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Evaluation of the results of salvage surgical treatment of distal phalanx injuries and substantiation of the algorithm of finger salvage treatment

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Abstract

Introduction The rates of hand injuries in the structure of total of injuries range from 30 to 50 % in recent decades. The improvement of approaches to the choice of optimal options for treatment of injuries of the distal phalanges of fingers that ensure the preservation of anatomical integrity and function of fingers remains relevant.

The purpose of the work was a comparative analysis of the clinical efficacy of various methods for surgical treatment of trauma to the distal phalanx of fingers.

Methods Forty-seven patients (18 men and 29 women, mean age 34.2 ± 13.3 years) with injuries to the distal phalanges of the fingers were examined and treated. The patients were divided into 2 groups. Group 1 (comparison) was 25 patients. Conventional approaches to the formation of finger stumps were used by shortening the bone part of the phalanx, forming two opposite flaps and applying several interrupted sutures; group 2 (main group) were 22 patients treated according to the surgical tactics developed by us. The proposed tactics of reconstructive plasty of the defects in the nail phalanges of three joint fingers involves the formation of a stump of the nail phalanx with a visual effect of elongation of the phalanx due to local or cross-plasty with dermo-fascial flaps. Comparison of treatment results in the groups of patients was performed 1, 3, 6, 12 months after reconstruction operations.

Results It was established that the use of the developed surgical treatment of the injury to the distal phalanx of the fingers results in less severity (compared to the use of standard methods) of pain on days 10-21 after surgery (by 44.8-54.3 %), lower levels of the Quick DASH indicators after 3-12 months, decrease in Vancouver scoring of skin scar severity changes after 6-12 months, higher patient satisfaction with the functional result of treatment. Based on the results obtained, a diagnostic and treatment algorithm for providing medical care to hand injuries has been proposed.

Discussion The results of the study indicate the effectiveness of the developed method of plastic surgery of fingertip defects of nail phalanges in the three joint fingers by moving the palmar-lateral and dorsal-lateral blood-supplied flaps from the fingers of the same name and neighboring fingers without shortening the bone stumps of the nail phalanges while achieving an esthetic result by visual lengthening of the fingertip phalanx. Based on the results obtained, a diagnostic and treatment algorithm for providing medical care to patients with finger injuries has been proposed.

Conclusion The proven method improves the results of reconstructive surgical interventions in the treatment of fingertip defects the of tnail phalanx in three joint fingers.

Keywords: finger injury, nail phalanx, end defect, skin flap plastic surgery, pain syndrome, skin scar

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INTRODUCTION

The recent incidence of hand injuries in the total trauma ranges from 30 to 50 % [1-4]. Moreover, the rates of disability after hand injuries remain high [2, 5-7]. One of severe injuries is traumatic hand segment detachment and hand amputation in which the disability rates range 54-67 % [6, 8, 9].

A number of complications may develop after distal finger phalanx amputation, including long-term wound healing, hypersensitivity, sensation of pain, intolerance of cold, scar retraction, flexion contracture, chronic ulcers, infection and other disturbances [10-14]. The necessity of complex treatment that includes recovery of the desmo-myo-arthrogenic component is substantiated firstly by the importance of adequate repair of the dermogenic component since the normal function of the hand is possible only if skin is integral, especially its palmar (support) surface [3, 9, 15, 16]. However, the principles of choosing the tactics and methods of skin plasty surgery for distal finger phalanx injuries have been studies insufficiently while the data of the available literature have not been systematized and the general principles of management of such patients have not been well developed.

At present, a number of authors opine that the formation of the stump (including the one with some residual shortening) that is able to preserve some types of grasping and to optimize the terms of rehabilitation is the method of choice in traumatic destruction and amputation of finger phalanges [17-22].

Therefore, the improvement of approaches to the choice of optimal methods of skin plasty in patients with deep burns, extensive laceration wounds with bone exposure and post-burn deformities of the hand that would preserve anatomical integrity and functions of fingers has clinical relevance.

The **purpose** of the work was a comparative analysis of the clinical efficacy of various methods for surgical treatment of trauma to the distal phalanx of fingers.

MATERIALS AND METHODS

Forty-seven injured patients were examined and treated (18 males and 29 females) in the mean age 36.3 ± 14.2 year (range, 22 to 52 years) who were admitted to the clinic of thermal injuries of the Kirov Military Medical Academy with injuries of nail phalanges of fingers.

The patients were enrolled into two groups.

– Group 1 (comparison group) included 25 patients who were treated for trauma or thermal injury with standard methods of finger stump formation by shortening of the bony part of the phalanx, creation of the opposite flaps and applying several interrupted sutures.

– Group 2 (research) included 22 patients who were treated with the proposed surgical tactics comprising reconstruction plasty of soft-tissue structures of the nail phalanx that did not involve its bony component shortening.

Patients' groups matched in age and in morphological features of the distal injuries in three joint fingers.

Inclusion criteria were:

– вage from 18 to 50 years;

– post-traumatic fingertip defects of three joint fingers in acute, subacute and long-term periods after injuries.

Exclusion criteria were:

– decompensated somatic pathology;

– infection in the involved area;

– type 2 diabetes mellitus in sub- and decompenstion stage.

Patients with soft-tissue defect area less than 10 mm² were not included in the study as the wounds of such size may be covered through wound edge epithalization to restore the integrity of skin integuments.

Distribution of patients according to traumatic disease duration is given in Table 1. Twenty patients were injured several hours before admission and the rest 27 were injured: 9 patients not more than 24 hours prior to admission (19.1 %), 15 subjects up to 7 days (31.9 %), three individuals had trauma within 7 days to 1.5 months (6.4 %). There were significant differences in terms of fingertip trauma duration.

Table 1

Distribution of patients according to traumatic disease duration at admission

Injury term prior to admission for surgical treatment	Group 1 (comparison), *n* = 25		Group 2 (main research), *n* = 22	
	Abs. *n*	%	Abs. *n*	%
First hours post-injury	12	48.0	8	36.4
Up to 24 hours	5	20.0	4	18.2
From 1 to 7 days	7	28.0	8	36.4
From 7 days to 1.5 months	1	4.0	2	9.0

The clinical picture in the patients included in the study was determined by the factors of injury, thermal or mechanical. Burns as a trauma factor for finger partial soft-tissue loss was a factor in 11 cases (23.4 %), including 6 (27.3 %) in the research group and 5 (20.0 %) in the comparison group (Table 2).

Таблица 2

Распределение пациентов по повреждающим факторам травмы

Trauma factor	Group 1 (comparison), *n* = 25		Group 2 (main research), *n* = 22	
	Abs. *n*	%	Abs. *n*	%
Burns	5	20.0	6	27.3
Laceration	15	60.0	13	59.1
Crush wounds	5	20.0	3	13.6

Laceration and cut wounds were most frequent, in 28 patients (60.0 %), including 13 (59.1 %) in the main group and 15 cases (59.1 %) in the comparison group. Eight patients (17.0 %) referred with crush fractures of nail phalanges and soft-tissue crushing of varying severity including three cases (13.6 %) in the main research and five (20.0 %) in the comparison groups.

All patients underwent a radiographic study of the injured area.

High variability in the shape and size of injuries made planning of standard surgical interventions difficult. However, the approach proposed by us to surgical treatment of such patients was based on the principle of preservation of the nail phalanx bony part.

One more factor that affected the clinical stage of the study was varied vectors of phalanx detachment, and first of all, with matrix and nail plate base loss. There were three such patients in the whole sample (6.4 %); soft-tissue crushing was diagnosed in two cases of the main group (9.1 %) and in three patients of the comparison group (11.1 %). An oblique line of phalanx evulsion with preservation of a nail part (1-2 mm) and of nail matrix was seen in 9 cases of the main research group (40.9 %) and in 12 cases (54.5 %) of the comparison group.

Figure 1 shows an almost circular defect of the 5th finger and a preserved part of the nail phalanx and preserved nail plate. The fourth digit is intact.

The main objective in the use of the reconstruction plasty variant proposed for fingertip defects in the three-joint fingers that was proven by the treatment of the research group was a plasty of the nail phalanx defect with a visual effect of its lengthening. It is provided by local and cross plasty with faciocutaneous flaps. Tailoring of such flaps is defined by defect shape and sizes.

Fig. 1 Appearance of fingers 4 and 5 before surgery

The principle difference of such approach from the standard technique for finger stump formation is rejection to shorten the bony part of the nail phalanx, use of fasciocutaneous flap capable not only to cover the defect but also to visually lengthen the nail phalanx by a special tailoring of the flap shape.

The intervention was performed under combined anesthesia (conduction one with sedative support); skin, subcutaneous fat and superficial fascia were cut in the shape of rectangle, rhomb or racket-shaped. The complex of tissues in all three shapes was formed in such a way that enabled to include the transverse branch of the proper lateral palmar digital artery.

The blood-supplied fasciocutaneous flap formed was harvested with holders, turned towards the defect so that a small excess of tissues was available on the peripheral part of the transferred tissue complex to shape the fingertip. First two fixing stitches were done in the area of the nail matrix on its edges, the rest ones were

The plastic material was the skin of the elbow fold or of the axilla area in females and forearm skin in males. Such an approach hides the skin scar defect. The flap was harvested with electrical dermatom, the set thickness of the flap was 0.2-0.3 mm (thin flap). The donor site defect was sutured in a line and separation to 5-8 mm from the wound edges.

The size of the tissue complex depended on the defect size but did not exceed (36 ± 5) × (16 ± 3) mm for lateral flaps and (32 ± 3) × (15 ± 2) mm for rectangular and rhomb flaps.

Figure 2 shows the appearance after flap transfer from the 4th finger on the nail phalanx of the 5th digit. The donor site defect has not been closed yet.

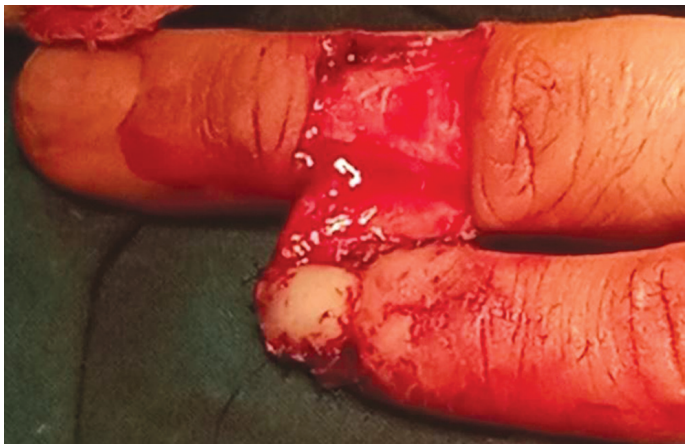

Fig. 2 The donor site defect before closure

The transferred tissue complex was fixed with independent interrupted sutures leaving long ends of stitches. Next, two layers of gauze napkins were applied. Several (5-7) premade small gauze balls were placed inside. The edges of the napkin were folded so as to form a compression dressing. It was fixed by pair-wise binding separate long stitches. The bandage tightly held the tissue complex and prevented it shift during 7-9 days, and then was removed.

Figure 3 shows stages of donor site defect closure with a split cutaneous flap (0.4 mm thick) harvested from the ipsilateral forearm. The integument tissues of the nail phalanx of the 5th finger were repaired. The support surface has a fasciocutaneos flap on the dorsal side of the 4th finger that is stable to loads.

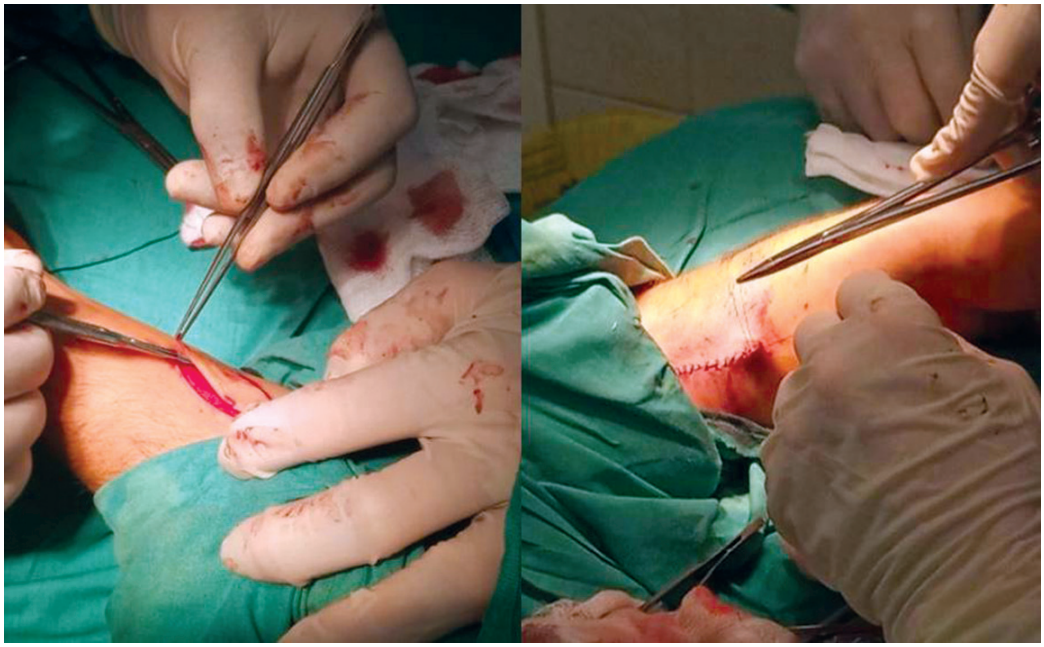

Fig. 3 Appearance of the donor site defect after surgery

An oblique U-shaped cut on the dorsal surface of the neighbor finger at the level of the middle phalanx was formed in such a way that it provided defect coverage and soft-tissue stock by turning the flap to the side of the recipient finger.

The recipient bed was prepared with a second cut; the edges of the fasciocutaneous defect were refreshed and if required 1-2 mm of the nail phalanx stump was resected. The rest of the nail phalanx was not resected.

Once stable blood flow in the fasciocutaneous flap had restored, its shaping continued until reasonable fingertip shape. If there were at least 1-2 mm of the nail plate, the distal part of the fasciocutaneous flap was stitched to it with 2-3 sutures of 4/0 thread.

The final stage of surgical intervention included applying anticeptic napkins, separation of adjoining fingers with cotton or gauze discs followed by plaster bandage for 18 to 21 days for fixation of the donor and recipient fingers for exclusion of occasional displacement. Once this term ended, the flap was cut to have final modeling which should be oriented by the shape of the nail phalanx of the neighboring finger (Fig. 4).

Fig. 4 Appearance of fingers 4 and 5 after the operation

Postoperative care of the patients followed general standards that foresee prophylactic administration of antibiotics and anticoagulants in the therapeutical doses for prevention of complications.

Medication therapy was performed to relieve pain; analgetics and vitamins were prescribed; local cooling bandages were used; the limb position was elevated to reduce swelling.

The specificity of the management was immobilization of the involved fingers and of the entire hand for a relatively long period (for 4-5 weeks). Immobilization was produced with a plaster cast or bandaging with currently used fixation materials (turbocast, cellacast, etc). The measures were directed to prophylaxis of blood flow disturbances in the transferred tissue complexes, creation of favourable conditions for qualitative survival of tissues on the wounded surface of the stump tip.

Once the wound healed, exercises to recover the range of motion were initiated, gradually increasing loading from finger flexion to holding 2-3 kg loads for three weeks. Long immobilization resulted in combined contractures of interphalangeal and metacarpal phalangeal joints but implemented the possibility of healing and remodeling of the tissue flaps without rough scars. The patients regularly trained to recover the range of motion in the finger joints that started straight upon completion of immobilization, continued with gradual increase in flexion range for one to two months.

As far as the patients of the study had different types of injuries, the treatment approaches also varied. In particular, one to three corrective operations were required to cover post-burn defects of finger integuments (elimination of flap fat, removal of excessive skin to shape the stumps) versus the trauma caused with cutting objects.

To analyze the results of treatment, the data of patients' examinations were compared in the early postoperative period and 3, 6 and 12 months after reconstruction interventions.

Postoperative pain severity was measured with a 10-point Visual Analogue Scale (VAS) on days 10 to 21. In the following terms, the functional state of the arm and hand was assessed in everyday life with DASH (Disability of the Arm, Shoulder and Hand) outcome measure.

Also, the presence and severity of skin scars in the area of surgical intervention were studied with modified Vancouver scar scoring scale (P1:scar type; P2:consistence; P3:colour; P4 scar sensitivity).

Statistical analysis of the study results was performed using Statsoft software packages STATISTICA 10 and Microsoft Excel 2016. Mean values with standard error of the mean were calculated, while qualitative parameters were presented as frequencies of occurrence of signs as a percentage of the total number of patients in the corresponding groups.

Intergroup comparisons on quantitative indicators were carried out using the nonparametric Mann – Whitney rank test in the case of a nonparametric distribution of indicator values and/or a significant difference in variances in the groups. To analyze differences in qualitative parameters, the chi-square test or Fisher's exact test was used. Differences were considered significant if p did not reach the threshold value of the statistical significance level of the null hypothesis (alpha) equal to 0.05.

RESULTS

Examination of the intervention area in the postoperative period showed that swelling and venous flow disturbance in the transferred flap tissues subsided within 7 to 9 days in the majority of patients. In most cases, flap survival was complete. Primary healing was achieved in all 22 patients of the main research group treated with the use of the method proposed by us. No complications were observed in the course of treatment. Sutures were removed on average after 12-14 days after the intervention. The bandage from the donor site was taken off after the same term. Flap excess dissection and final shaping of the soft-tissue complex was performed not earlier than 21 days after the operation that ensured the positive outcome of the treatment en general.

The analysis of pain in the early postoperative period showed that the VAS values did not differ in the groups on the first postoperative days but in the following days the pain value was significantly lower ($p < 0.05$) in the main group relative the corresponding values in the comparison group (Table 3).

Table 3

Dynamics of patients' subjective evaluation of pain severity in the involved and surgical intervention area in the early postoperative period (VAS points)

Post-surgery term	Group 1 (comparison), *n* = 25	Group 2 (main research), *n* = 22
1	8.4 ± 1.3	8.2 ± 0.8
7	6.5 ± 0.4	4.9 ± 0.6*
14	5.2 ± 0.3	3.3 ± 0.2*
21	3.9 ± 0.3	1.8 ± 0.4*

Note: * – significant differences (at p < 005) relative values in group 1 (comparison group) Mann – Whitney U-test

The evaluation of the Quick DASH indicators showed that its values before surgery and one months after surgery were similar but three months after and in the following terms after treatment the parameters of this scale in the main research group were significantly lower (p < 0.05) than in the comparison group (Fig. 5). Those data proved a higher functional result of the proposed by us treatment approach.

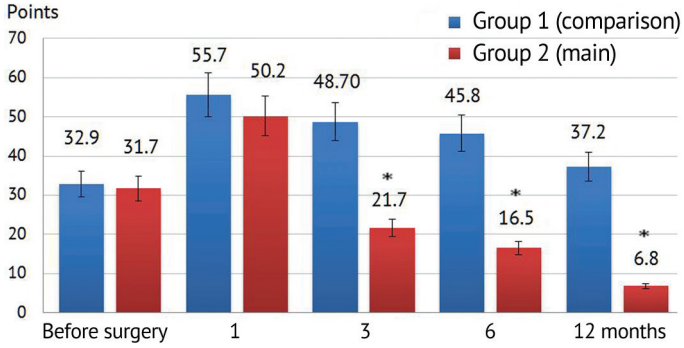

Fig. 5 Quick DASH dynamics, points (M ± m): * – significant differences (at p < 005) relative values in group 1 (comparison group) (Mann-Whitney test)

The analysis of subjective satisfaction of the patients with the results of treatment showed that there were more patients that estimated the results as "excellent" or "good" in the main group and the value was statistically higher (p < 0.05) than in the comparison group (Table 4). Moreover, there were 10 patients (40.0 %) that evaluated the treatment result as "poor" in this group while in group 2 there was only one patient (4.6 %) (p < 0.05).

Таблица 4

Распределение пациентов по степени удовлетворенности функциональным результатом проведенного лечения

Treatment results	Group 1 (comparison), *n* = 25	Group 2 (main research), *n* = 22	Group 1 (comparison), *n* = 25	Group 2 (main research), *n* = 22
	Abs. *n*	%	Abs. *n*	%
Excellent	–	–	**7**	**31.8***
Good	**5**	**20.0**	**11**	**50.0***
Fair	10	40.0	3	13.6
Poor	**10**	**40.0**	**1**	**4.6***

Notes: * – significant differences (at p < 005) relative values in group 1 (comparison group) in χ^2

It should be noted that the main reason of low subjective satisfaction with anatomical, functional and esthetic treatment results is residual asymmetry in comparison with the healthy fingers of the contralateral hand. Absence of bone fragment of the nail phalanx that could support soft tissue of the finger pad also caused lower satisfaction with treatment results in a number of patients. The proportion of such individuals among patients with defects of the fingertip stump, operated on in accordance with the proposed surgical approaches, was statistically lower than in the comparison group.

Skin scar changes were assessed six to 12 months after surgical treatment. Table 5 shows that the Vancouver scar score was statistically lower (p < 0.05) in the main research group than in the comparison group 6 months after treatment. After 12 months post-surgery, the expressiveness of objective components of that scale and values of subjective assessment reduced in most patients. The expressiveness of patients' proper attitude to residual defect of fingers also decreased. A more

expressed decrease in the Vancouver score was characteristic for patients of the main group. In that term of the study, the value of the parameter in the patients treated with the proposed by us method was statistically lower ($p < 0.05$) of the corresponding value of group 1.

Table 5

Dynamics of the Vancouver skin scar scoring, points, $M \pm m$

Post-surgery term	Group 1 (comparison), $n = 25$	Group 2 (main research), $n = 22$
6 months	6.13 ± 1.12	4.12 ± 0.38*
12 months	4.95 ± 0.87	2.43 ± 0.54*

Note: * – significant intergroup differences ($p < 0.05$) in comparison with the corresponding value of group 1 (Mann – Whitney criterion)

DISCUSSION

In general, the comparison of the results achieved in the studied groups showed higher (compared to conventional treatment methods) clinical efficiency of the proposed approach to surgical treatment of fingertip trauma that is based on the plasty of fingertip defects of the peripheral parts of three joint fingers relative to the results obtained in the comparison group.

The results of the study prove that the use of the surgical tactics proposed for the category of patients discussed provides improvement in the treatment results of the patients with injuries to the distal parts of three joint fingers associated with the loss of nail phalanx part and soft tissues of the finger pad.

The results obtained by us are consistent with the results reported in the studies of other authors [15, 16, 23-26]. Thus, Yildirim et al analyzed long-term functional and esthetic outcomes of homodigital neurovascular island flap of fingertip injuries in children when performing reconstruction of extensive pulp defects with bone range of motion, and total finger length over an average follow-up of 7.8 years (range, 2 to 13 years). Eleven patients exposure. Twenty-three children (mean age 4.8 years, range 1 to 10 years) with fingertip injuries underwent reconstruction using a single-digit pedicled flap. The authors assessed finger skin sensitivity, cold intolerance, scar formation, nail deformity, reported cold sensitivity in the operated fingertip, and 15 had a hooked nail deformity. The range of total active movements of the injured finger was significantly lower than that on the uninjured side ($p < 0.001$). However, the approach used in this work demonstrated an effective and reliable method of reconstructive treatment for fingertip injuries in children [15].

Schultz et al in their study, developed and tested a silicone cap that fits over the injured finger, creating a moist chamber surrounding the area of injury. The study analyzed data from patients with full-thickness fingertip injuries for whom simple primary closure of the defect was not possible; patients were randomized into 2 groups; the injured areas were either covered with a bandage or a silicone finger cap was used. The authors included 11 patients aged 2 to 72 years in each of two groups. All patients were satisfied with the cosmetic result of treatment, 88.9 % had no changes in the sensitivity of the skin of the fingers, and 73.7 % had no finger deformity. The duration of epithelization was from 5 weeks. There were no serious side effects observed with the means used in the work. The authors concluded that the tested approach is highly effective [16].

The results of our study confirm the success of the trial of the developed method of fingertip defect coverage of the nail phalanx of three joint fingers by transfer of palmar lateral and dorsal lateral blood supply flaps harvested from the ipsilateral and neighbor fingers without bone stump shortening of the nail phalanges with simultaneous esthetic effect due to visual lengthening of the fingertip phalanges. The obtained data allowed us to offer an algorithm of diagnostic and treatment measures in finger injuries that is presented in Figure 6.

We believe that the diagnosis of the injuries to the structures of the distal phalanx of three joint fingers should be based on the size and severity of injury to both soft tissues and bone component. Thereby, one should also assess the condition of boundary tissues with the level of detachment [23-28].

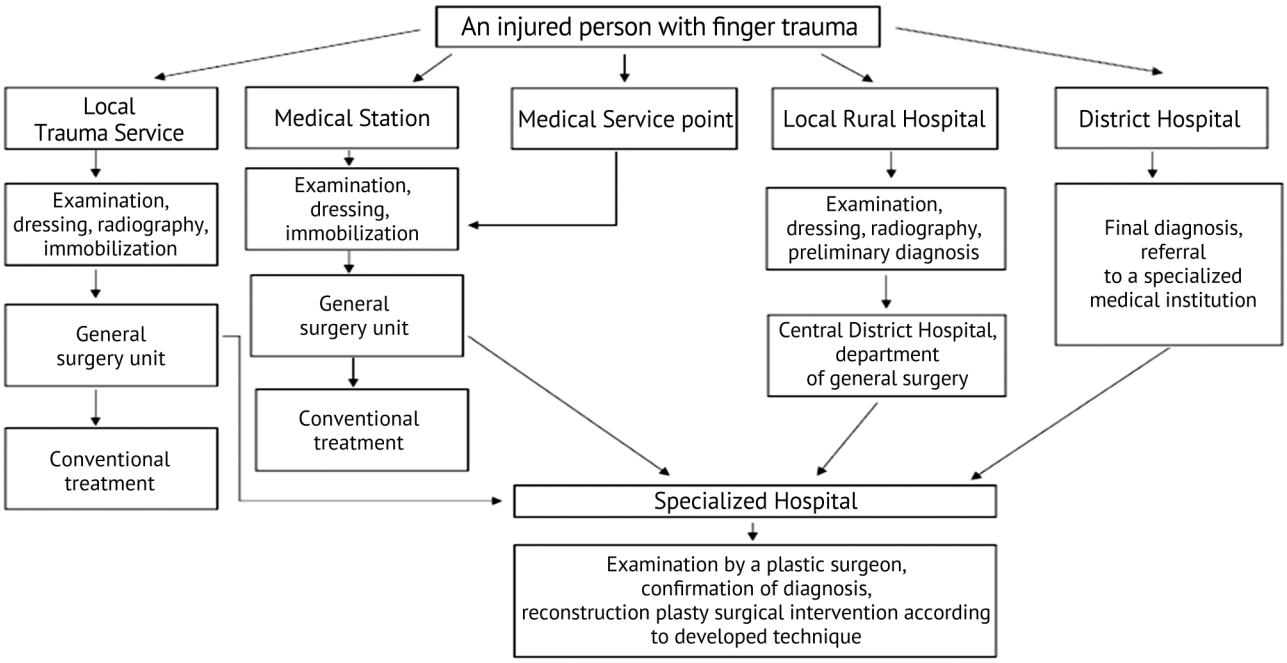

Fig. 6 Diagnosis and treatment algorithm of medical care delivery to injured persons with finger trauma

Crushed character of injuries may set doubt in the success of surgical treatment. In such case, economic primary surgical debridement of the wound and removal of nonviable tissues should be performed. A rich capillary net of the distal phalanx of fingers provides preservation of soft tissues that will be viable enough in 2 to 3 days if corresponding treatment is performed [29-33]. The base of final diagnosis that determines the severity of injuries to the studied structures should be the result of radiographic study that enables to reveal or exclude the presence of bone fragments and their connection with the proximal part of the phalanx bone [25, 34, 35]. If a free bone fragment is detected, it should be removed, as our experience showed, as its viability is minimal and could cause infection in the long term (osteomyelitis). If vascular pathology is detected, it should be treated to provide conditions for reconstructive plastic intervention [36-39].

CONCLUSION

The method for coverage of nail phalanx fingertip defects of fingers 2 to 5 has been developed. Its realization includes formation of a U-shaped cut on the dorsal surface of the neighboring finger at the level of the middle phalanx enabling to cover the defect and create excessive stock of soft tissues by producing the turn of the flap to the side of the recipient finger. The use of the developed method provides a lower (compared with the use of standard surgical treatment methods) pain severity on days 10-21 after the operation, lower values of Quick DASH after 3-12 months, reduction of Vancouver scar score after 6-12 months, higher patients' satisfaction with the results of treatment.

Conflict of interests *Absent.*
Funding source *Absent.*
Ethical approval *Ethical board approval was supplied.*
Informed consent *Not required.*

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