



## Defying standard criteria for digital replantation: A case series



Diogo Casal<sup>a,b,\*</sup>, Manuel Macemino Gomez<sup>c</sup>, Paula Antunes<sup>a</sup>, Henrique Candeias<sup>d</sup>,  
Maria Angélica Almeida<sup>a</sup>

<sup>a</sup> Department of Plastic and Reconstructive Surgery and Burn Unit, São José Hospital, Lisbon, Portugal

<sup>b</sup> Lisbon Medical Sciences Faculty, Portugal

<sup>c</sup> Department of Plastic and Reconstructive Surgery, São Bernardo Hospital, Setúbal, Portugal

<sup>d</sup> Department of General Surgery, São Bernardo Hospital, Setúbal, Portugal

### ARTICLE INFO

#### Article history:

Received 5 August 2012

Received in revised form 27 February 2013

Accepted 29 March 2013

Available online 10 April 2013

#### Keywords:

Amputation

Traumatic/classification

Finger injuries/surgery

Fingers/surgery

Graft survival

Humans

Outcome assessment (health care)

Replantation/contraindications/methods

### ABSTRACT

**INTRODUCTION:** There is much controversy regarding the current indications and contraindications for digital replantation.

**PRESENTATION OF CASE:** Three patients with absolute contraindications for digital replantation according to classical criteria are presented (*Case 1*: multilevel amputation of the hand and fingers; *Case 3*: avulsion of the thumb; *Case 4*: index amputation proximal to the insertion of the flexor digitorum superficialis). In addition a patient with a very distal digital amputation (*Case 2*), whose indication for replantation is controversial is also presented. In all cases, the patients were replanted and showed good functional and aesthetical results.

**DISCUSSION:** Most authors advocate that the classical indications for replantation have been validated by experience, are predicated on the potential for long-term function, and should be followed in most if not all cases. However, some surgeons have been adopting a more liberal attitude with good results.

**CONCLUSION:** The clinical cases presented in this paper suggest that the standard criteria for digital replantation should not be followed rigidly but instead should be regarded as a general guide.

© 2013 Surgical Associates Ltd. Published by Elsevier Ltd. Open access under [CC BY-NC-ND license](http://creativecommons.org/licenses/by-nc-nd/3.0/).

## 1. Introduction

Since the first successful digital replantation was performed in Japan in 1968, much has been written on this topic.<sup>1,2</sup> Digital replantation is frequently requested in many trauma centers all over the world.<sup>1,3,4</sup> However, it is widely accepted that replantation is not always the best option in the case of a severed finger.<sup>5</sup> In fact, there is much controversy regarding the indications and contraindications for digital replantation.<sup>1,3–6</sup> To make matters worse, most individual surgeons never gain extensive personal experience in this field.<sup>7,8</sup> For example, a recent epidemiologic study in the United States of America estimated that only a few hospitals perform digital replantation procedures regularly, and only approximately 2 percent execute more than 10 replantations each year.<sup>7,8</sup> In addition, on the one hand, bold but unfruitful trials at replantation are very likely to result in litigation.<sup>5</sup> On the other hand, a recent review on litigation in the realm of hand replantation in a major trauma center revealed that most patients that had filed claims did so because the attending physician decided not to replant the severed part.<sup>5</sup>

To facilitate the decision making process, several authors have proposed a list of indications and contraindications for digital replantation that are largely followed (Table 1).<sup>1,3,5,9</sup> In this paper, the authors present 4 clinical cases of patients that were replanted despite these contraindications, with good viability, function and cosmesis of the replanted segments.

## 2. Presentation of cases

In all patients, radiographs of both the amputated parts and the hands were obtained at admission in the emergency department. In the operating theatre, the amputated segments were cleansed with 500ml of sterile lactated Ringer's solution mixed with 80mg of gentamicin. These segments were then carefully debrided under the microscope, and their vessels and nerves identified and tagged with a 8/0 nylon suture.

After bony fixation, the extensor tendons were repaired with two horizontal mattress sutures of 3-0 Nylon. The flexor tendons were repaired with 3-0 Nylon using the Tajima suture method.<sup>10–12</sup> Arteries and veins were repaired only after observing normal intima under high-power magnification. Vascular defects were bridged by interposition vein grafts. Before arterial anastomoses were performed, blood flow was confirmed from the proximal artery. Vessels were sutured using interrupted sutures of 9-0, 10-0 or 11-0 nylon, depending on the vessel's size. Nerves were repaired under

\* Corresponding author at: Plastic and Reconstructive Surgery Department, São José Hospital, Rua José António Serrano, 1150-199 Lisbon, Portugal.  
Tel.: +351 916117315.

E-mail address: [diogo.bogalhao@yahoo.co.uk](mailto:diogo.bogalhao@yahoo.co.uk) (D. Casal).

**Table 1**  
Indications and contraindications for hand and digital replantation according to most authors (1–4).

| Indications  | Contraindications  |
|--|--|
| Thumb amputation   | Single digits proximal to the insertion of the flexor digitorum superficialis (Zone II) – particularly in the index or small fingers |
| Multiple digits  | Severely crushed, avulsed or mangled parts   |
| Hand amputation through palm   | Multilevel amputations   |
| Hand amputation (distal wrist)   | Prolonged warm ischemia time   |
| Any part in a child  | Severely arteriosclerotic vessels  |
| Finger distal to the insertion of the flexor digitorum superficialis tendon (Zone I) | Multiple trauma to other regions <sup>a</sup>  |
|  | Severe comorbidities <sup>a</sup>  |

<sup>a</sup> Relative contra-indications.

the operating microscope with interrupted epineurial sutures of 8-0, 9-0 or 10-0 nylon, after fascicular alignment was confirmed.

In all patients 40 mg of enoxaparin given subcutaneously and 100 mg of aspirin given enterally were administered in the operating room and once a day for the following 14 days.

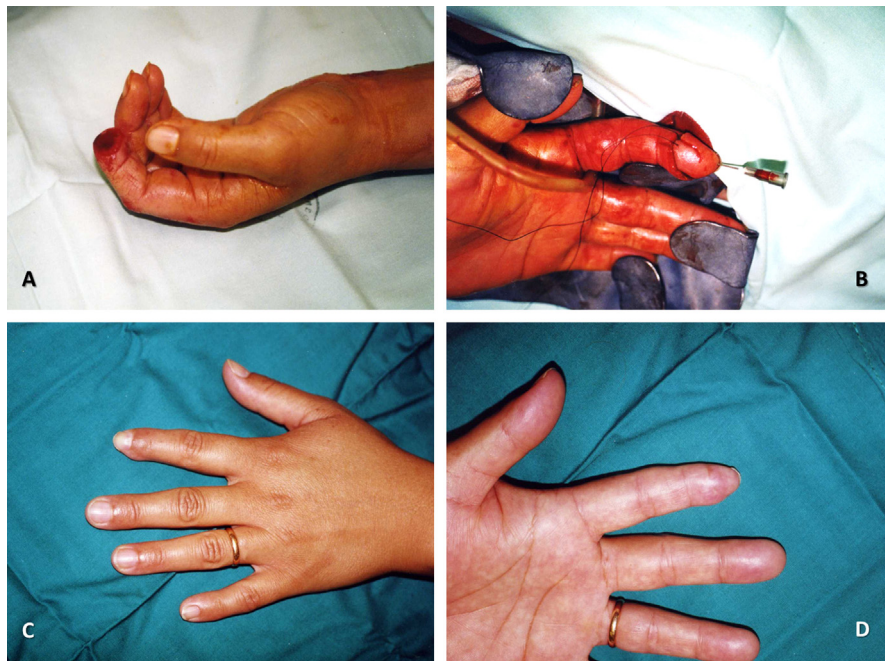
2.1. Clinical Case 1 – multilevel amputation (Fig. 1)

A 59-year-old right-handed male sustained a double amputation of his left hand with an electric saw (Fig. 1A and B). There was amputation of the ring and small fingers at the distal metacarpal level and amputation of the ring finger at the distal part of the middle phalanx. Replantation of the two segments was performed in sequence from proximal to distal by the second author (M.M.G.). The bones were fixed with Kirschner wires. One artery and two veins were repaired for each finger. Palmar digital nerves were repaired, as well as the extensor tendons and the flexor digitorum profundus tendons. The ischemia time was 2 h for the proximal segment and four and a half hours for the distal segment. Since the end of the surgery the replanted segments remained well perfused (Fig. 1C and D). The patient was discharged home 7 days after surgery. Kirschner wires were removed after 6 weeks. After that, the patient moved to another part of the country and stopped coming to the clinic. In addition, he did not attend any more physiotherapy treatments. 7 years after surgery, the patient returned to the clinic (Fig. 1E and F). He presented rigidity in the involved joints, but had an overall acceptable functional and cosmetic result (Video). The patient used his hand in all daily living activities and was satisfied with the end result.



**Fig. 1.** Mangled left hand with amputation of the ring and small fingers at the distal metacarpal level and amputation of the ring finger at the distal part of the middle phalanx. The amputated segments were replanted with good functional and aesthetical results. (A) Volar aspect of the amputated portion of the hand with double amputation of the ring finger; (B) Posterior aspect of the amputated stump; (C) Immediate postoperative appearance of the dorsal aspect of the replanted segments; (D) Immediate postoperative appearance of the volar aspect of the replanted segments; (E and F) Dorsal and volar aspects (respectively) of the hand 7 years after surgery, showing complete viability and adequate healing of the amputated segments.





**Fig. 2.** Replantation of the distal phalanx of the left index finger. (A) Left index finger after amputation of the distal phalanx; (B) Aspect of the distal phalanx after microvascular anastomoses; (C and D) Dorsal and volar aspect of the hand (respectively) one year after replantation showing complete viability of the replanted segment and a good functional and cosmetic result.

### 2.2. Clinical Case 2 – Distal phalanx partial amputation (Fig. 2)

A 40-year-old right-handed female suffered an amputation of the distal portion of the distal phalanx of her left index finger, corresponding to a type IV amputation according to Allen's classification<sup>13</sup> (Fig. 2A). Osteosynthesis was performed with a Kirschner wire, and an artery, a vein and branches of the palmar digital nerves were repaired under the microscope (Fig. 2B). The ischemia time was 4 h. The replanted part survived uneventfully. 1 year after surgery, she showed good function and cosmesis of the replanted segment (Fig. 2C and D).

### 2.3. Clinical Case 3 – avulsion of the distal phalanx of the thumb (Fig. 3)

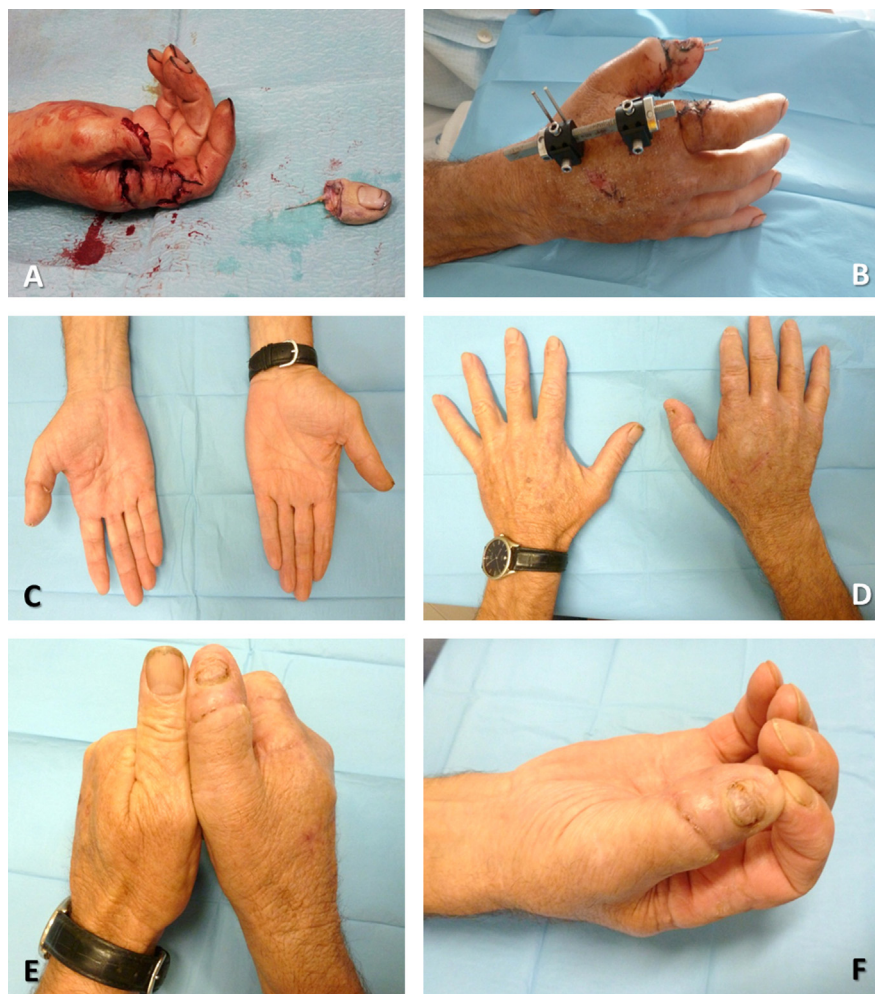
A 60-year-old right-handed male, with an history of smoking 30 cigarettes per day for the previous 40 years, suffered an avulsion of the distal phalanx of the his right thumb in an industrial machine accident (Fig. 3A). Concurrently, he had also sustained a comminuted fracture in the subcapital region of the second metacarpal bone with bony shortening. The amputated segment of the thumb was fixated with two Kirschner wires. The two palmar arteries were anastomosed using two vein grafts (each around 4 cm in length) taken from the volar aspect of the forearm; a single venous anastomosis in the dorsum of the thumb was performed using a 5-cm long vein graft taken from the same region; the two palmar digital nerves were repaired, as were the extensor pollicis longus and the flexor pollicis longus tendons. The ischemia time was 5 h. The fracture on the second metacarpal bone was reduced and immobilized with an external fixator. The severed phalanx survived uneventfully (Fig. 3B). The hardware was removed at 6 weeks. 2 months after the accident, the patient showed a functionally and aesthetically acceptable result, using his thumb in his daily life activities (Fig. 3C–F).

### 2.4. Clinical Case 4 – amputation of the index finger proximal to the insertion of the flexor digitorum superficialis tendon (Fig. 4)

A 50-year-old right-handed lady with a smoking history of 20 cigarettes per day during the previous 33 years sustained multiple cutting/crushing injuries to her right hand with a lawn-mower (Fig. 4A). These injuries included amputation of the index finger at the proximal phalanx level. The index finger presented additional injuries, especially at the level of the distal phalanx. The patient adamantly expressed her wish to have her finger replanted, even after being explained that function would most likely be compromised if that option was pursued. Osteosynthesis was performed with 2 crossed Kirschner wires. The extensor tendons and the flexor digitorum profundus tendon were sutured. Under the microscope the two palmar digital arteries, the palmar digital nerves and one dorsal vein bridged by a 4 cm-long vein graft from the dorsum of the hand, were repaired (Fig. 4B). The ischemia time was 4 h. Part of the distal phalanx and part of the medial aspect of the proximal phalanx of the index finger suffered skin necrosis, mandating fingertip revision and a skin graft coverage of the proximal phalanx. 6 months after surgery the patient could flex the interphalangeal joints as well as the metacarpal-phalangeal joint of the index finger (Fig. 4C and D). She was able to use that digit in her daily activities, including writing, and she was satisfied with the end result.

## 3. Discussion

Most authors argue that the classical indications for digital replantation have been validated by experience, are predicated on the potential for long-term function, and should be followed in most if not all cases.<sup>1,9,11</sup> Table 1 indicates the most often cited criteria for digital replantation. However, some surgeons have been adopting a more liberal attitude and try to replant most fingers.<sup>4,6,14–16</sup> For example, successful replantations after avulsion amputations or amputation of small parts of fingers are ever more performed with resort to the liberal use of veins grafts, free flaps, including venous arterialized flaps, with arteriovenous fistulas, and



**Fig. 3.** Replantation of the avulsed distal phalanx of the right thumb. (A) Avulsed distal phalanx and proximal stump immediately after the accident; (B) 1 week after the accident, the replanted phalanx showed good viability; (C and D) Volar and dorsal aspects (respectively) of the hands 2 months after the accident, showing complete viability of the replanted segment, and reasonable hand symmetry and cosmesis; (E and F) Two months after surgery, the patient thumb shows good thumb function, including fine pinching, and an acceptable aesthetical result.

sometimes with temporary ectopic replantation of the amputated segment before transfer to the original location, when the amputation stump is too dirty or too damaged for immediate orthotopic replantation.<sup>4,6,14–19</sup> All these options as well as the increasing microsurgical and supermicrosurgical expertise of many surgeons have allowed to replant many digits and digital parts that would be deemed unsalvageable in the past.<sup>4,6,14–18</sup> Therefore, the traditional indications and contraindications for digital replantation mentioned in classical textbooks are being increasingly challenged in many medical centers.<sup>4,6,14–16</sup>

In this paper we have presented three patients with absolute contraindications for digital replantation according to classical criteria (*Case 1*: Multilevel amputation; *Case 3*: Avulsion of the thumb; *Case 4*: Index replantation proximal to the insertion of the flexor digitorum superficialis). Moreover, we presented a patient with a distal digital amputation (*Case 2*), whose replantation is controversial.<sup>11,12</sup> In all cases, the patients fared well functionally and aesthetically, and were pleased with the final result.

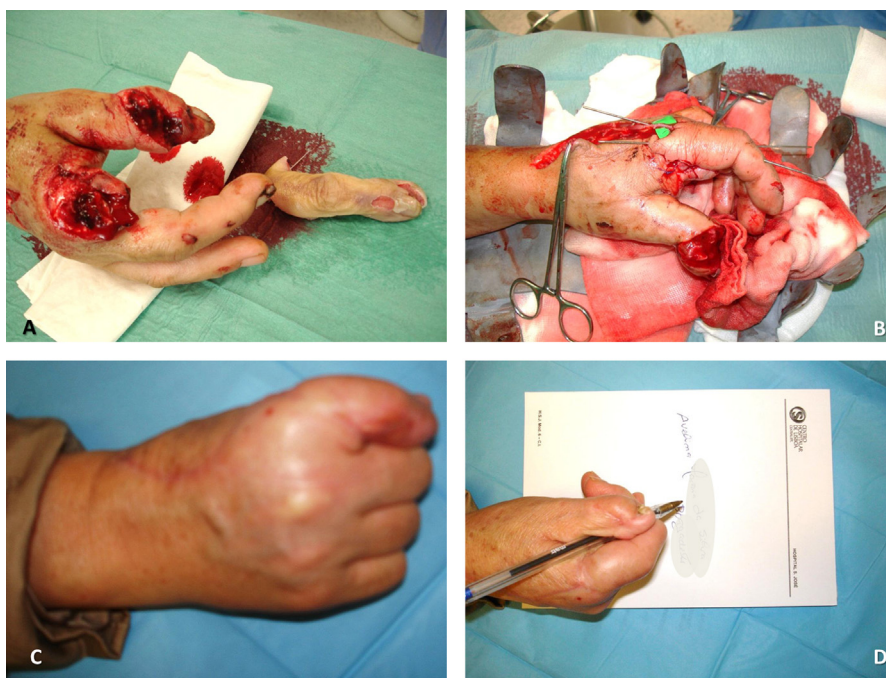
Classically, in patients with multilevel amputations in the same limb, it is recommended either to close the amputation stump or to replant only the most proximal segment.<sup>6,11,12</sup> Notwithstanding, in Asia several upper limb multilevel replantations have been described.<sup>6</sup> In 2008, Cavadas described for the first time in Europe a bi-level hand amputation, similar to the one we present in *Case*

1.<sup>6</sup> As far as we could determine, this is the second description of the kind outside Asia.

Distal digital replantation, as the one described in *Case 2*, is not routinely performed because it is a technically challenging procedure requiring supermicrosurgical skills.<sup>8</sup> Moreover, several studies suggest completion amputation at this level guarantees a similar functional outcome with a faster return to daily activities.<sup>5</sup> The risk of replantation failure with the subsequent need for a secondary revision surgery, longer surgery time, a prolonged hospital stay, longer time off from work, and higher costs further deter surgeons to perform distal digital replantation of this kind.<sup>5</sup> Finally, the loss of function caused by a missing fingertip is generally perceived to be insignificant.<sup>8</sup> However, several of these arguments have been questioned lately. For example, a recent metaanalysis showed a similar survival rate in distal digital replantation and more proximal replantation, particularly in centers in Asia where these procedures are performed routinely.<sup>8,20,21</sup> Furthermore, the one study designed to compare the results of distal finger replantation and those of revision amputation, showed that replantation provided not only the best appearance, but also a better functional outcome.<sup>9,22</sup>

Avulsion amputations, as the one depicted in *Case 3*, are usually considered contraindications for replantation.<sup>3,9</sup> In fact, in several large series a significant part of avulsed thumbs is





**Fig. 4.** Replantation of a mangled right index finger in a smoker. (A) Appearance after the accident; (B) intra-operative view of the replanted finger after reperfusion; (C) 6 months after surgery the patient could flex the interphalangeal joints as well as the metacarpal-phalangeal joint. (D) 6 months after surgery, the patient was able to use her hand in daily activities, including writing.

considered non-replantable.<sup>23,24</sup> Additionally, when replantation is attempted, significant inferior success rates are reported with avulsion injuries compared with clean-cut amputations.<sup>8,25</sup> However, several authors believe that when possible, replantation of avulsed thumbs should be tried, recurring to vein grafts if needed, since the thumb is the single most important digit and its structure and function cannot be fully replicated by any other means.<sup>11,12,26</sup>

Concerning single finger amputations, as the one presented in Case 4, there is a large consensus in the literature that in adults replantation of a single finger other than the thumb proximal to the insertion of the flexor digitorum superficialis should not be performed.<sup>1,3,5,11</sup> This is due to the almost invariably poor results observed in the long run, particularly rigidity that hampers the movement of the remaining fingers.<sup>1,3,5</sup> This is especially true in the case of index finger amputation, as the brain tends to exclude this digit and substitutes the middle finger for thumb-middle finger pinch.<sup>3,5</sup> However, several authors have reported cases similar to the one we described with good results in intelligent and well-motivated people.<sup>11</sup>

#### 4. Conclusion

The 4 clinical cases presented in this paper illustrate that the standard criteria for digital replantation should not be followed rigidly but instead should be regarded as a general guide.<sup>3</sup> In this way, patients who do not meet the standard criteria for digital replantation can still be offered the possibility of replantation, provided they are willing to accept the risks, costs and time off work, and that surgeons have reasons to believe that the end result for that particular patient will be better with replantation than with simple stump revision with or without a flap.<sup>3</sup>

#### Conflict of interest statement

The authors have no financial interest to declare in relation to the content of this article.

#### Funding

Diogo Casal (the first author of the paper) received a grant from “The Programme for Advanced Medical Education” sponsored by “Fundação Calouste Gulbenkian, Fundação Champalimaud, Ministério da Saúde and Fundação para a Ciência e Tecnologia, Portugal.”

#### Ethical approval

Written informed consent was obtained from the patients for publication of these case reports and accompanying images. Copies of the written consents are available for review by the Editor-in-Chief of this journal on request.

#### Author contributions

Diogo Casal played a major role in the treatment of the patients described, in addition to collecting and analysing the data, and writing the manuscript.

Manuel Macemino Gomez played a major role in the treatment of the patients described, in addition to collecting and analysing the data, and writing the manuscript.

Paula Antunes participated in the treatment of the patients described, as well as in the data collection and analysis, and in the writing and editing of the final manuscript.

Henrique Candeias participated in the treatment of the patients described, as well as in the data collection and analysis, and in the writing and editing of the final manuscript.

Maria Angélica Almeida played a major role in the in treatment of the patients described, as well as in the data collection, and in the editing of the final manuscript.

#### Acknowledgments

Part of this work was funded by “The Programme for Advanced Medical Education” sponsored by “Fundação Calouste Gulbenkian,

Fundação Champalimaud, Ministério da Saúde and Fundação para a Ciência e Tecnologia, Portugal.”

#### Appendix A. Supplementary data

Supplementary data associated with this article can be found, in the online version, at <http://dx.doi.org/10.1016/j.ijscr.2013.03.033>.

#### References

- Pederson WC. Replantation. *Plastic and Reconstructive Surgery* 2001;**107**(3):823–41.
- Komatsu S, Tamai S. Successful replantation of a completely cut-off thumb. *Plastic and Reconstructive Surgery* 1968;**42**:374.
- Chang J, Jones N. Twelve simple maneuvers to optimize digital replantation and revascularization. *Techniques in Hand & Upper Extremity Surgery* 2004;**8**(3):161–6.
- Dos Remedios C, Leps P, Schoofs M. Results of 46 digital replantations. With a minimal follow-up of one year. *Chirurgie de la Main* 2005;**24**(5):236–42.
- Bastidas N, Cassidy L, Hoffman L, Sharma S. A single-institution experience of hand surgery litigation in a major replantation center. *Plastic and Reconstructive Surgery* 2011;**127**(1):284–92.
- Cavadas PC. Multilevel replantation of the palm and digits. *Plastic and Reconstructive Surgery* 2008;**122**(2):95e–6e.
- Chung KC, Kowalski CP, Walters MR. Finger replantation in the United States: rates and resource use from the 1996 healthcare cost and utilization project. *Journal of Hand Surgery* 2000;**25**(6):1038–42.
- Sebastin SJ, Chung KC. A systematic review of the outcomes of replantation of distal digital amputation. *Plastic and Reconstructive Surgery* 2011;**128**(3):723–37 [Epub 2011/05/17].
- Soucaos PN. Indications and selection for digital amputation and replantation. *Journal of Hand Surgery (Edinburgh, Lothian)* 2001;**26**(6):572–81 [Epub 2002/03/09].
- Tajima T. History, current status, and aspects of hand surgery in Japan. *Clinical Orthopaedics and Related Research* 1984;(184):41–9 [Epub 1984/04/01].
- Goldner RD, Urbaniak JR. Replantation. In: Wolfe SW, Hotchkiss RN, Pederson WC, Kozin SH, editors. *Green's operative hand surgery*. 6th ed. Philadelphia: Elsevier Churchill Livingstone; 2011. p. 1585–601.
- Jones NF. Replantation in the upper extremity. In: Thorne CH, Beasley RW, Aston SJ, Bartlett SP, Gurtner GC, Spear SL, editors. *Grabb & Smith's plastic surgery*. 6th ed. USA: Lippincott Williams & Wilkins; 2007. p. 868–83.
- Allen MJ. Conservative management of finger tip injuries in adults. *The Hand* 1980;**12**(3):257–65 [Epub 1980/10/01].
- Cavadas PC. Salvage of replanted upper extremities with major soft-tissue complications. *Journal of Plastic, Reconstructive & Aesthetic Surgery* 2007;**60**(7):769–75 [Epub 2007/05/05].
- Cavadas PC. Microvascular free on-top plasty in multidigital amputations. *Journal of Plastic, Reconstructive & Aesthetic Surgery* 2007;**60**(7):720–3 [Epub 2007/05/01].
- Cavadas PC, Landin L, Thione A. Secondary ectopic transfer for replantation salvage after severe wound infection. *Microsurgery* 2011;**31**(4):288–92 [Epub 2011/05/11].
- Brooks D, Buntic RF, Taylor C. Use of the venous flap for salvage of difficult ring avulsion injuries. *Microsurgery* 2008;**28**(6):397–402 [Epub 2008/07/16].
- Yan H, Brooks D, Ladner R, Jackson WD, Gao W, Angel MF. Arterialized venous flaps: a review of the literature. *Microsurgery* 2010;**30**(6):472–8 [Epub 2010/03/20].
- Li J, Guo Z, Zhu Q, Lei W, Han Y, Li M, et al. Fingertip replantation: determinants of survival. *Plastic and Reconstructive Surgery* 2008;**122**(3):833–9.
- Morrison WA, McCombe D. Digital replantation. *Hand Clinics* 2007;**23**(1):1–12 [Epub 2007/05/05].
- Morrison WA, O'Brien BM, MacLeod AM. Evaluation of digital replantation – a review of 100 cases. *Orthopedic Clinics of North America* 1977;**8**(2):295–308 [Epub 1977/04/01].
- Hattori Y, Doi K, Ikeda K, Estrella EP. A retrospective study of functional outcomes after successful replantation versus amputation closure for single fingertip amputations. *The Journal of Hand Surgery* 2006;**31**(5):811–8.
- Gulgonen A, Bayri O, Ozkan T, Gudemez E. Replantation of thumb avulsion injuries. *Handchirurgie, Mikrochirurgie, Plastische Chirurgie* 2007;**39**(4):231–7.
- Aziz W, Noojin F, Arakaki A, Kutz JE. Avulsion injuries of the thumb: survival factors and functional results of replantation. *Orthopedics* 1998;**21**(10):1113–7.
- Dec W. A meta-analysis of success rates for digit replantation. *Techniques in Hand & Upper Extremity Surgery* 2006;**10**(3):124–9.
- Heitmann C, Levin LS. Alternatives to thumb replantation. *Plastic and Reconstructive Surgery* 2002;**110**(6):1492–503, quiz 504–5. [Epub 2002/11/01].