LIMB REPLANTATION AFTER AVULSION INJURIES: TECHNIQUES AND TACTICS FOR SUCCESS

RENATA GREGORIO PAULOS, DANIELLE TIEMI SIMÃO, RAMES MATTAR JÚNIOR, MARCELO ROSA DE REZENDE
TENG HSIANG WEI, LUCIANO RUIZ TORRES

ABSTRACT

Objectives: Retrospective evaluation of cases of limb replantation after avulsion injuries. Evaluation of the techniques and tactics used, that contributed to success and good functional results. Methods: Forty-three patients' records were assessed. All the cases had been submitted to limb replantation after avulsion injuries. Results: The majority of the cases were young men. The most common injury was to the thumbs. The surgical techniques and tactics used were: nerve grafting, vein grafting, transposition of the digital vessels, limb shortening, and heterotopic replantation. The most commonly used technique was vein graft. The limb survival rate was high (93%), as was patient satisfaction. Conclusion: Replantation after avulsion injury depends on the correct diagnosis of the limb viability and the use of appropriate surgical techniques and tactics for each case. The experience of the team of surgeons and a good hospital structure are essential for good results. There are few articles in medical literature about the indications, techniques and results of limb replantation after avulsion injuries. We believe that this retrospective evaluation can bring new information and contributions to the correct management of this highly complex situation. ***Level of evidence IV, Case Series.***

Keywords: Traumatic amputation. Replantation. Evaluation of the results of therapeutic interventions.

Citation: *Paulos RG, Simão DT, Mattar Júnior R, Rezende MR, Wei TH, Torres LR. Limb replantation after avulsion injuries: technics and tactics for success. Acta Ortop Bras. 2012;20(2):104-9. Available from URL: http://www.scielo.br/aob.*

INTRODUCTION

The indication of replantation procedures is often complex and based on several factors such as: age of patient, amputation level, trauma mechanism, comorbidities of the patient, ischemic time and others.[1-4]

The main goals to be achieved in replantation are not only the survival of the amputated limb, but also satisfactory long-term functional recovery.[5,6]

In this context, replantation after avulsion injuries constitutes a challenge for the microsurgeon.[7] In avulsion injuries the lesions of the vessels, nerves and tendons extend lengthwise beyond the level of amputation.[8,9] Vessel anastomosis is frequently not possible in the termino-terminal mode, and it is necessary to use a vein graft, artery graft or other techniques, such as blood vessel transfer.[10,11] The avulsed tendons, when allowing primary reconstruction, will usually evolve with less satisfactory function than in cases of replantation due to other injuries.[12]

Avulsion injuries entail greater difficulty, not only for replantation, but also for secondary procedures.[5] One or more additional secondary procedures (skin coverage, tenolysis, tendon transfers) are usually necessary to improve the function of the avulsed and replanted limb.[13]

In the not-so-distant past, avulsion injuries constituted an absolute contraindication to the replantation procedure. Now this reality has changed.[2]

Advances in microsurgical techniques have enabled the hand surgeon/microsurgeon to recommend and to achieve success in cases of replantation after more complex injuries.[14-16]

Knowing that replanted upper limbs present function that is superior to the prostheses available nowadays, the possibility of replantation, even in cases of severe lesions such as in avulsion injuries, should always be considered.[17]

CASUISTRY

The study consists of the retrospective evaluation of the medical records of 43 patients who presented upper or lower limb avulsion injuries and were submitted to the replantation procedure. These patients represent a small portion of the total number of replantation surgeries effectively performed, yet presented rich documentation that allowed a better evaluation of the pre-, intra- and postoperative data.

All the authors declare that there is no potential conflict of interest referring to this article.

Hand Group of the Institute of Orthopedics and Traumatology of Hospital das Clínicas of the School of Medicine of Universidade de São Paulo – São Paulo, SP, Brazil.

Study conducted at LIM 41 – Laboratory of Medical Investigation of the Musculoskeletal System of the Department of Orthopedics and Traumatology of the School of Medicine of Universidade de São Paulo.
Mailing address: Rua Dr. Ovídio Pires de Campos, 116. CEP 05403-010. Email: renata_paulos@yahoo.com.br

Article received on 8/9/10 and approved on 9/30/10.

The patients were operated at the Institute of Orthopedics and Traumatology of Hospital das Clínicas of FMUSP and at other private hospitals in the period from 1988 to July 2009, with all surgeries performed by members of the hand and microsurgery group.
The data were gathered through searches in the patients' medical records and the surgeons' personal records.
Cases that were poorly documented or that lost follow-up, were excluded from this study.

METHODOLOGY

The following data were obtained from the patients' medical records:
1. Age at the time of the injury
2. Sex
3. Affected limb (upper/lower and right/left)
4. Amputation level
5. Ischemic time until the start of replantation
6. Surgical techniques used in replantation
7. Life expectancy of replantation
8. Patient satisfaction with replantation (subjective)

RESULTS

The age of the patients ranged from three years to 56 years (average of 26 years).
Of the 43 patients analyzed most (77 % of the cases) were of the male sex.
Only one case involved lower limb avulsion (case of bilateral traumatic amputation). The other 42 cases corresponded to upper limb avulsions.
As regards the side affected in the amputations, 62.8 % of the cases involved the right limb.
As regards the level of amputation, the case of avulsion of the lower limbs corresponded to bilateral amputation at ankle level.
In the cases of avulsion of the upper limbs, one case was of amputations at arm level, one case at elbow level, six cases at forearm level, two cases at wrist level, 23 cases of thumb avulsion and 9 cases of avulsion of one or more fingers (except thumb). (Figure 1)
The ischemic time ranged from 2 hours to 13 hours (average of 6 hours).

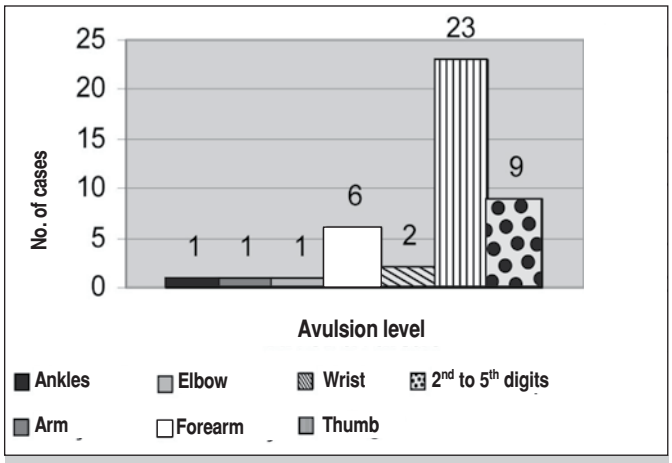

Figure 1. *Level of avulsion injury of the patients evaluated.*

As regards the surgical techniques used in replantation after avulsion, these varied in the following techniques: vein grafting, nerve grafting, limb shortening, transfer of digital vessel, microsurgical flaps and heterotopic replantation.
It is worth remembering that in most cases, the surgical techniques mentioned here were used jointly (e.g.: vein grafting + nerve grafting), since the type of injury increases the technical complexity of replantation.
Vein grafts were used with greater frequency (70.8% of the cases).
In the cases of digital replantation, a technique that can be used is the transfer of a whole digital vessel originating from a donor finger on the same hand. This technique was applied in 44.4 % of the cases of digital replantation in this study.
Nerve grafts were used in 33.3% of the cases in this study.
The replanted limb shortening technique was used in 16.6% of the cases.
In the specific cases of multiple finger amputations, another surgical technique that can be used is heterotopic replantation. This technique was used in 8.3% of the cases of digital replantation included in this study.
Primary coverage with microsurgical flaps was necessary in 8.3% of the cases. (Figure 2)

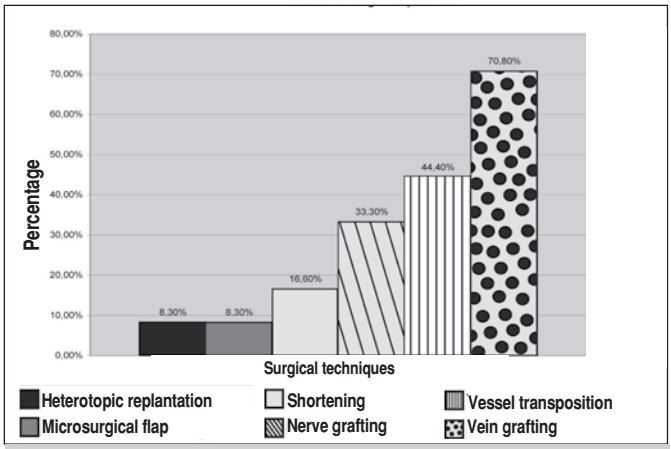

Figure 2. *Surgical techniques applied.*

Of the 43 cases, four had to be readdressed for review of the microsurgical anastomoses. Of these, one case evolved with survival of the limb and three cases with regularization after loss of replantation, which results in a survival rate of 93%.
As regards the last item of data analyzed, but not the least important, we sought to estimate patient satisfaction with the replanted limb. Not all the patients are fully satisfied in terms of function expected for the replanted limb, but all the patients declare they are more satisfied having their original limb replanted than making use of prostheses.

DISCUSSION

Since 1962, the year in which the first successful replantation was described in the world, surgical techniques in replantation and microsurgical techniques have evolved at a surprising speed.[3,5,18] Thanks to the advances of instruments, optics and specialization among microsurgeons, today we have access to a technology that allows us to acquire a wealth of details and affords the dexterity to perform microsurgeries with increasing safety and success.

In replantation cases, factors that previously represented absolute contraindications for its performance, due to microsurgical technical advances, are currently relative contraindications.[2,9,10,19] Technically speaking, replantation after avulsion injuries is more laborious,[7] but can be executed by a qualified microsurgeon, and it is possible to use various microsurgical techniques.

In the bibliographical survey carried out for the performance of this trial, we did not find many case series with such a significant casuistry as that obtained in our study. We believe that the shortage of studies referring to replantation in amputations after avulsion injuries is due to the fact that until recently avulsion injuries were considered a contraindication to the replantation procedure.[12]

In evaluating the results obtained in this study, we observed that the average age was 26 years. Most of the patients were of working age, and suffered accidents during the work period. Male predominance, the greater involvement of the upper limbs and of the dominant side (right, in the majority of the population), reinforces the idea that the population most susceptible to traumatic amputations is made up of manual workers.

The greater frequency of involvement of the male sex, between the third and fourth decades of life, was also observed in other studies.[4,8,20,21]

The level of amputation that predominated in this study, was amputation of the thumb (23 of the 43 cases). We believe that cases of thumb avulsion predominated because the thumb is known to be the most important digit for digital pinch function, and rarely has its replantation contraindicated. A large part of the studies found on replantation after avulsion injuries are about thumb replantation.[4,7,11,13-16,19,21]

The ischemic time ranged from 2 to 13 hours. Most authors accept the time of six hours as the time limit for macro-replantation.[9] The more distal the level of amputation, the smaller the quantity of soft parts affected and the longer the acceptable ischemic time.[8]

As concerns the surgical techniques applied in the cases evaluated, these varied from simple procedures such as stump shortening with performance of primary anastomoses, to more complex procedures such as vein and nerve grafting associated with primary tendon transfers.

Vein grafts allow the surgeon to offset the longitudinally extensive lesion of the vessels associated with the avulsion injury.[22] They can be applied in arterial or venous anastomoses. It is technically more laborious, since it requires the performance of two anastomoses for each vessel that receives the vein graft segment, also increasing the chances of technical complications. The most frequent donor sites are the saphenous veins, the volar superficial antebrachial veins or superficial dorsalis pedis veins.[22,23] The surgical tactic consists of performing the vein graft first in the arterial segment, allowing temporary perfusion of the limb with the flow of blood through the venous system, thus facilitating the visualization and the anastomosis of the graft in this system.[22-24]

Some of the case series encountered during the bibliographical survey already indicated the use of vein grafts as a fundamental and necessary step towards success in replantation after avulsion injuries.[25]

The transfer of digital vessels can be used in digital replantation. This calls for delicate dissection, besides the precaution of checking whether the vessel to be displaced will not impair the vascularization of the donor finger. This check can be carried out by clamping the digital vessel to be transposed, before it is transected, and verifying whether the other digital vessel of the donor finger is sufficient to maintain its vascularization.

Avulsed nerves, like vessels, present longitudinal lesions that reach beyond the skin level of the amputation.[26] They can be reconstructed in a second surgical procedure, but should ideally be carried out in the same procedure as the replantation.[27] They are usually taken from the sural nerve or from other cutaneous sensory nerves.[26]

In cases of macro- or micro-replantation, a simple surgical technique, which can be used often without major functional impairment, is limb shortening. This technique allows the longitudinal component of the lesion in the vessels and nerves to be neutralized, often allowing primary anastomosis of the vessels and the primary suturing of the nerves.[28]

In lesions of multiple fingers, we can use the heterotopic replantation technique, which consists of replanting an amputated finger on a non-corresponding stump. This technique aims to prioritize the replantation of fingers that are functionally more important, in cases of amputation of two or more fingers.[7] Moreover, it sometimes allows us to associate the shortening technique, technically facilitating the replantation procedure.

As already discussed, in avulsion injuries, especially of large segments, we often come across associated loss of skin cover. Many cases can be resolved with a simple partial skin graft, yet some more complex cases require coverage with microsurgical flaps.[29] Ideally the skin coverage should be performed in conjunction with the replantation procedure, but it is necessary to weigh the patient's clinical state and the prolonged surgical time. (Figures 3 to 12)

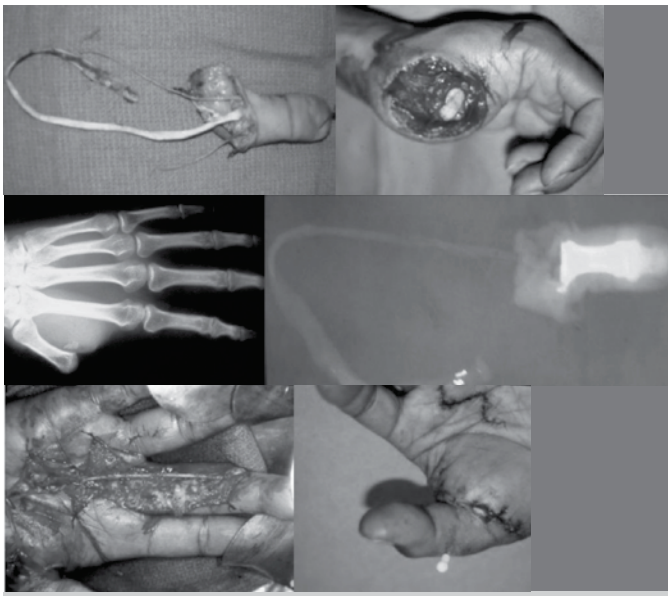

Figure 3. *Male patient, aged 32 years. Avulsion of left thumb caused by lawn mower 4 hours ago. Surgical technique: Transposition of the ulnar artery of the left 3rd digit Left thumb.*

Figure 4. *Male patient, aged 28 years. Amputation left 1st, 2nd and 3rd digits by paper cutter (guillotine + avulsion) 6 hours ago. Surgical technique: Heterotopic replantation of the 3rd digit in the left thumb*.

Figure 5. *Male patient, aged 7 years. Degloving injury left hand with avulsion of the left thumb 2 hours ago caused by industrial machine (bakery). Surgical technique: Dorsalis pedis vein graft for anastomosis between radial artery (anatomical snuffbox) and princeps pollicis artery. Dorsalis pedis vein graft for creation of arteriovenous shunt between radial digital artery of the thumb and dorsal vein of the forearm. Anterolateral microsurgical flap from the arm and skin grafting for coverage of hand degloving injury (same surgical procedure).*

Figure 6. *Male patient, aged 46 years. Avulsion of left thumb caused by motorcycle chain 5 hours ago. Surgical technique: Stump shortening with primary anastomosis of the vessels and nerves. Interphalangeal arthrodesis of the thumb.*

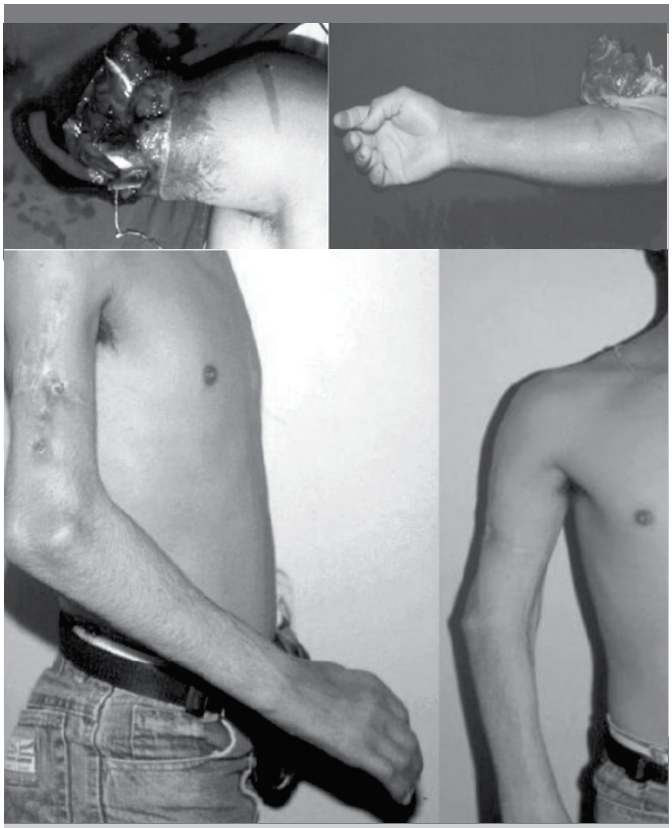

Figure 7. *Male patient, aged 33 years. Avulsion of the right arm 3 hours ago after motorcycle accident. Surgical technique: humeral shortening, vascular grafts (great saphenous vein) for artery reconstruction and brachial vein, sural nerve graft for reconstruction of the median and radial nerves (ulnar abandoned). Latissimus dorsi rotation for skin coverage and biceps function recovery.*

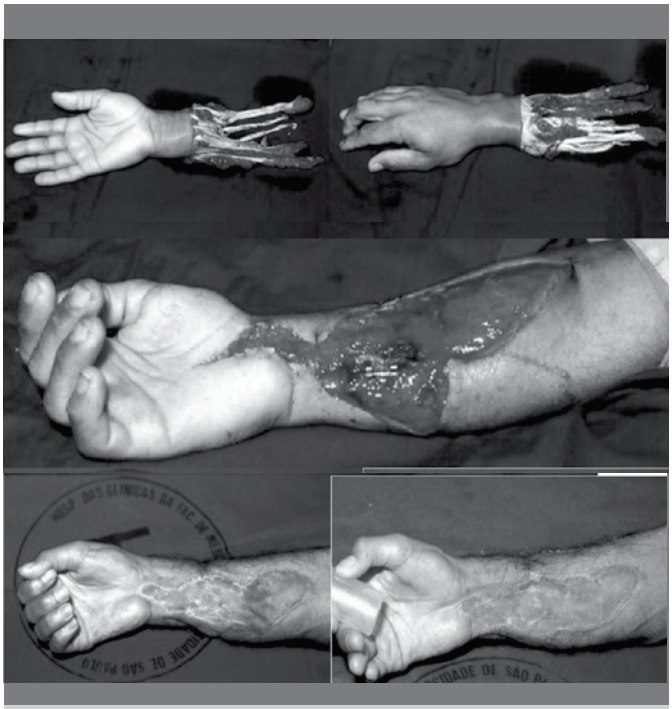

Figure 8. *Male patient, aged 24 years. Avulsion of the right forearm 5 hours ago, caused by industrial machine. Surgical technique: forearm shortening; vascular grafts (great saphenous vein) for reconstruction of radial and ulnar arteries and cephalic and basilic veins, and two others from the superficial dorsal system; sural nerve graft for reconstruction of the median and ulnar nerves. Prophylactic fasciotomy (closure with skin graft).*

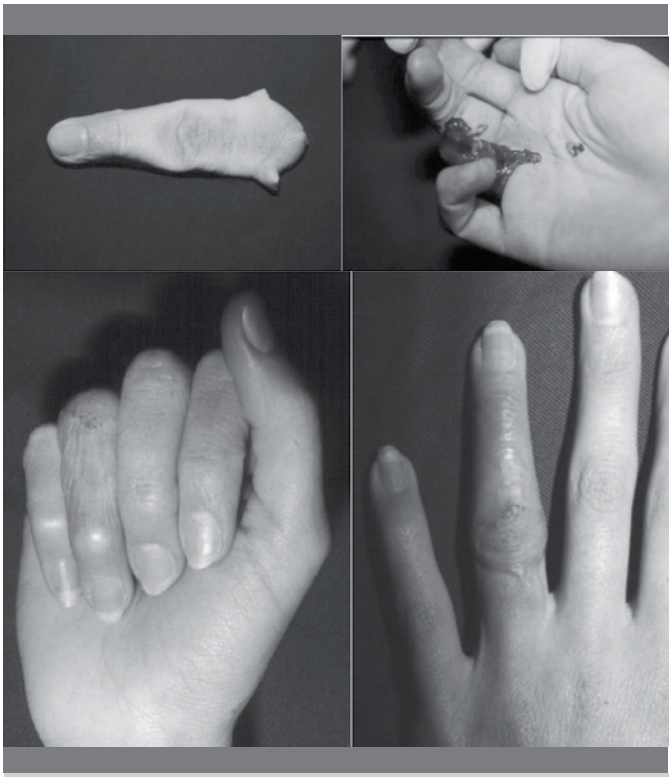

Figure 9. *Female patient, aged 29 years. Avulsion of right 4th digit by ring hours ago. Surgical technique: Vascular grafts (veins from palmar system of wrist) for arteries reconstruction and digital veins; Suture of the digital nerves.*

Figure 10. *Male patient, aged 17 years. Bilateral avulsion of the feet caused by a crane 8 hours ago. Surgical technique: bone shortening; vascular grafts (great saphenous vein of the leg not replanted) for reconstruction of the anterior and posterior tibial arteries and veins; sural nerve graft for reconstruction of the tibial nerve.*

Figure 11. *Male patient, aged 32 years. Avulsion of the right thumb caused by motor belt 4 hours ago. Surgical technique: transfer of radial digital artery of the middle finger to princeps pollicis artery of the thumb, vein grafts to dorsal veins. Radial sensory nerve graft to digital nerves. Tendon transfers: superficial flexor of the middle finger to long flexor of the thumb and own extensor of the index finger to long extensor of the thumb.*

Figure 12. *Female patient, aged 21 years. Avulsion of the left thumb 4 hours ago after a car accident. Surgical technique: vein graft for reconstruction of the princeps pollicis artery of the thumb, vein grafts to dorsal veins. Radial sensitive nerve graft to digital nerves. Tendon transfers: superficial flexor of the ring finger to long flexor of the thumb and own extensor of the index finger to long extensor of the thumb.*

As regards the replantation life expectancy, we believe that we have worked with a biased sample of cases. The cases that are usually well documented and that maintain follow-up are those that presented good results. The cases that evolved poorly, without survival of the limb, are not usually filed and do not maintain long-term follow-up.

It is still the consensus that in the case of amputation of the upper limbs, no prosthesis is able to restore the total functions of the lost limb, a fact that justifies the effort in replanting a segment of amputated upper limb.[2,17,30]

CONCLUSION

Based on our data, we concluded that replantation after avulsion injuries depends on the use of complementary surgical techniques (nerve grafting, vein grafting, transposition of vessels, heterotopic replantation, limb shortening, coverage with flaps) in order to achieve success.

If there is an adequate structure (specialized and available microsurgical team, adequate microscope, microsurgery instruments, ICU support, qualified nursing staff and therapists), and if the participants know how to recommend the most appropriate surgical technique, replantation due to unfavorable mechanisms, such as avulsion injuries, can be executed nowadays with a very good chance of survival and satisfaction of the patient.

REFERENCES

1. Gülgönen A, Bayri O, Ozkan T, Güdemez E. Replantation of thumb avulsion injuries. Handchir Mikrochir Plast Chir. 2007;39(4):231-7.
2. Molski M. Replantation of fingers and hands after avulsion and crush injuries. J Plast Reconstr Aesthet Surg. 2007;60(7):748-54.
3. Sanmartin M, Fernandes F, Lajoie AS, Gupta A. Analysis of prognostic factors in ring avulsion injuries. J Hand Surg Am. 2004;29(6):1028-37.
4. 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.
5. Ozkan O, Ozgenta HE, Safak T, Dogan O. Unique superiority of microsurgical repair technique with its functional and aesthetic outcomes in ring avulsion injuries. J Plast Reconstr Aesthet Surg. 2006;59(5):451-9.
6. Brooks D, Buntic RF, Taylor C. Use of the venous flap for salvage of difficult ring avulsion injuries. Microsurgery. 2008;28(6):397-402.
7. Chen KT, Chen YC, Mardini S, Wei FC. Salvage of an avulsion amputated thumb at the interphalangeal joint level using afferent arteriovenous shunting. Br J Plast Surg. 2005;58(6):869-72.
8. Tseng OF, Tsai YC, Wei FC, Staffenberg DA. Replantation of ring avulsion of index, long, and ring fingers. Ann Plast Surg. 1996;36(6):625-8.
9. Hidalgo DA. Lower extremity avulsion injuries. Clin Plast Surg. 1986;13(4):701-10.
10. Castagnetti C, Adani R, Squarzina PB, Caroli A. Transfer of vessels in the management of ring avulsion injury. Case report. Scand J Plast Reconstr Surg Hand Surg. 1992;26(3):331-3.
11. Filippini A, Zuccarini F, Trulli R, Aceto L, Serafini P, Rapani C et al. [Venous grafts in reimplantation of the thumb]. G Chir. 1990;11(10):545-50.
12. Vilkki SK. [Thumb replantation: results of avulsion injuries and other traumatic amputations--a comparison]. Handchir Mikrochir Plast Chir. 1982;14(3):156-60.
13. Chen HC, Tang YB. Replantation of the thumb, especially avulsion. Hand Clin. 2001;17(3):433-45.
14. Sharma S, Lin S, Panozzo A, Tepper R, Friedman D. Thumb replantation: a retrospective review of 103 cases. Ann Plast Surg. 2005;55(4):352-6.
15. Friedel R, Bach O, Nestmann H, Lemberg I, Markgraf E. [Late results following avulsion injuries of the thumb]. Handchir Mikrochir Plast Chir. 2002;34(5):314-8.
16. Chen L, Gu J. Replantation of a completely detached degloved thumb. Microsurgery. 1996;17(1):48-50.
17. The Hoang N, Hai LH, Staudenmaier R, Hoehnke C. Complete middle forearm amputations after avulsion injuries--microsurgical replantation results in Vietnamese patients. J Trauma. 2009;66(4):1167-72.
18. Yüksel F, Karacaoğlu E, Ulkür E, Güler MM. Replantation of an avulsive amputation of a foot after recovering the foot from the sea. Plast Reconstr Surg. 2000;105(4):1435-7.
19. Isenberg JS. Rodeo thumb: an unusual etiology of avulsion amputation of the thumb. Ann Plast Surg. 1996;37(2):187-90.
20. Bieber EJ, Wood MB, Cooney WP, Amadio PC. Thumb avulsion: results of replantation/revascularization. J Hand Surg Am. 1987;12(5 Pt 1):786-90.
21. Unglaub F, Demir E, Von Reim R, Van Schoonhoven J, Hahn P. Long-term functional and subjective results of thumb replantation. Microsurgery. 2006;26(8):552-6.
22. Adani R, Castagnetti C, Busa R, Caroli A. Transfer of vessels in the management of thumb and ring avulsion injuries. Ann Acad Med Singapore. 1995;24(4 Suppl):51-7.
23. Nyström A, Backman C. Replantation of the completely avulsed thumb using long arterial and venous grafts. J Hand Surg Br. 1991;16(4):389-91.
24. Vlastou C, Earle AS. Avulsion injuries of the thumb. J Hand Surg Am. 1986;11(1):51-6.
25. Stevanovic MV, Vucetic C, Bumbasirevic M, Vuckovic C. Avulsion injuries of the thumb. Plast Reconstr Surg. 1991;87:1099-104.
26. Yamano Y, Namba Y, Hino Y, Hasegawa T, Ugawa A, Ise M. Digital nerve grafts in replanted digits. Hand. 1982;14(3):255-62.
27. Krarup C, Upton J, Creager MA. Nerve regeneration and reinnervation after limb amputation and replantation: clinical and physiological findings. Muscle Nerve. 1990;13(4):291-304.
28. Burkhalter WE. Ring avulsion injuries, care of amputated parts, replants, and revascularization. Emerg Med Clin North Am. 1985;3(2):365-71.
29. Schoeller T, Wechselberger G, Hussl H, Huemer GM. Functional transposition of the latissimus dorsi muscle for biceps reconstruction after upper arm replantation. J Plast Reconstr Aesthet Surg. 2007;60(7):755-9.
30. Chuang DC, Lai JB, Cheng SL, Jain V, Lin CH, Chen HC. Traction avulsion amputation of the major upper limb: a proposed new classification, guidelines for acute management, and strategies for secondary reconstruction. Plast Reconstr Surg. 2001;108(6):1624-38.