Review article
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Surgical correction of posttraumatic triphalangeal joint flexion contractures of the fingers (systematic literature review)

N.V. Abdiba✉, L.A. Rodomanova, A.O. Afanasyev, A.E. Chizhov, A.R. Mironov, D.V. Romanov, E.S. Tsybul

Vreden National Medical Research Center for Traumatology and Orthopedics,
St. Petersburg, Russian Federation

Corresponding author: Nino V Abdiba, ninoabdiba@gmail.com

Abstract

Introduction Triphalangeal joint flexion contracture of the fingers is a common and challeging posttraumatic hand condition. The goal of surgical treatment is to correct finger deformity and increase interphalangeal range of motion.

The **objective** was to systematize data on the causes of post-traumatic triphalangeal joint flexion contracture of the fingers and methods of surgical correction.

Material and methods The original literature search was conducted on key resources including Scientific Electronic Library (www.elibrary.ru), the National Library of Medicine (www.pubmed.org), ScienceDirect, Google Scholar, Ovid databases according to PRISMA recommendations. Literature searches included both Russian and English studies, with one or more cases of post-traumatic triphalangeal joint flexion contracture of the fingers with the deformity surgically corrected. Cases of non-traumatic flexion contractures were excluded. Etiological factors of flexion contractures, heterogeneity of definitions and methods for recording the range of motion in the joint, anatomical features, surgical correction of flexion contractures and postoperative complications were reviewed.

Results Common causes of flexion contractures included burns (32.3 %), dislocations and fracture-dislocations of the finger joints (23.5 %). The median postoperative follow-up period was 13.5 months after surgical treatment. Surgical correction was produced with external fixation device (EFD) in 40 % of cases, open procedures performed in 50 % and a combined technique employed in one case (10 %). Based on calculations of the odds ratios of postoperative complications, a weak positive linear relationship was revealed between EFD and pain syndrome, and a weak negative linear relationship was observed between the open procedure and pain.

Discussion There is heterogeneity of approaches regarding methods for correcting flexion contractures, surgical approaches, techniques for mobilizing joints and releasing the anatomical structures of the finger with open procedures, the distraction rate with EFD, methods for repair of soft tissue defects following the treatment of flexion contractures of interphalangeal joint of a finger.

Conclusion Open procedures are commonly used for precise elimination of all components of flexion contracture of the joint and repair of soft tissue defects of the finger. A weak positive linear relationship was revealed between EF and pain syndrome. There was no significant correlation between open techniques and complications. There were no correlations between the treatment method and the contracture type; there are no treatment regimens for patients with this pathology.

Keywords: interphalangeal joint, contracture, flexion contracture of the joints of the fingers, stiff finger, contracture of the fingers, posttraumatic contracture of the fingers

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INTRODUCTION

Improvements in surgical techniques, metal constructs and suture material have significantly improved repair of hand injuries, but the long-term consequences of these injuries remain pertinent in modern traumatology and orthopedics [1]. Stiff finger joints, flexion contractures of the interphalangeal joints are difficult to treat. Contractures of the interphalangeal joints develop in 20–38 % of cases after hand injuries of varying severity [2–4]. In 1956, Sterling Bunnell was the first to note that the fingers tend to become rigid and assume a physiologically disadvantageous position reducing the limb function [5, 6]. Flexion contracture has a pathophysiological origin and becomes the outcome of hand injury with inadequate treatment strategy and postoperative rehabilitation [5]. There are many classifications of contractures of the finger joints.

Yang et al. graded contractures depending on the involvement of certain anatomical structures including pathology of the skin and fascia; muscle and tendon damage; injury to the capsular-ligamentous apparatus; injury to the bone structures of the hand [7]. Considering the anatomical substrate and the deficiency of joint function, contractures are graded as dermatogenous with a deficient function of 30 % of the norm; dermatodesmogenic with a deficient function of 60 %; dermatodesmoarthrogenic with a functional deficit of more than 60 % [8]. Jupiter et al. identified 8 types of finger joint contractures depending on injury to the volar or dorsal aspects of the fingers and limited range of passive or active movements in the joint [9]. A similar ambiguous situation is typical for methods of surgical treatment of flexion contractures. Depending on the severity of the contracture and involved hand structures, tenolysis of the flexors, reconstructive operations on the flexor and extensor apparatus of the hand [10, 11]; reconstruction, mobilization of the volar plate and retinaculum of the volar plate [7]; release of collateral ligaments of joints; elimination of scar contractures of the skin, including non-free and free skin grafting [12–14]; corrective operations on the bones of the hand can be produced [15]. A variety of methods for surgical correction of contractures is not a predictor of successful treatment; therefore, there is no consensus or strict algorithm for the treatment of flexion contractures of the three-phalangeal fingers in the world literature.

The **objective** was to systematize data on the causes of post-traumatic triphalangeal joint flexion contracture of the fingers and methods of surgical correction.

MATERIALS AND METHODS

Search and selection of publications

The systematic review was performed in accordance with the international requirements of Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA). First, three authors (A.N.V., A.A.O., Ch.A.E.) selected publications independently using the keywords: interphalangeal joint, contracture, surgical treatment, flexion contractures, stiff finger, posttraumatic / post-traumatic, digital, finger joint, joint mobilization / arthrolysis in Russian and in English.

The original literature search was conducted on key resources including Scientific Electronic Library (www.elibrary.ru), the National Library of Medicine (www.pubmed.org), ScienceDirect, Google Scholar, Ovid databases according to PRISMA recommendations using combinations of operators OR, AND, NOT and the above keywords. The search in PubMed (MEDLINE) included the following combination of keywords: (posttraumatic OR post-traumatic) AND (flexion deformity finger) OR (stiff OR contracture) AND (finger OR proximal OR distal interphalangeal joint) AND (surgery OR surgical) NOT arthritis NOT Dupuytren NOT congenital NOT foot NOT elbow.

The retrospective search was unrestricted and the last search date was 01/10/2023. Literature search included the MeSH term (Flexion contracture of finger). Search queries in the databases were used in various combinations as a preliminary option. Inclusion and exclusion criteria of articles were determined at the first stage.

Inclusion criteria included:

— articles in Russian or English;

— patients aged greater than 9 years at the time of surgical treatment;

— use of surgical techniques aimed at correcting flexion deformity of the three-phalangeal fingers;

— etiologically post-traumatic nature of the flexion contracture of the three-phalangeal fingers;

— case reports analyzing treatment outcomes of one or more patients - the study included articles of level IV (case series) and higher in accordance with the hierarchy of evidence of the National Health and Medical Research Council (NHMRC);

— combination of post-traumatic deformity of the interphalangeal joint and metacarpophalangeal joint was acceptable, provided that the first was necessarily present.

Exclusion criteria:

— neurogenic contractures of the interphalangeal joints of the fingers, diseases and consequences of damage to the central nervous system;

— multiple malformations of the upper limbs;

— severe burns grades 3, 4, extensive burns covering the hand and fingers;

— orthopedic consequences of autoimmune diseases (systemic lupus erythematosus, scleroderma, rheumatoid arthritis, etc.);

— flexion contractures of the finger joints due to palmar fascial fibromatosis (Dupuytren's disease);

— exclusively minor research subjects (articles with groups of patients of heterogeneous age characteristics are included in the review).

The study included original articles with information about minor patients due to a paucity of publications matching the inclusion criteria. A manual search of references in identified articles was conducted to review additional studies that may be of interest. At the second stage, abstracts of publications were analyzed for compliance with inclusion and exclusion criteria, and duplicate works were searched for the purpose of the elimination. Full-text articles that met the criteria of the systematic review were examined at the third stage. The analysis of the literature in the libraries over the past 50 years revealed a paucity of contributions on the topic, a lack of uniformity in definitions, interpretation of goniometry parameters and calculation of the amplitude of movements in the interphalangeal joint of the hand, therefore, articles with incomplete data were included in the work. To avoid misunderstandings, we would discuss flexion contractures of the interphalangeal joints of the fingers, meaning the finger flexed in the interphalangeal joint with limited active and passive extension, preserved or deficient flexion in the joint [16]. The articles where the condition was interpreted in a different manner were excluded to maintain the homogeneity of the study.

Design of the study

An initial search in the databases identified 267 sources. Articles that were not relevant to the topic, book chapters, comments to articles, and articles in other languages (except for English and Russian) were excluded and 136 articles were selected for initial screening. With titles, abstracts, and full-text publications reviewed 10 articles (3.7 %) were identified that met the inclusion criteria and were relevant to the objective of the work, considering the exclusion criteria and heterogeneity in the interpretation of nosology definitions. The study selection process is presented in Figure 1.

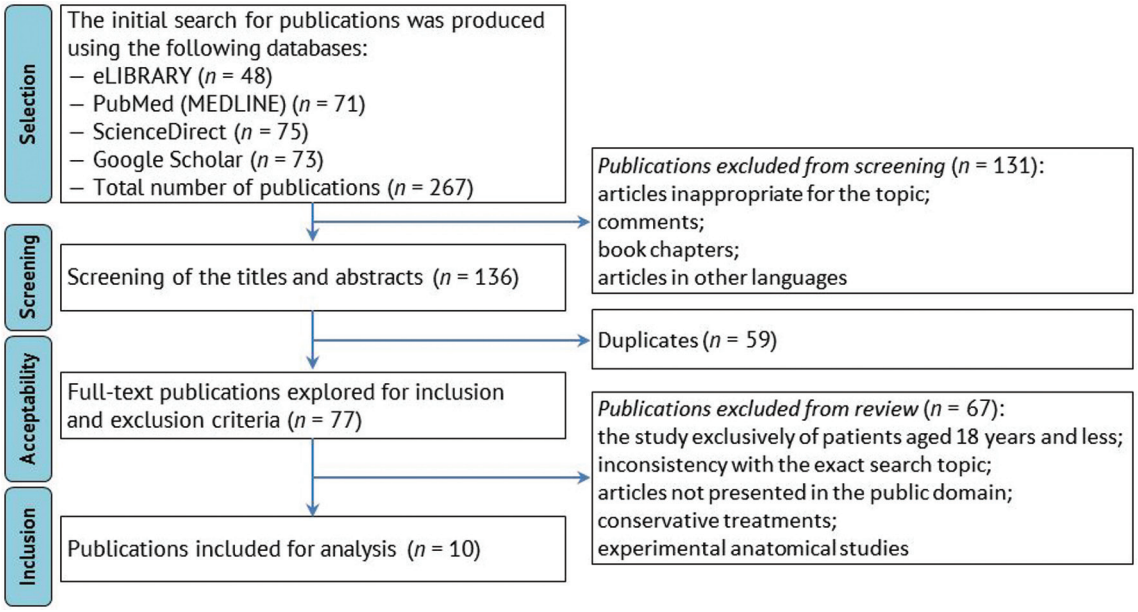

Fig. 1 Study inclusion flowchart using Preferred Reporting Items for Systematic Reviews and Meta-Analysis Guidelines [26]

Table 1

Summary table of articles included in the systematic literature review

Authors	Number of patients included in the study (*n*)	Patients who received treatments (*n*)	Type/mechanism of primary injury (*n*)	Average time from injury to surgery (months)	The joint of the triphalangeal finger involved in the deformity (*n*)
Ravishanker et al., 2003 [18]	17	21	burn (*n* = 15); posttraumatic (*n* = 2) (ns)	–	PIPJ DIPJ
da Silva et al., 2004 [17]	1	2 (II — 1; III — 1)	flexor tendon injury. 2,3 fingers	240	PIPJ DIPJ
Houshian et al., 2007 [24]	10	10 (II — 2; III — 1; IV — 2; V — 5)	dislocations, fracture-dislocations (ns)	15.5	PIPJ
Houshian et al., 2007 [19]	30	30 (II — 5; III — 2; IV — 7; V — 16)	dorsal fracture-dislocation (*n* = 19); volar fracture-dislocations of the middle phalanx (*n* = 7); dislocation of the middle phalanx (*n* = 4)	20	PIPJ
Hahn et al., 2010 [20]	9	9 (III — 1; IV — 5; V — 3)	burn (*n* = 4); use of split skin grafts to repair defects on the palmar surface of fingers (*n* = 3); tumor removal (*n* = 2)	249.6	PIPJ
Ahmad, 2014 [21]	56	–	burn (*n* = 31); posttraumatic (ns) (*n* = 21); post-infection (*n* = 4)	–	PIPJ
Antonova, Ivchenko, 2016 [14]	13	14 (II — 6; III — 5; I — 3)	burn (*n* = 5); electric trauma (*n* = 2); laceration (*n* = 3); incised wound (*n* = 2); mine-blast wound (*n* = 1)	5	PIPJ
Tsenget al., 2017 [22]	2	3 (III — 1; IV — 2)	surgery for stenosing ligamentitis (*n* = 1); industrial combined injury (ns) (*n* = 1)	–	PIPJ
Bogov et al., 2022 [25]	30	37	posttraumatic genesis (ns)	–	PIPJ
Su et al., 2023 [23]	2	2 (III — 1; IV — 1)	Impact with a ball (n = 1) (ns); incised wound and flexor tendon injury (*n* = 1)	1 patient (240) 2 patient (> 12)	PIPJ

Table 1 (continued)

Summary table of articles included in the systematic literature review

Authors	Surgical treatment used	Conservative treatment added	Mean follow-up period (mo)	Complications (*n*)
Ravishanker et al., 2003 [18]	EFD	hand rehabilitation; antimicrobial therapy	the longest follow-up period of 31 months	pin tract infection (*n* = 2); marginal necrosis (*n* = 2)
da Silva et al., 2004 [17]	EFD (patent) monolateral external fixator	hand rehabilitation	9	none
Houshian et al., 2007 [24]	EFD	hand rehabilitation	12	relieved pain syndrome (*n* = 3)
Houshian et al., 2007 [19]	EFD monolateral external fixator	hand rehabilitation; antimicrobial therapy; NSAID	34	pin tract infection (*n* = 5); relieved pain syndrome (*n* = 9); temporary flexion deformity of the DIPJ (*n* = 1)
Hahn et al., 2010 [20]	scar excision, arthrolysis, transarticular fixation of the PIP joint with a wire, defect repaired with a cross flap	hand rehabilitation	41.2	paresthesia of the fingers (*n* = 2); marginal necrosis (*n* = 1)
Ahmad, 2014 [21]	Z-plasty (*n* = 4); mobilization, skin graft (n = 38); mobilization, flap (*n* = 11)	hand rehabilitation	15	partial necrosis of the skin graft (*n* = 5); infection (*n* = 3);
Antonova, Ivchenko, 2016 [14]	island flap on the proper digital artery from the adjacent finger (*n* = 14), of which (*n* = 9) the proper digital nerve was included in the flap pedicle; PMJ capsulotomy of PIPJ (*n* = 4)	hand rehabilitation, NSAID, drugs that improve rheologic blood properties (ns)	12	relapse (*n* = 2)
Tsenget al., 2017 [22]	palmar neurovascular displacement flap (*n* = 3); tenolysis of the flexors (*n* = 2) and mobilization of the palmar plates, collateral ligaments (*n* = 3)	hand rehabilitation	–	hypaesthesia of the flap (*n* = 5); marginal necrosis (*n* = 1)
Bogov et al., 2022 [25]	arthrolysis, dynamic distraction device (modified)	hand rehabilitation, administration of hyaluronic acid and platelet-rich plasma	–	none
Su et al., 2023 [23]	arthrolysis, tenolysis, replacement of the defect with a displaced skin-fat flap	hand rehabilitation	3	–

Note. PIPJ — proximal interphalangeal joint; DIPJ — distal interphalangeal joint; NSAID — nonsteroid anti-inflammatory drugs; n — number of observations; IPJ — interphalangeal joint; EFD — external fixation device; «–» — no data presented in the article; ns — not specified.

Risk of systemic errors

A methodological quality assessment was produced for each series according to the Oxford Center for Evidence-Based Medicine (CEBM) criteria to determine the level of evidence. Case reports and case series were analyzed using the eight-item Joanna Briggs Institute Critical Appraisal Tool (JBI), and the same JBI Critical Appraisal Tool consisting of eleven questions was used for two cohort studies. The results of the study are presented in Figure 2.

Statistical analysis

Statistical analysis was performed for 10 articles corresponding to the objectives of the work; summing up the study objects, 170 patients were identified. Treatment effectiveness could not be evaluated due to the fact that 80 % of the studies [14, 17–23] were represented by case series and individual clinical observations. The available data allowed us to identify common surgical treatments, anatomical application of surgical correction, analysis of outcomes (primary evidence of effectiveness), and complications. Descriptive statistics methods were used: percentage of etiological causes of flexion contractures, median postoperative observation period, percentage distribution of surgical correction methods.

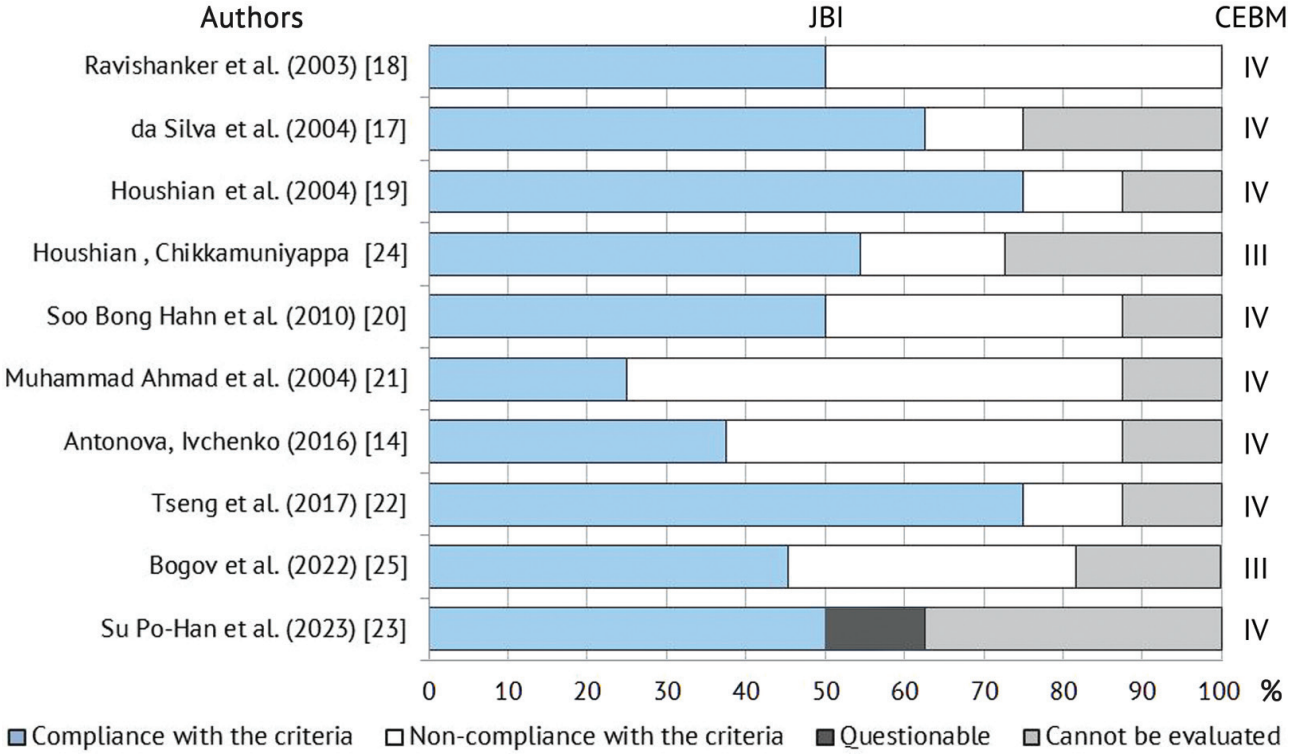

Fig. 2 Methodological assessment of the quality of articles included in a systematic literature review

Postoperative complications were analyzed using the odds ratio (OR) with the compilation of a multifield contingency table. None of the studies revealed correlations between the choice of treatment method and the type of contracture; none of the classifications mentioned were used. The linear relationship between two methods of surgical treatment (EFD, open method) and six types of complications (marginal necrosis, infection, recurrence of deformity, pain, other nonspecific complications, neurological disorders) was considered.

The data are presented on a dichotomous scale (Table 2), where:

(1) presence of a complication or use of an appropriate treatment method;

(0) no complication or use of another treatment method.

The calculation was produced using a contingency table, which reflects the number of joint occurrences of pairs of values of two variables (method, complication):

To determine the linear relationship, we used the correlation coefficient for dichotomous variables — coefficient φ:

Table 2

Scheme for constructing a contingency table

		Method	
		0	1
Complication	0	*A*	*B*
	1	*C*	*D*

Note: *A* is the number of cases when variables were equal to 0 at the same time; *B* is the number of cases when the "Method" variable was equal to 1, the "Complication" variable was equal to 0; *C* was the number of cases when the "Method" variable was equal to 0, the "Complication" variable was equal to 1; *D* was the number of cases when the variables were equal to 1 at the same time

$$\varphi = \frac{(AD - BC)}{\sqrt{(A + C)(B + D)(A + B)(C + D)}}.$$

Table 3 presents the correlation between surgical treatment methods and types of complications. The resulting correlation coefficient allowed us to assess the strength of the relationship between two variables (Table 4).

Table 3

Correlation coefficient of two methods in relation to various types of complications

Complication	EFD	Open method
Marginal necrosis	–0.06452903769908233	0.06452903769908233
Infection	0.17059725865786293	–0.17059725865786293
Recurrent deformity	–0.07839895392736086	0.07839895392736086
Pain	0.35317945776459336	–0.35317945776459336
Other nonspecific complications	0.09884244757168141	–0.09884244757168141
Neurological disorders	–0.1487282099557987	0.1487282099557987

Table 4

Correlation of the resulting coefficient with the strength of the relationship between two variables

Value (modulo)	Correlation
up to 0.2	very weak
up to 0.5	weak
up to 0.7	medium
up to 0.9	high
over 0.9	very high

RESULTS

Based on this number of patients, the percentage of etiological causes of flexion contractures of the finger joints was calculated, which are presented in Table 5. Common causes of flexion contractures included burns (32.3 %) [14, 18, 20, 21], dislocations and fractures. dislocations of the joints of the fingers (23.5 %) [19, 24]; post-traumatic genesis of the pathology without an accurate description of the mechanism of injury and damaged structures (32.3 %) was reported [18, 21, 23, 25].

Table 5

Etiology of flexion contractures of the finger joints

Etiology	Number of patients	
	abs.	%
Posttraumatic genesis (not specified)	55	32.3
Burn	55	32.3
Dislocation, fracture-dislocation	40	23.5
Complication after surgery for stenosing ligamentitis	1	0.6
Electric trauma	2	1.2
Laceration	6	3.5
Incised wound	4	2.4
Mine-blast trauma	1	0.6
Removal of tumour	2	1.2
Post-infection genesis	4	2.4

The causes of flexion contractures can be predictable with explainable etiological factors to include electrical injuries, mine blast wounds and infections. Incised and lacerated wounds with the directions of skin injury being spontaneous and not corresponding to the surgical lines of the incisions can be associated with pathological scars and limited mobility in the joint [27, 28].

In our series, the procedure caused flexion contracture in one patient [22], and complications were reported in some articles that were not included in the systematic review [29, 30]

The frequency of complications after open ligamentotomy ranges from 1 to 43 %. Surgical outcomes of 795 fingers were associated with complications (pain, swelling, stiffness, recurrence, superficial infection, deep infection, neuropraxia, bowstring deformity) recorded in 12 % *(n* = 95) of cases and flexion contracture of the finger joints was observed in 2.5 % (*n* = 20) [29, 30]. The median postoperative follow-up period was 13.5 months, with the longest follow-up period of 41.2 months reported by Hahn et al. [20], the shortest follow-up period of 3 months [23]. Follow-up period was not reported in several studies [22, 25]. Surgical correction was produced with EFD in 40 % (*n* = 4), open procedures in 50 % of cases (*n* = 5) and a combined technique was used in one case (10 %) with sequential mobilization of the joints of the involved finger and fixation with a dynamic distraction device.

Postoperative complications were analyzed using the odds ratio (OR) with the compilation of a multifield contingency table. The calculations showed a weak positive linear relationship between the EFD and pain. This meant that the use of the EFD method might cause pain to a minor extent. A weak negative linear relationship was discovered between the open procedure and pain. A very weak linear correlation was detected in other cases (marginal necrosis, infection, recurrence of deformity, other nonspecific complications, neurological disorders). However, the possibility of a non-linear relationship should be taken into account, which requires a more complex study using more data.

DISCUSSION

The problem of definitions and standardization of measuring the range of motion in the finger joints

In the Russian literature, the term “flexion contracture of a joint” refers to the stable position in which the joint is located, but there is also an interpretation that implies a deficient joint function, that is, flexion with a fixed extension in the joint [31–33].

Probably, an erroneous judgment regarding the definition of flexion contractures is based on one of the fundamental works written by Marx in 1978, where the following definition is given: “The position of contracture is understood as the forced position that the joint takes due to the restriction of movements in it.” This phrase, which can be interpreted as the contracture caused by one or another type of impaired movement in the joint, is taken out of the context, and the author clarifies: “Flexion contracture means a limited extension in the joint; extension contracture, on the contrary, means a limitation of extension movements in the joint — limitation of flexion" [34].

An inaccurate definition can be found in the neurorehabilitation manual, which provides the following: “In accordance with the position in which the limb is located as a result of a limited movement, contractures can be graded as flexion (limited flexion), extension (limited extension), adductor or abductor (limited adduction or abduction), rotational (limited rotation) contractures” [35]. Flexion contractures are defined in a similar way in the Great Medical Encyclopedia (https://бмэ.орг/index.php/КОНТРАКТУРА). For instance, flexion contracture is described as a defective position of flexion in the joint in the textbook edited by Volkov and Ter-Egiazarov [33]. In modern books on traumatology and orthopedics, Joint contractures are classified by malpositioned limb segment in flexion, extension, rotation and multicomponent” [31, 32].

In foreign literature, the Human Phenotype Ontology (HPO) was launched in 2008 with the support of the Monarch initiative (a large scale bioinformatics web resource) to provide a standardized

vocabulary of phenotypic abnormalities and clinical features found in human disease [36]. In this library, flexion contracture of a finger joint is interpreted as a bent joint of a finger or toe that cannot be straightened actively or passively [16].

In addition to different definitions of flexion contracture, there is a variety of terms for the pathology including stiff finger, hook finger, fixed flexion deformity, flexion deformity of the finger [11, 37, 38].

The range of motion in the joint measured perioperatively and at a long-term period is the most reliable indicator of the outcomes in traumatology and orthopedics, and in the surgery of flexion contractures of the finger joints, in particular. The terms "amplitude of movements" and "range of movements" are used in the Russian literature and the standardized term ROM can be found in foreign literature [39, 40]. Total active motion (TAM) is an important indicator in the surgery of flexion contractures described by the American Society for Surgery of the Hand (ASSH) as the sum of active MCP, PIP and DIP minus any extension deficits in the joint [41]. A goniometer is used to measure the range of motion, the angle of deformity, and it is important to accurately determine the preoperative position in the joint (reference point) or "zero degrees". Witthaut et al. designated the neutral position of the goniometer as zero degrees [42], while Lee reported full extension as 180° [43]. Full extension in a joint is often defined as 0°, and if both options are acceptable in clinical practice, numerical discrepancies in the preoperative measurements may cause incorrect interpretation of goniometric data in the literature or the impossibility of comparing two or more studies.

None of the studies presented in the systematic review reported calculated TAM, and preoperative and postoperative ROM measurements reported in some studies. The starting point with ROM was reported in the publications reviewed. Since goniometry has been recognized as the most common outcome measurement method [37, 44], therefore, it can be argued that the ROM and TAM protocol should be presented as a standard in publications to improve research transparency.

Surgical anatomy

The theoretical and practical complexity of flexion contractures of the interphalangeal joints of the fingers is associated with an obviously small area of surgical maneuvering and in the combination of a large number of anatomical structures. The interphalangeal joints are simple hinge-type joints that are surrounded by external stabilizers with a flexion/extension of approximately 90° to 100° at the PIP and 80° to 100° at the DIP [45].

The integrity of the joint is maintained by the balance of soft tissues at motion, primarily the volar plate, the own and accessory collateral ligaments [7, 45]. The flexor and extensor tendons provide secondary contributions to maintaining joint stability. The palmar plate is the main passive limiter of hyperextension of the IPJ; it is pleated in flexion and stretched in extension (Fig. 3). The palmar plate is stretched between adjacent phalanges, and there are the ulnar and radial retaining ligaments of the palmar plate (checkrein ligaments) at the site of the PIPJ [7, 15]. Stability in the frontal plane of the joint is provided by its own and additional collateral ligaments [45]. These structures have a biomechanical role in the formation of flexion contracture of the IPJ. Thus, the collateral ligament is attached proximally and distally to the bones and in a tension at each movement; additionally, the collateral ligament is attached distally to the palmar plate and tense in extension in the IPJ is, and in flexion in the MFS it is corrugated in flexion (Fig. 3), with a greater risk of fibrosis when immobilized in flexion, and often additional collateral ligaments become the point of application with elimination of flexion contracture of the fingers [11]. The dorsal structures of the MFS are more vulnerable to injury: the joint capsule is thin, the central fascicle and the terminal part of the extensor apparatus are susceptible to rupture during translation in the joint [45, 46].

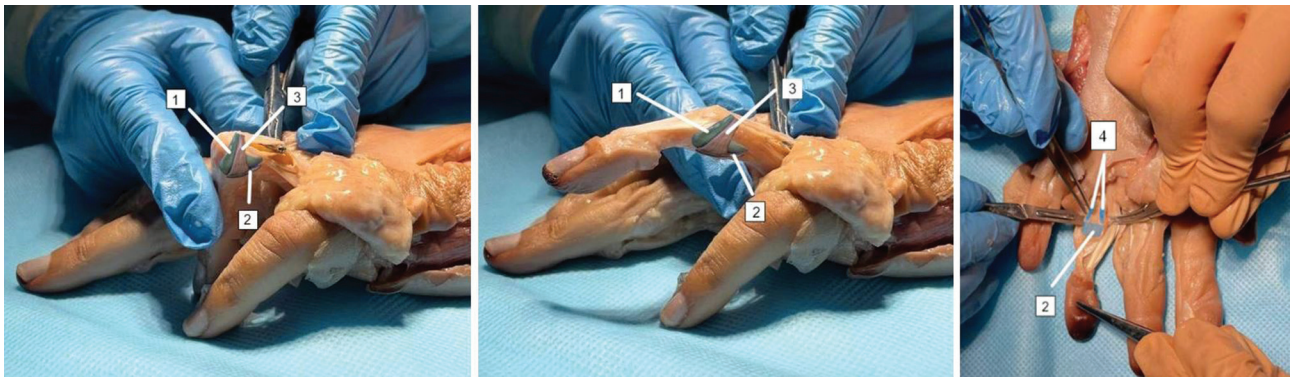

Fig. 3 Anatomy of the PIPJ: (1) the collateral ligament; (2) palmar plate; (3) accessory collateral ligament; (4) retaining ligaments of the palmar plate (checkrein ligaments)

The etiology of flexion contracture can be associated with the interphalangeal joint, the palmar plate, the ligaments that hold the palmar plate (checkrein ligaments), the flexor tendons of the finger, the osteofibrous canal of the flexor tendons, the extensor apparatus, a pathological scar of the skin finger [47, 48].

Surgical options

The surgical treatments of patients with flexion contractures of the interphalangeal joints of the fingers can be divided into two different groups: closed techniques (EFD of various modifications), open techniques (arthrolysis, release of the involved anatomical structures, mobilization/tomy of the palmar plate, etc.).

Open surgical correction of all components of the deformity is the standard method for eliminating post-traumatic flexion contracture of the finger joints, resistant to conservative treatment. Curtis [49] was the first who described the sequential release of the joint capsule and reported a slight increase in the amplitude of movement in the joint (by 13°) with involution of movements to values less than in the preoperative period, and then a series of studies appeared [50] with questionable results of open methods, and then a series of studies [50] reported questionable results of open methods, which caused the popularization of closed hardware methods for eliminating flexion contractures of the finger joints at the end of the 20th century and in the first decade of the 21st century.

Hardware techniques are justified by distraction histogenesis — the first general biological principle described by G.A. Ilizarov, based on the fundamental discovery of the general biological capability of tissues to respond to dosed stretching with regeneration and growth [51]. In our series, 50 % of the studies reported EFD as the method of choice with 30 % using 1.0 to 1.2 mm wires and the use of 2.0 mm half-pins were mentioned in two studies (20 %). Monoplanar devices were common, with the exception of R. Ravishanker, who used a two-plane wire device in a series of adult patients [18].

Various rates and frequencies of distraction ranging from 0.25 to 1 mm/day were reported [18] lasting from one to four weeks [17, 18, 24, 52].

A detailed prospective study on a small group of patients was conducted by Houshian et al. [24] to identify optimal distraction parameters. A comparison of two groups of patients with a distraction rate of 0.5 mm per day for 14 days and 1 mm per day for 7 days did not reveal statistically significant differences, so the authors gave their preference to the second distraction mode, and also emphasized the importance of further studies on a larger scale [24]. The studies report the use of the apparatus consisting of two wires or half-pins (the distal one is passed through the base of the middle phalanx, the proximal one through the border between the middle and distal third of the main phalanx), two fixing blocks and a threaded rod for a measured step [17–19].

Bogov et al. reported the use of a modified dynamic distraction device in a cohort study similar to the Suzuki clamp, which is described in the literature primarily for extrafocal osteosynthesis for fractures of the phalanges of the fingers [25, 53]. The method of distraction histogenesis is not always applicable and effective in treatment of flexion contractures of the fingers, taking into account the inconvenience and sometimes impossibility of early rehabilitation and the lack of differentiated effects on all components of flexion contracture [24].

A number of studies report contraindications to the use of EFD for flexion contractures: post-burn deformities, congenital deformities, Dupuytren's contracture, chronic regional pain, tendon injuries, crush injuries, history of replantation of segments [24].

Open operations are aimed at removal of scars or intersecting pathologically altered structures with the mobilization being not effective. Both palmar and dorsal anatomical formations are important. Surgeries on soft tissues are not effective for pathological changes in the metaepiphyseal surfaces articulating the joint and assessment of the condition and congruence of the joint is essential. Fusion of the phalanges of the fingers with rotational or angular deformity, the presence of exostoses in the joint area can cause the formation of contractures [11]. Surgical treatment in such cases is aimed at eliminating the deformity and resection of exostosis. In some series, patients with more than 30 % damage to the articular surface involved in finger flexion contracture were excluded from the studies [24]. The patients with the post-traumatic defect initially might have other goals and expectations from treatment, such as pain relief, stabilizing the finger to improve the hand functionality. These goals can be achieved either by arthrodesis in a functionally advantageous position, or by joint replacement, however, it is obvious that in the first case the range of motion in the joint (ROM) will not increase; with replacement, pain relief can be be achieved with a certain amount of active and passive movements, but numerous reviews have not demonstrated a significant improvement in range of motion compared to baseline [54, 55].

With regard to the volar structures of the proximal interphalangeal joint, some authors report mobilization of the volar plate, others describe its intersection without subsequent restoration or intersection of the ligaments holding the volar plate (checkrein ligaments) [11, 56]. Joint mobilization suggests cutting the accessory collateral ligaments and mobilizing the native collateral ligaments, if needed.

Surgical access to eliminate flexion contractures of the finger joints is also debatable. In a series of studies, preference is given to an incision made along the neutral line/midlateral of the joint, so that the neurovascular bundle is volar to the incision. The approach suggests the following sequence of actions: skin dissection, subcutaneous fat tissue, visualization of the osteofibrous canal of the flexors, dissection of the A3 ligament. The flexors and soft tissues of the volar surface are retracted with a hook, then the palmar plate is dissected, the ligaments holding the palmar plate are crossed, avoiding damage to the transverse digital artery, the joint is examined for the need of dissection/mobilization of the remaining anatomical structures (accessory and proper collateral ligaments) [4, 47].

Bruser et al. reported a greater increase in the range of motion in the joint at a long term with an incision made along neutral lines in their cohort study in comparison with the classic zigzag Bruner incision due to less trauma and the possibility of dynamic splinting early post surgery [57].

However, an adhesive process can be observed along the osteofibrous canal even in the absence of a history of flexor injury; this process is most pronounced in the second zone, at the site of the physiological intersection of the superficial and deep flexor tendons (R Camper). In this case, the incision along the neutral line of the finger can be ineffective with the zigzag Bruner incision and its modifications being most practical [28]. Saun et al. reported the volar oblique incision as a satisfactory alternative to the classic Bruner incision based on scar assessment using the Patient

and Observer Scar Assessment Scale (POSAS). Future studies are needed to assess the optimal approach for arthrolysis and tenolysis of the digital flexors [58].

The problems that can be associated with the dorsal structures of the finger include adhesions of the extensor apparatus, requiring tenolysis; dysfunction of the extensor apparatus of the finger, requiring its reconstruction [59].

Tenolysis of the extensor apparatus of the fingers, detachment of the tendon from the bone and medialization of the lateral bundles that the latter can be performed either openly under visualization or transcutaneously are reported [10, 58, 60].

A soft tissue defect can develop in case of a severe long-term contracture or pathological volar scars after eliminating the flexion contracture of the finger in the extension position [12, 22, 61, 62].

In our series, open methods for correcting flexion contractures were reported in 50 % of the studies reviewed and plastic replacement of the resulting tissue deficit of the volar surface was required after elimination of the flexion contracture in all cases. The authors use the following methods: cross skin grafting [20], displaced skin-fat flap, modifications of V-Y flaps [23], homodigital flaps with antegrade and reverse blood flow [14] were employed for the repair. Table 6 presents major surgical techniques used to repair flexion contracture by different authors.

Table 6

Articles reporting methods for open elimination of flexion contractures of the finger joints

Authors	Number of patients (*n*)	Type/mechanism of primary injury (*n*)	The joint involved in the deformity	Surgical technique	Anatomical structures "subjected" to arthrolysis/ tenolysis
Hahn et al. [20]	9	burn (*n* = 4); use of split skin grafts for repair of palmar defects (*n* = 3); tumor removal (*n* = 2)	PIPJ	scar excision, arthrolysis, transarticular fixation of the PIP joint with a wire, repair of the defect with a cross flap	release of the palmar plate, retinaculum of the palmar plate, collateral ligaments; partial release of accessory collateral ligaments
Ahmad [21]	56	burn (*n* = 31); posttraumatic (*n* = 21); postinfection (*n* = 4)	PIPJ	plastic repair of soft tissue defect after elimination of contracture	non specified
Antonova, Ivchenko [14]	13	burn (*n* = 5); electric trauma (*n* = 2); laceration (*n* = 3); incised wound (*n* = 2); mining injury (*n* = 1)	PIPJ	island flap on the proper digital artery from the adjacent finger	capsulotomy of PIPJ (*n* = 4) (non specified)
Tseng et al. [22]	2	surgery for stenosing ligamentitis (*n* = 1); occupational associated injury (*n* = 2)	PIPJ	tenolysis, arthrolysis, palmar neurovascular displaced flap	tomy of the palmar plate at the site of attachment on the base of the phalanx, tomy of the accessory collateral ligaments
Su et al. [23]	2	bump with a ball (*n* = 1) (not specified); incised wound with damage to the flexor tendons and surgical repair (*n* = 1)	PIPJ	arthrolysis, tenolysis, replacement of the defect with a displaced skin-fat flap	non specified

CONCLUSION

Review of the articles included in the statistical section showed that flexion contractures were caused by burns (32.3 %), dislocations and fracture-dislocations of the finger joints (23.5 %) and a routine surgery for stenosing ligamentitis (0.6 %).

Analysis of the literature revealed discrepancies in definitions and abundant terminology describing the same phenomena. Uniform terminology, initial angles for measuring the range of motion in joints,

a unified methodology for calculating TAM and ROM would be practical to ensure comparability of results in future studies. Accurate description of the calculation method used by the authors in the study is essential for correct interpretation of the data. The Human Phenotype Ontology (HPO, https://hpo.jax.org) dictionary can be useful for unification of scientific information from foreign and Russian literature.

Surgical methods offered for treatment of patients with flexion contractures of the interphalangeal joints were divided into two groups: closed techniques of external fixation devices of various modifications (50 %) and open procedures (40 %). A combined treatment technique with sequential mobilization of the joints of the involved finger and placement of a dynamic distraction device (10 %) was reported in one of the articles. A weak positive linear relationship was revealed between the EFD and pain based on calculations of the odds ratio (OR) of postoperative complications. However, no significant correlation was found between open techniques and complications (marginal necrosis, infection, recurrent deformity, other nonspecific complications, neurological disorders). Soft-tissue deficiency and the need for plastic repair of the volar tissues of the finger after eliminating the flexion contracture is one of the problems in the treatment of flexion contractures. Cross-cut skin grafting, displaced skin-fat flap, modifications of V-Y flaps, homodigital flaps with antegrade and reverse blood flow were methods used for the repair and reported in 50 % of contributions. Open techniques are commonly used for accurate correction of all components of the flexion contracture of the joint and repair of soft-tissue deficiency. No correlations between the treatment modality and the type of contracture were identified with the variety of treatment methods and classifications of the condition, and no treatment regimens were determined for patients with the pathology. The development of a universal decision-making algorithm is essential for the treatment of contractures of the interphalangeal joints of the fingers depending on the type of nosology and further research on larger cohorts groups of patients is required.

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Information about the authors:

Nino V. Abdiba — orthopaedic surgeon, research assistant, ninoabdiba@gmail.com, https://orcid.org/0000-0001-9152-5299;

Lyubov A. Rodomanova — Doctor of Medical Sciences, Professor, orthopaedic surgeon, Head of Department, rodomanovaliubov@yandex.ru, https://orcid.org/0000-0003-2402-7307;

Artem O. Afanasyev — orthopaedic surgeon, afar_kav@mail.ru, https://orcid.org/0009-0003-6407-5888;

Alexander E. Chizhov — resident doctor, Santillabox@mail.ru, https://orcid.org/0009-0002-2019-6242;

Artem R. Mironov — orthopaedic surgeon, laboratory assistant-researcher, ortopedix@yandex.ru, https://orcid.org/0009-0001-9273-8680;

Dmitry V. Romanov — orthopaedic surgeon, Head of Department, dr.romanov79@gmail.com, https://orcid.org/0000-0001-9847-7867;

Evgeny S. Tsybul — Candidate of Medical Sciences, orthopaedic surgeon, researcher, na4med@inbox.ru, https://orcid.org/0009-0001-8105-3635.