reviewers (R.B. and G.M.) to determine whether inclusion and exclusion criteria were met. Full-length manuscripts were reviewed for all articles that met inclusion criteria.

Primary data were collected from all manuscripts, and patients were pooled together by class of ring avulsion injury using the Urbaniak classification:

Class I: Circulation adequate

Class II: Circulation inadequate

Class III: Complete degloving injury or complete amputation.

Class of injury, treatment modality, outcomes, microsurgical repair rates, and amputation rates were recorded from each study for each patient. Age, gender, total arc of motion (TAM), 2-point discrimination (2PD), and cold intolerance were collected when available.

Although the Urbaniak classification appeared to be more commonly used, several authors did use the Kay classification as well. Based on the case descriptions, we were easily able to reclassify patients so that we could uniformly apply the Urbaniak classification system to all patients studied.

Figure 1. Flowchart of MEDLINE search, including number of citations identified at each part of search.

The PRISMA checklist was used in our review. The PRISMA statement is a 27-item checklist to produce transparent reporting of systematic reviews.²⁵

Results

Study and Patient Characteristics

The initial search resulted in 1239 citations, and after title screening, 42 studies were selected for abstract and manuscript review (Figure 1). Twenty-two studies were excluded for (a) less than 5 patients ($n = 3$) and (b) inclusion of non-ring-related injuries ($n = 19$). Twenty studies of ring avulsion injuries met the inclusion criteria.^{1,3-5,7-9,15,22,23,29,30,32-34,36,41,43,44,47} All studies were retrospective reviews at single institutions. The 20 studies were conducted in Europe ($n = 10$), United States ($n = 9$), and Australia ($n = 1$).

There were a total of 572 patients reported with ring avulsion injuries. The Urbaniak class breakdown was class I (54 patients), class II (204 patients), and class III (314 patients). Age and gender were not available for all patients, but for those reported, the average age was 34.7 years ($n = 170$), and 72.5% were male ($n = 124$) with 27.5% being female ($n = 47$; Table 1).

Table 2 lists the class breakdown for each study, amputation rates for class III injuries, microsurgical repair and success rates for class II/III injuries, TAM breakdown by class, 2PD by class, and cold intolerance rates (for those undergoing microsurgical repair).

Table 1. Study Demographics.

Study	Location	No. of patients	Male	Female	Average age, y	Level of evidence
Urbaniak et al ⁴³	Durham, North Carolina	24	—	—	—	IV
Nissenbaum ³²	Philadelphia, Pennsylvania	22	4	3	36	IV
Tsai et al ⁴¹	Louisville, Kentucky	7	4	3	40	VI
Kay et al ²³	Louisville, Kentucky	55	35	20	35	IV
van der Horst et al ⁴⁴	Rotterdam, The Netherlands	48	—	—	—	IV
Weil et al ⁴⁷	Loma Linda, California	16	12	4	40	VI
McGeorge and Stilwell ³⁰	Prescot, United Kingdom	5	—	—	—	VI
Beris et al ⁷	Ioannina, Greece	14	8	6	26	IV
Adani et al ²	Modena, Italy	31	23	8	37	IV
McDonald et al ²⁹	Victoria, Australia	6	5	1	—	VI
Akyurek et al ⁵	Ankara, Turkey	7	4	3	27	VI
Adani et al ³	Modena, Italy	10	5	5	40	IV
Sanmartin et al ³⁶	Louisville, Kentucky	105	82	23	34	IV
Ozkan et al ³⁴	Ankara, Turkey	6	4	2	32	VI
Hyza et al ²²	Brno, Czech Republic	6	5	1	35	IV
Brooks et al ⁸	San Francisco, California	101	77	24	35	IV
Brooks et al ⁹	San Francisco, California	8	8	0	—	IV
Ozaksar et al ³³	Izmir, Turkey	43	36	7	30	IV
Adani et al ⁴	Modena, Italy	39	23	10	36	IV
Crosby et al ¹⁵	Erie, Pennsylvania	33	24	9	40	IV

Urbaniak Class I Injury

When pooling all studies together, there were a total of 54 patients who had an Urbaniak class I injury. None of these patients required microsurgical intervention. Two patients did require surgical debridement. The average TAM for patients with a class I injury was 201.25 (n = 40). The average 2PD was 5.6 (n = 10; Table 3).

Urbaniak Class II Injury

When pooling all studies together, there were a total of 204 patients who had an Urbaniak class II injury. Twelve completion amputations were performed (5.9%), and 9 patients underwent observation (4.4%). One hundred eighty-three patients underwent microsurgical intervention (89.7%). The failure rate of microsurgical reconstruction was 9%. The average TAM for patients with a class II injury undergoing microsurgical revascularization was 187.0 (n = 114), and the average 2PD was 8.3 (n = 40; Table 3).

Urbaniak Class III Injury

When pooling all studies together, there were a total of 314 patients who had an Urbaniak class III injury. (Due to inconsistency in usage of ring avulsion injury grading systems, Kay class III was recorded as Urbaniak class II, and Kay class IV was recorded as Urbaniak class III.) Ninety-six completion amputations were performed (30.6%). The remaining 218 patients underwent microsurgical intervention (69.4%). The failure rate of microsurgical

reconstruction was 15.9%. The average TAM for patients with a class III injury undergoing microsurgical revascularization was 168.2 (n = 170), and the average 2PD was 10.5 (n = 97; Table 3).

Discussion

The treatment of ring avulsion injuries over time has been challenging and controversial.³⁵ Contemporary reconstructive microsurgery has revolutionized the management of class II injuries. However, class III injuries still provoke discussions on when to replant and when to amputate. The dearth of literature on ring avulsion injuries reflects the rarity of the injury. Of the existing literature, there is likely a publication bias given series of successful replants are more likely to be reported than a series of completion amputations. Randomized control trials are not feasible due to the ethical and cultural considerations that are used when considering replantation. However, pooling data of cases series provides some insight into potential successful strategies.

Class I Injuries

Urbaniak et al⁴³ describe class I ring avulsion injuries as those that have adequate perfusion. In addition to circumferential skin loss of a variable extent, these injuries can involve the flexor and extensor apparatus, the flexor pulley system, and the volar plate among other structures.⁴³ They represent 9.4% of ring avulsion injuries in the literature; however, this

Table 2. Outcomes by Study.

Study	Class breakdown	Amputation rates (class III/IV only)	Microsurgical rates (class II/III/IV only)	Success rates	TAM	2PD	Cold intolerance
Urbaniak et al ⁴³	Class I: 2 Class II: 9 Class III: 13	46.2%	72.7% (16/22)	87.5% (14/16)	Class II: 206 Class III: 145	—	—
Nissenbaum ⁸	Class I: 3 Class II: 7 Class III: 5	—	71.40%	100% (5/5)	II a: 236	II a: 236	—
Tsai et al ⁴¹	Class I: 0 Class II: 0 Class III: 0 Class IV: 7	—	100%	85.7% (6/7)	IV: 189	IV: 189	4/6 (67%)
Kay et al ²³	Class I: 3 Class II: 25 Class III: 27	18.50%	85%	79.5% (35/44)	I: 127.5 II: 102.5 III: 91.5	I: 127.5 II: 102.5 III: 91.5	15/23 (65.2%)
van der Horst et al ⁴⁴	Class I: 0 Class II: 23 Class III: 25	48%	43.8% (21/48)	90.5% (19/21)	—	—	11/28 (39.3%)
Weil et al ⁴⁷	Class I: 2 Class II: 7 Class III: 7	100%	42.9% (6/14)	83.3% (5/6)	I: 192 II: 224	—	—
McGeorge and Stilwell ³⁰	Class I: 0 Class II: 0 Class III: 5	—	—	—	—	—	—
Beris et al ⁷	Class I: 0 Class II: 1 Class III: 13	—	100%	64.3% (9/14)	—	9.4 (all)	—
Adani et al ²	Class I: 8 Class II: 10 Class III: 3 Class IV: 10	61.50%	65.20%	80% (12/15)	II: 253 III: 202.5 IV: 190	II: 9.6 III: 7 IV: 13.5	1/12 (8.3%)
McDonald et al ²⁹	Class I: 0 Class II: 3 Class III: 1 Class IV: 2	—	100%	100%	II: 126.7 III: 115 IV: 65	II: 126.7 III: 115 IV: 65	5/5 (100%)
Akyurek et al ⁵	Class I: 0 Class II: 0 Class III: 7	—	100%	85.7% (6/7)	III: 194	III: 7.8	—
Adani et al ³	Class I: 0 Class II: 0 Class III: 0 Class IV: 10	30%	70%	85.7% (6/7)	IV: 200	IV: 13.8	2/6 (33%)
Sanmartin et al ³⁶	Class I: 19 Class II: 18 Class III: 33 Class IV: 35	12.80%	87.20%	81.3% (61/76)	II: 203 III: 181 IV: 173	II: 203 III: 181 IV: 173	4/61 (6.6%)
Ozkan et al ³⁴	Class I: 0 Class II: 0 Class III: 3 Class IV: 3	—	100%	100% (6/6)	III: 217.7 IV: 190	III: 217.7 IV: 190	0% (0/6)
Hyza et al ²²	Class I: 0 Class II: 0 Class III: 6	0%	100%	100% (6/6)	III: 195	III: 8.6	4/6 (67%)
Brooks et al ⁸	Class I: 9 Class II: 45 Class III: 40	29.40%	72.80%	85.5% (59/69)	I: 210 II: 190 III: 174	—	—

(continued)

Table 2. (continued)

Study	Class breakdown	Amputation rates (class III/IV only)	Microsurgical rates (class II/III/IV only)	Success rates	TAM	2PD	Cold intolerance
Brooks et al ⁹	Class I: 0 Class II: 3 Class III: 5	—	100%	100% (8/8)	185 (all)	—	—
Ozaksar et al ³³	Class I: 0 Class II: 0 Class III: 0 Class IV: 43	14%	86%	83.4% (31/37)	IV: 172	IV: 172	12/26 (46.2%)
Adani et al ⁴	Class I: 0 Class II: 0 Class III: 0 Class IV: 39	15.40%	84.60%	87.9% (29/33)	IVi: 206 IVd: 180	IVi: 11.8 IVd: 12.1	5/29 (17.2%)
Crosby et al ¹⁵	Class I: 8 Class II: 13 Class III: 12	75.00%	64.00%	93.4% (15/16)	I: 224.4 II: 175.1 III: NR	—	3/33 (9.1%)

Note. TAM = total arc of motion; 2PD = 2-point discrimination.

Table 3. Outcomes by Urbaniak Class of Injury.

	Total	TAM	Amputation	Primary amputation rate, %	2PD	Success rate, %	Failure rate, %	Nonsurgical rate, %
Class I	54	201.25	0	0	5.6	—	—	100
Class II	204	187	12	5.9	8.3	91	9	4.4
Class III	314	168.2	96	30.6	10.5	84.1	15.9	0

Note. TAM = total arc of motion; 2PD = 2-point discrimination.

is likely an underrepresentation of the incidence of class I injuries given a potential publication bias of higher grade injuries. In a biomechanical study of ring injuries, low forces were required for all ring injuries, but as expected, class I injuries required the least amount of force.²⁴

Treatment involves wound assessment and standard management of soft tissue injuries; by definition, no revascularization is required. Outcomes have been reported in only a handful of case series. Brooks et al⁸ reported results on 9 patients; all digits survived with excellent motion and strength. Crosby et al¹⁵ reported on 8 patients with damage limited to the skin, all patients healed with full range of motion and normal sensation. Others^{1,36} have similarly reported excellent outcomes after class I injuries, and results are uniformly better than for class II and III injuries.

One of the limitations of the Urbaniak classification⁴³ is that it does not account for the degree of soft tissue injury. Almost all case series report on patients with skin avulsions and intact deeper structures, and this almost certainly contributes to the excellent reported outcomes. The literature is missing data on a group of patients with more extensive soft tissue injuries but an intact vascular status. It is likely that these injuries are quite infrequent, as greater soft tissue injury should correlate with vascular insufficiency.

Class II Injuries

Urbaniak originally defined a class II ring avulsion by inadequate circulation in need of vessel repair. Microsurgical intervention is the treatment of choice. The complication and failure rates after microsurgical treatment of class II injuries are low.¹⁵ Several microsurgical principles and techniques have been described to treat these injuries and to increase the odds of successful revascularization. Authors have advocated that reestablishing 1 artery with at least 2 veins is necessary.⁷ This can, however, be a daunting task even for an experienced microsurgeon as the zone of injury frequently extends beyond what is seen with the microscope as a result of the longitudinal traction injury.³¹ Extensive debridement of avulsed vasculature coupled with vascular grafts may be necessary.^{8,21} Another successful strategy for difficult class II injuries when tissue adequacy is in question is the use of venous flaps which were described by Tsai et al⁴² and Brooks et al.⁹ These are usually harvested from the dorsal forearm and contain skin, subcutaneous tissue, and long segments of veins. In addition to providing veins of a suitable caliber that can be used for arterial or venous interposition, the flaps also provide a patch of healthy vascularized skin that can be very useful for frequently encountered

skin defects. A third option that has been used with excellent results involves transferring neurovascular bundles from an adjacent digit.^{4,11,26} This technique has the advantage of involving only a single anastomosis and eliminates the issue of vessel mismatch, which sometimes necessitates 2 interposition grafts to step down the vessel caliber.⁵

The outcomes for class II ring avulsion injuries are good. The average reported 2PD and TAM is worse than class I injuries, but this finding was expected. Given these findings, microsurgical repair of class II injuries is commonly feasible and should usually be attempted.

Although primary amputation for class 2 injuries is not extensively discussed in the literature, there certainly is a role for it. The primary amputation rate in the literature of class II injuries was 5.9% with most of the amputations being in earlier studies. Unfortunately, the authors did not provide details of their decision-making process for amputation in these few patients.^{23,32,36,44} One can assume that for class II injuries with damage to the proximal interphalangeal (PIP) joint or injury to both the sublimis and profundus tendons, functional outcomes will be worse. In such cases, it may be worth considering a primary amputation, although this decision should be made by an experienced surgeon after a thorough discussion with the patient.

Class III Injuries

Urbaniak described class III injuries as a complete degloving or complete amputation. Classically, these were treated with primary amputation, ray resection, or remote pedicled flaps from the groin or anterior pectoral region.^{12,18,26,30,40} An amputated finger or extensive soft tissue loss would have been considered indications for a completion amputation. Today, however, with the refinement of microsurgical revascularization techniques, the ability to preserve a digit after a class III injury has vastly improved.

We found a survival rate of 84.1% when pooling the data for class III injuries. While this number is likely to be inflated secondary to a publication bias, large series of continuous patients show a similar result. In 2 of the largest series published in the last decade, Adani et al demonstrated an 88% survival rate and Ozaksar et al had an 84% survival rate after replantation. The techniques and principles employed are similar to those discussed for class II injuries. Hyza et al, Adani et al, and Ozaksar et al, among others, have popularized the principle of aggressively resecting the “zone of contusion” prior to microsurgical repair; this in part is responsible for the improved survival rates in the modern literature.^{3,22,33}

As our ability to preserve these digits has improved, the discussion has shifted from “can we perform a replant?” to “should we perform a replant?” Functional outcomes, cost, cultural differences, time off from work, and need for multiple surgeries are all factors that need to be considered by the patient and surgeon.

Pooled data demonstrate a TAM of 168.2° and a 2PD of 10.5 mm. Poorer motion and 2PD were noted for class III injuries when compared with class I and II injuries. Sanmartin et al,³⁶ however, in their large series, did not find statistically worse outcomes in replanted class III injuries, demonstrating a heterogeneity in patient outcomes. Several authors have avoided replantation when amputation occurred proximal to the FDS insertion.^{4,8,23,42,43}

Adani et al⁴ classified patients into 3 groups, those with complete skin degloving but with intact tendons, amputation distal to FDS insertion, and amputation proximal to the FDS insertion; they had excellent results with replantation in the first 2 groups and opted to amputate all digits in the final group.

Survival rates of microsurgical revascularizations and replantations have increased through the years. However, traditionally, hand surgeons are hesitant to replant single digits. A recent survey of US hand surgeons revealed low rates of willingness to replant single digits.³⁹ Cultural and socioeconomic factors affect replantation rates. Replantation is more likely to be attempted in the young and females.^{2,39} Replant attempts also vary by race and insurance status.²⁷ Cultural factors are also a consideration in the decision to replant. For example, there is more stigma attached to amputees in Japan compared with the United States, but both Japanese and American societies view amputation more negatively than their respective surgeons.²⁸

While the rate of secondary surgery after replantation is likely to be high, this was not discussed in the literature in the context of ring avulsion injuries. Brooks et al performed an extensor and flexor tenolysis, DIP joint fusion, 2 skin reductions, and a PIP joint arthroplasty in their series of 59 patients in all classes of injury. Time off from work, time to recovery, and cost were not adequately addressed in the literature.

There are many factors to be taken into account with advanced ring avulsion injuries. The literature has described numerous cases of successful replantation of high-grade ring avulsion injuries. However, measuring outcomes in hand surgery can be difficult.^{6,19} Interpreting the literature can be challenging due to varying uses of outcomes measures. TAM and 2PD are inconsistently reported, and standardized outcome measures are currently evolving. There has been a recent rise in patient-reported outcomes across different surgical specialties.⁴⁵ Patient-reported outcomes have been extensively investigated in hand surgery,^{13,14,17,20,37-39,46} and the development of standardized outcome measure tools will help with shared decision making. Hand surgeons and patients may have different definitions of successful replantations, and it is important to have open discussions with patients when making the decision of whether or not to reimplant.

Systematic reviews and meta-analyses are ideal methods for evaluating clinical questions. However, their power and conclusions are limited by the quality of evidence available. Ideally, these studies will consist of uniform level I studies. In our present review, no level I studies were available.

Pooled data can be useful, which help transform heterogeneous data into a uniform study. In the study of ring avulsion injury, there is the limit of publication bias as well as studies with small sample sizes. At the current time, our pooled data provide a summary of published literature and a useful reference for hand surgeons for outcomes of ring avulsion injuries.

Conclusion

Ring avulsion injuries require hand surgeons to balance aesthetics and function when determining treatment. The Urbaniak classification is the most commonly used system. Class I injuries are defined as those with adequate circulation and require soft tissue injury treatment and often result in excellent hand function. Class II injuries are defined as those with inadequate circulation. The treatment of class II injuries has improved for the past few decades with emerging microsurgical techniques. Outcomes of class II injuries are generally inferior to class I injuries, but function is usually adequate. Class III injuries include complete degloving injuries and complete amputation. Determining treatment for class III injuries remains controversial. A review of the literature specified that distal ring avulsion injuries are more amenable to replantation but that overall, class III injuries have poorer outcomes than lower grade ring avulsion injuries. No overarching treatment strategy can be developed for class III injuries, and it is important to engage in the process of shared decision making with patients to determine treatment strategies. With this in mind, patient-specific and anatomical factors should be evaluated to determine whether replantation is appropriate.

Ethical Approval

This study was approved by our institutional review board.

Statement of Human and Animal Rights

This article does not contain any studies with human or animal subjects.

Statement of Informed Consent

This article did not require the use of informed consent.

Declaration of Conflicting Interests

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