Battiston *et al. Plast Aesthet Res* 2023;10:25
DOI: 10.20517/2347-9264.2022.130

Plastic and Aesthetic Research

Review

Open Access

Soft tissue defects of the hand: etiology and classification

Bruno Battiston[1], Camillo Fulchignoni[2]

[1]U.O.C Orthopaedics, Traumatology and Hand Surgery, U.O.D. Microsurgery, C.T.O. Hospital, Turin 10126, Italy.
[2]Orthopedics & Hand Surgery Unit, Department of Orthopedics, Fondazione Policlinico Universitario A. Gemelli, IRCCS-Catholic University of the Sacred Hearth, Rome 00168, Italy.

Correspondence to: Dr. Camillo Fulchignoni, Orthopedics & Hand Surgery Unit, Department of Orthopedics, Fondazione Policlinico Universitario A. Gemelli, IRCCS-Catholic University of the Sacred Hearth, Rome 00168, Italy. E-mail: camillo.fulchignoni@gmail.com

How to cite this article: Battiston B, Fulchignoni C. Soft tissue defects of the hand: etiology and classification. *Plast Aesthet Res* 2023;10:25. https://dx.doi.org/10.20517/2347-9264.2022.130

Received: 10 Nov 2022 **First Decision:** 25 Apr 2023 **Revised:** 14 May 2023 **Accepted:** 23 May 2023 **Published:** 29 May 2023

Academic Editor: Raymund E. Horch **Copy Editor:** Yanbing Bai **Production Editor:** Yanbing Bai

Abstract

Soft tissue defects of the hand may result from trauma, oncological procedures, or severe infections. Different etiologies have been discussed. In all cases, an accurate clinical examination is mandatory to understand which structures are involved and what must be reconstructed. It can be helpful to simplify the decision-making process to classify these lesions. However, there is no consensus on which classification is best to be used among those described in the literature. This review presents the most common ones, differentiating those classically used to describe tissue loss consequential to a traumatic event from those used to classify soft tissue defects consequent to other events.

Keywords: Soft tissue, defect, trauma, oncological, infection, tissue loss

INTRODUCTION

The goals of hand soft tissue defect reconstruction are to provide good soft tissue coverage to protect underlying structures, to achieve functional outcomes as quickly and as completely as possible, and to obtain the best possible aesthetic results[1,2]. Composite reconstructions[3,4] mainly refer to defects caused by severe trauma or by oncological or septic treatments. The high functional requirements of the hand with an

intact osteoarticular structure depend not only on the skin coverage but also on the maintained function of tendons, vessels, and nerves. The new achievements in the research of skin blood supply, biological repair, and tissue bioengineering[5,6], together with the advances in reconstructive surgery, allowed the finding of a vast armamentarium of methods to solve this kind of defect. The skin of the palmar region differs from the dorsal one in thickness and flexibility and is important for the coverage of noble structures. Additionally, the dorsal skin is characterized by high mobility with respect to the underlying tissues, allowing complete flexion and extension of the fingers[7,8]. The accurate reconstruction of the involved tissues and early mobilization are the cornerstones for restoring proper function. One of the aspects, which still sparks a lot of discussions, is the right timing for the reconstruction[9,10]: immediate or delayed, one or two stages. If a staged approach is deemed to be the best for the patient, the primary reconstruction should enhance and in no way compromise the secondary procedures.

This issue will focus on the type of defects (site, size, involved tissues), the timing of reconstruction, and the possible methods to be used, always considering the patient's profile with their general clinical conditions.

ETIOLOGY

Soft tissue defects of the hand may result from trauma or may follow surgery as it happens in oncological procedures or after debridement of severe infections. A systematic and correct anamnesis, together with the first clinical evaluation of the patient and the lesion, may help to determine the nature of problem and then the etiology. The anamnestic data are essential to understand the etiology and focus on possible factors[11] influencing the treatment and prognosis, defining possible complications and eventual final disabilities: age, sex, diabetes or other systemic diseases, vascular problems, conjoint drug assumption, smoking, and alcohol dependency. However, sometimes this might be difficult, i.e., when facing a traumatic defect in polytrauma or unconscious or non-cooperative patients. Then, laboratory and instrumental exams will follow to guide the surgeon to the right treatment plan.

Traumatic defects

The nature of the trauma responsible for the loss of substance must be taken into consideration, as well as the causing agent and the mechanism of injury, the energy of the trauma, the timing of the accident, the site, dimensions, and characteristics of the lesion, as those pieces of information can guide to plan the extent of trimming, to predict the risk of edema and its consequences and, possibly, to guide the choice of a therapeutic option. The most common types of trauma leading to loss of substance are[12]:

• *Abrasion*: abrasion lesions mainly concern the dorsal surface of the hand and fingers and may be accompanied by tendon and joint lesions. The classic "door hand" is encountered during road accidents and results from violent abrasion of the dorsal side of the hand and fingers against the road pavement. Tendon lesions and osteoarticular apparatus may be associated.

• *Avulsion*: cutaneous avulsions occur on the dorsal or palmar surface, often in continuity with the avulsion of the digital skin. These injuries are usually caused by industrial machines with driving rollers; underlying osteoarticular lesions by crushing can be observed[13].

• *Crushing*: those injuries are caused by industrial machinery such as a pneumatic press or power hammer; the articular lesions are often complex and comminuted, and it is sometimes difficult to appreciate the importance of the cutaneous trimming to carry out in urgency. In this context of crushing, one must fear the occurrence of significant postoperative edema[14,15].

• *Burn*: splashes of molten metal or lesions due to heating presses can cause deep third-degree burns, sometimes concerning both the palmar and dorsal sides of the hand. Again, the occurrence of significant postoperative edema should be feared. Several successive trimming times are often necessary, given the difficulty of urgently assessing the exact extent of the burn[16,17].

• *Gun wounds* often cause stereotypical lesions with an inconspicuous entry portal and an extremely dilapidated exit orifice. Regarding penetrating wounds, the lesions are usually mixed: vascular, tendinous, osteoarticular, and cutaneous[18].

The involved structures (skin, muscles, tendons, bone and joints, vessels, nerves) are finally the elements to be examined individually for precise evaluation and classification of the lesion. After an accurate inspection of the defect, a functional exam is mandatory to check distal vascularization through the presence of peripheral pulses, lack of function due to muscle-tendon damage or nerve lesions, looking not only for the motor but also for sensory deficits[19].

Instrumental exams should complete the clinical evaluation[20]. Even if the lesion mainly involves soft tissues, an X-ray examination may help identify underlying bone and joint problems or foreign bodies. Echography[21,22] is a rapid and non-invasive system to evaluate soft tissues, even dynamically if necessary, completed by an echo-Doppler if the vascular system needs to be assessed. Second-level exams may be MRI and angiography or angio TC when required.

The clinical exam of a severe lesion with tissue loss is often better performed in the operating room, in sterile conditions, and with good illumination. The lesion should preferably be documented even with photos. The debridement and gradual exam of the lesion, going from superficial to deep, should give data on vascular perfusion through the color of the structures, turgor, bleeding, and capillary refill. Particularly, the muscle evaluation should follow the four C's rule[23]: Color, Contractility through mechanical or electrical stimulation, Consistence, and bleeding Capacity. Tendon and nerve continuity is finally assessed.

Defects from surgical procedures

The technical issue of reconstructing a tissue loss from the surgical excision of a tumor or severely infected tissues may be similar. In both situations, the surgeon performing the excision of the involved tissues should do it widely to avoid recurrences of the pathology, eventually leaving tissue loss but with healthy margins. As for the traumatic defects, the treatment plan should consider the site, dimensions, and characteristics of the defect together with the involved structures.

Tumors

The current multimodal approaches, combining wide surgical resection with radiotherapy and/or chemotherapy, allow limb preservation in 90%-95% of patients[24,25]. The excision plan is generally performed after the pre-operative clinical and instrumental data acquisition, allowing the reconstructive surgeon to program the best anatomical and functional repair option. Ultrasound and MRI are helpful diagnostic tools[26,27]. Surgical margins are the essential factor associated with local tumor control[28-30], but obtaining good oncological margins can result in extensive or critical loss of bone and soft-tissue components[31-33] which could then need an appropriate plan of reconstruction which is generally to be performed after the tumor resection in the same surgical act.

Malignant tumors of the hand needing extended resections with a risk of soft tissue defects are uncommon, though it is important to know them[34]. Among the bone tumors of the hand are described high-grade

chondrosarcoma, osteogenic sarcoma, and Ewing sarcoma. Among the soft-tissue sarcomas, the common subtypes are epithelioid sarcoma, synovial sarcoma, myxofibrosarcoma, rhabdomyosarcoma, and liposarcoma.

Infections

Infections are always more frequent in hand surgery. Early identification and antibiotic treatment are usually sufficient to achieve optimal outcomes and avoid tissue losses. However, it is not uncommon to miss or delay diagnosis, eventually leading to the necessity for extensive trimming, amputation, or death[35,36]. Conditions necessitating urgent attention are:

• *Necrotizing fasciitis*: fascia and subcutaneous tissue are involved, typically in immunocompromised patients. Extremities are usually affected in type 2 due to group A Streptococcus and/or Staphylococcus infections. Extensive debridement to healthy tissue is necessary and has to be repeated every 24-48 h to reduce the risk of amputation. Nevertheless, mortality rates will not be reduced, ranging from 23% to 76%[36].

• *Pyogenic flexor tenosynovitis*: bacterial infection of the tendon sheath can lead to the "necrotic stage" (stage 3), necessitating tendon and adjacent soft tissue excision.

• *Deep hand space infections* are less frequent and usually result from the spread of flexor tenosynovitis or a penetrating injury. Thenar and hypothenar abscesses might need both volar and dorsal approach, whereas midpalmar abscesses should be approached with a midpalmar transverse incision.

• *Septic arthritis*: infections of the joints of the hand, if not recognized, can lead to osteomyelitis. Although osteomyelitis is rare in hand, it has to be recognized as it can lead to amputations (especially when distal bones are involved) or massive excisions of bone and surrounding tissues needing reconstruction.

Beyond clinical diagnosis and laboratory tests, radiological exams such as echography, CT, and MRI are mandatory to evaluate the extent of the infection.

CLASSIFICATIONS

After accurate clinical and radiological examinations, such as those described above, the surgeon can understand and classify the lesion. However, we suggest classifying it after the appropriate excision of the compromised tissues, which may change the picture of the final lacking and remaining tissues. There is no consensus on which classification is best among those described in the literature. We present the most common classifications, differentiating those classically used to describe tissue loss consequential to a traumatic event from those used to classify soft tissue defects consequent to other events.

Traumatic defects

Several systems are present in literature with the object of classifying lesions secondary to trauma: Gustilo-Anderson[37] and Tsherne and Hannover scale[38] evaluate both soft tissues and bone lesions (open fractures). As for systems conceived mainly for soft tissues, the AO soft tissues classification[39] and the TIC-TAC-TOE system[40] are the most known and used.

The Gustilo-Anderson classification[37], first proposed for lower limbs open fractures, describes the exposition size and whether intervention from a plastic or a vascular surgeon is necessary. However, it does not help to discriminate which type of reconstruction will be needed.

The Hannover Fracture Scale (HFS)[38] was initially conceived as an extension of the Tscherne classification, which was not only the first to describe open fractures but also included the damage of the soft tissues in apparently closed fractures. The HFS has been widely used to provide information on bone and soft tissue lesions but also their contamination and possible timing of treatment. Its main disadvantage is its long and laborious compilation, eventually leading to some difficulties when used in an emergency. As it also requires the systematic use of culture swabs before and after the initial debridement, several Centers report difficulties in the data compilation. Finally, it seems more suitable for research than for deciding on limb salvage in an emergency.

AO developed an anatomical classification system describing soft tissue lesions[39], including skin, muscles, tendons, vessels, and nerves [Table 1]. At the same time, fractures may be evaluated using the well-known and used Müller AO/OTA classification. The integrity of the cutaneous layer is one of the main elements to be considered. Lesions are then divided into closed (IC) or open (IO) with a severity degree ranging from 1 (minimal damage) to 5 (wide and severe loss of tissue). The muscle-tendinous (MT) evaluation is difficult to be used in clinical practice, especially in closed lesions. The problem arises, for example, when the functional deficit caused by compartment syndrome is attributed to muscle damage or a neurological problem. The most reliable and reproducible aspect of this system is the evaluation of nerves and vessels (NV). Carefully evaluating the nerve function is fundamental to correctly classifying the wound.

In 1997, Weinzweig and Weinzweig [40] described their "Tic-Tac-Toe" classification system, initially thought for mutilating hand injuries. The name comes from the anatomical part of the classification in which the different bones of the hand are divided into nine squares similar to those of the famous homonymous game [Table 2]. Along with the anatomical location of the lesion, this classification specifies the type of injury (dorsal mutilation, palmar mutilation, ulnar mutilation, radial mutilation, transverse amputation, degloving injury, and combination injury), the subtype (soft-tissue loss, bony loss, and combined tissue loss) and the vascular integrity (intact or devascularization). This system is accurate and easy to reproduce to classify traumatic lesions, especially when the surgeon faces complex injuries such as mutilated hands.

Non-traumatic defects

Due to the wide range of possible tissues involved, no specific classification of the tissue loss resulting from surgical procedures for oncologic or infectious diseases exists.

However, the reconstructive plan will depend on the need to restore only skin coverage or also to reconstruct muscle masses, vessels, and nerves. The element which may classify the problem guiding the following reconstruction is the need for marginal or compartmental excision. In case of surgical removal of one or more tissues involved by the tumor or the infection, the technique will aim to repair the single damaged tissues. On the contrary, a compartmental resection will generally require a composite reconstruction including all the tissues of that compartment preserving distal survival (vessels reconstruction) and restituting the limb function (muscles, tendons, nerves repair).

In deciding which kind of treatment for what type of defect in the hand, we believe that Ono's classification is very useful[41]. It is a general soft tissue defect of the hand classification that does not consider the etiology of the tissue loss. This classification takes into account whether the defect is palmar or dorsal, the location, and the size of the defect. The skin on the palmar side is hairless, immobile, and thick, whereas the skin on the ulnar side is thinner, supple, and mobile. The location follows the functional aesthetic units described by Rehim *et al.* and divides the hand into a distal finger (middle and distal phalanx)/thumb (distal phalanx) unit, a proximal finger /thumb unit (from the proximal interphalangeal joint to the metacarpal-phalangeal

Table 1. AO Soft tissue classification

Closed skin lesions (IC)	
IC 1	No evident skin lesion
IC 2	No skin laceration, but contusion
IC 3	Circumscribed degloving
IC 4	Extensive, closed degloving
IC 5	Necrosis from contusion
Open skin lesions (IO)	
IO 1	Skin breakage from inside out
IO 2	Skin breakage from outside in < 5 cm, contused edges
IO 3	Skin breakage from the outside in > 5 cm, increased contusion, devitalized edges
IO 4	Considerable, full-thickness contusion, abrasion, extensive open degloving, skin loss
IO 5	Extensive degloving
Muscle and tendon lesions (MT)	
MT 1	No muscle injury
MT 2	Circumscribed muscle injury, one compartment only
MT 3	Considerable muscle injury, two compartments
MT 4	Muscle defect, tendon laceration, extensive muscle contusion
MT 5	Compartment syndrome/crush syndrome with wide injury zone
Nerve and vessel lesions (NV)	
NV 1	No neurovascular injury
NV 2	Isolated nerve injury
NV 3	Localized vascular injury
NV 4	Extensive segmental vascular injury
NV 5	Combined neurovascular injury, including subtotal or even total amputation

Table 2. "Tic-Tac-Toe" classification of anatomical zones[40]

ZONE 1 Proximal and distal phalanx of the thumb	**ZONE 2** Proximal, middle, and distal phalanx of the index and middle finger	**ZONE 3** Proximal, middle, and distal phalanx of the ring and little finger
ZONE 4 First metacarpal bone	**ZONE 5** Second and third metacarpals bones	**ZONE 6** Fourth and fifth metacarpals bones
ZONE 7 Trapezium, trapezoid and scaphoid	**ZONE 8** Capitate and lunate	**ZONE 9** Hamate, triquetrum and pisiform

joint), and a hand unit (from the metacarpophalangeal joint to the wrist)[2]. Finally, the size is assessed in relation to anatomic features rather than in centimeters: the defect is considered small if it affects only one surface (dorsal, palmar, or lateral), medium if two surfaces are involved (two adjacent surfaces of the same phalanx, or one surface of two adjacent phalanges at the fingers; two adjacent surfaces of a single metacarpal or two adjacent metacarpals at hand), and large for any bigger or noncontiguous defects.

Similar to Ono's classification is Das De's[42], which analyzes the surface (dorsal and palmar) and the size (number of "units" involved), like the previous one, but differs in location description: it classifies soft tissue defects in radial, central and ulnar in order to indicate which local flap (when sufficient) is anatomically

more appropriate.

CONCLUSIONS

No classification has been proven comprehensive or superior in describing soft tissue defects of the hand. We believe that a good classification is the one used after all necrotic, oncological, and infectious tissue has been correctly removed, and is familiar to all surgeons and radiologists within the same center to facilitate communication and improve patient care.

DECLARATIONS

Author's contributions

Participated equally in this manuscript's conception, design, drafting, writing, and revision: Battiston B, Fulchignoni C

Availability of data and materials

Not applicable.

Financial support and sponsorship

None.

Conflicts of interest

All authors declared that there are no conflicts of interest.

Ethical approval and consent to participate

Not applicable.

Consent for publication

Not applicable.

REFERENCES

1. Zhao F. Flap repair technique for soft tissue defects of the hand. *Ann Plast Surg* 2021;86:S319-21. DOI PubMed
2. Rehim SA, Kowalski E, Chung KC. Enhancing aesthetic outcomes of soft-tissue coverage of the hand. *Plast Reconstr Surg* 2015;135:413e-28e. DOI PubMed PMC
3. Battiston B, Ciclamini D, Tang JB. Compound or specially designed flaps in the lower extremities. *Clin Plast Surg* 2020;47:535-46. DOI PubMed
4. Saint-Cyr M, Gupta A. Indications and selection of free flaps for soft tissue coverage of the upper extremity. *Hand Clin* 2007;23:37-48. DOI PubMed
5. Fulchignoni C, Rocchi L, Cauteruccio M, Merendi G. Matriderm dermal substitute in the treatment of post traumatic hand's fingertip tissue loss. *J Cosmet Dermatol* 2022;21:750-7. DOI PubMed
6. Choughri H, Weigert R, Heron A, et al. Indications and functional outcome of the use of integra(®) dermal regeneration template for the management of traumatic soft tissue defects on dorsal hand, fingers and thumb. *Arch Orthop Trauma Surg* 2020;140:2115-27. DOI PubMed
7. Massengill JB. Treatment of skin loss in the hand. *Orthop Rev* 1987;16:386-93. PubMed
8. Jemec GB, Selvaag E, Agren M, Wulf HC. Measurement of the mechanical properties of skin with ballistometer and suction cup. *Skin Res Technol* 2001;7:122-6. DOI PubMed
9. Giessler GA, Erdmann D, Germann G. Soft tissue coverage in devastating hand injuries. *Hand Clin* 2003;19:63-71, vi. DOI PubMed
10. Chim H, Ng ZY, Carlsen BT, Mohan AT, Saint-Cyr M. Soft tissue coverage of the upper extremity: an overview. *Hand Clin* 2014;30:459-73. DOI PubMed
11. Aziz KT, Nayar SK, LaPorte DM, Ingari JV, Giladi AM. Impact of Missing data on identifying risk factors for postoperative

complications in hand surgery. *Hand* 2022;17:1257-63. DOI PubMed PMC
12. Dautel G. Pertes de substance digitale et de la main. In: Merle M, Dautel G. La Main Traumatique- l'urgence. 3rd ed. Issy-les.Moulineaux: Elsevier Masson; 2010; 115-227.
13. Struckmann VF, Gaus S, Schilling T, et al. Digital avulsion injuries: epidemiology and factors influencing finger preservation. *Arch Orthop Trauma Surg* 2020;140:1575-83. DOI PubMed
14. Pai CH, Wei DC, Hu ST. Carpal bone dislocations: an analysis of twenty cases with relative emphasis on the role of crushing mechanisms. J Trauma. 1993;35(1):28-35. DOI PubMed
15. De S, Tai LS, Pho RW. Emergency repair and reconstruction in the severely crushed hand. *World J Surg* 1991;15:470-6. DOI PubMed
16. Nolan MM, Reppucci ML, Urban A, et al. A single institution's recent experience with pediatric hand burns. *J Burn Care Res* ;2022:irac174. DOI PubMed
17. Mc Kittrick A, Gustafsson L, Hodson T, Di Tommaso A. Exploration of individuals perspectives of recovery following severe hand burn injuries. *Burns* 2023;49:467-75. DOI PubMed
18. Tarkunde YR, Clohisy CJ, Calfee RP, Halverson SJ, Wall LB. Firearm injuries to the wrist and hand in children and adults: an epidemiologic study. *Hand* 2021:15589447211058815. DOI
19. Ciclamini D, Panero B, Titolo P, Tos P, Battiston B. Particularities of hand and wrist complex injuries in polytrauma management. *Injury* 2014;45:448-51. DOI PubMed
20. Sudoł-Szopińska I, Shahabpour M. Update on hand and wrist imaging. *Semin Musculoskelet Radiol* 2021;25:189-90. DOI PubMed
21. O'Malley P, Tayal VS. Use of emergency musculoskeletal sonography in diagnosis of an open fracture of the hand. *J Ultrasound Med* 2007;26:679-82. DOI PubMed
22. Nwawka OK, Desai R, Ko LM, et al. Sonographic assessment of hand injuries: diagnostic accuracy and review of pathology. *HSS J* 2023;19:22-31. DOI PubMed PMC
23. Bowyer G. Débridement of extremity war wounds. *J Am Acad Orthop Surg* 2006;14:S52-6. DOI PubMed
24. Nakayama R, Mori T, Okita Y, Shiraishi Y, Endo M. A multidisciplinary approach to soft-tissue sarcoma of the extremities. *Expert Rev Anticancer Ther* 2020;20:893-900. DOI PubMed
25. Dadras M, Steinau HU, Goertz O, et al. Limb preserving surgery for soft-tissue sarcoma in the hand: a retrospective study of 51 cases. *J Hand Surg Eur Vol* 2020;45:629-35. DOI
26. Stacy GS, Bonham J, Chang A, Thomas S. Soft-tissue tumors of the hand-imaging features. *Can Assoc Radiol J* 2020;71:161-73. DOI PubMed
27. Horcajadas AB, Lafuente JL, de la Cruz Burgos R, et al. Ultrasound and MR findings in tumor and tumor-like lesions of the fingers. *Eur Radiol* 2003;13:672-85. DOI
28. Bourcier K, Le Cesne A, Tselikas L, et al. Basic knowledge in soft tissue sarcoma. *Cardiovasc Intervent Radiol* 2019;42:1255-61. DOI
29. de Juan Ferré A, Álvarez Álvarez R, Casado Herráez A, et al. SEOM clinical guideline of management of soft-tissue sarcoma (2020). *Clin Transl Oncol* 2021;23:922-30. DOI PubMed PMC
30. Roland CL. Soft tissue tumors of the extremity. *Surg Clin North Am* ;100:669-680. DOI PubMed
31. Ring A, Kirchhoff P, Goertz O, et al. Reconstruction of soft-tissue defects at the foot and ankle after oncological resection. *Front Surg* 2016;3:15. DOI PubMed PMC
32. Penna V, Iblher N, Momeni A, Stark GB, Bannasch H. Free tissue transfer in reconstruction following soft tissue sarcoma resection. *Microsurgery* 2011;31:434-40. DOI PubMed
33. Monticelli A, Ciclamini D, Boffano M, et al. Lower limb core scale: a new application to evaluate and compare the outcomes of bone and soft-tissue tumours resection and reconstruction. *Biomed Res Int* 2014;2014:652141. DOI PubMed PMC
34. Chapman T, Athanasian E. Malignant tumors of the hand. *J Am Acad Orthop Surg* 2020;28:953-62. DOI PubMed
35. Koshy JC, Bell B. Hand infections. *J Hand Surg Am* 2019;44:46-54. DOI PubMed
36. Osterman M, Draeger R, Stern P. Acute hand infections. *J Hand Surg Am* 2014;39:1628-35; quiz 1635. DOI PubMed
37. Gustilo RB, Anderson JT. Prevention of infection in the treatment of one thousand and twenty-five open fractures of long bones: retrospective and prospective analyses. *J Bone Joint Surg Am* 1976;58:453-8. PMID: 773941. DOI PubMed
38. Tscherne H, Oestern HJ. Die Klassifizierung des Weichteilschadens bei offenen und geschlossenen Frakturen. Unfallheilkunde. 1982;85(3):111-5. (In German)
39. Südkamp. NP (2000) Soft-tissue injury: pathophysiology and its influence on fracture management. AO principles of fracture management. Ed. By Rüedi TP et al, USA: Thieme. pp.87-115.
40. Weinzweig J, Weinzweig N. The "Tic-Tac-Toe" classification system for mutilating injuries of the hand. *Plast Reconstr Surg* 1997;100:1200-11. DOI PubMed
41. Ono S, Sebastin SJ, Ohi H, Chung KC. Microsurgical flaps in repair and reconstruction of the hand. *Hand Clin* 2017;33:425-41. DOI PubMed
42. Das De S, Sebastin SJ. Considerations in flap selection for soft tissue defects of the hand. *Clin Plast Surg* 2019;46:393-406. DOI PubMed