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Assessment of the Foot Donor Site Morbidity After Non-Vascularized Toe Phalanx Transfer to the Hand

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Background. Non-vascularized is one of the available methods of reconstructive surgery for the treatment of the hand congenital anomalies. The the impact of toe phalanx transfer on the appearance and functionality of the donor site in the long term is relevant.

Aim of the study — an objective assessment of the appearance, shape and functional state of the foot in the long-term period after the toe phalanx transfer into defects of the fingers in congenital and obtained hand pathologies.

Methods. On the basis of the Federal Scientific Center for the Rehabilitation of the Disabled named after G.A. Albrecht 40 patients were examined, who, aged from 8 months to 11 years (in the period 2013-2022), underwent 54 toe phalanx transfer to the hand. The proximal or middle phalanx of the IV and II toes were used as a graft. To assess the condition of the feet in the long term, all patients underwent clinical and radiological studies. 12 patients aged 3 to 13 years underwent computerized plantography, podometry and barodynamoplantography.

Results. After donor feet examination in the long-term period, lots of them showed a linear shortening of the donor toes compared to the contralateral foot, which was recorded by a computer planto-podometric method for evidence. The barodinamoplantographic study did not show significant signs of a decrease in the support ability of the foot, which could be associated with non-vascularized toe phalanx transfer. When walking, there were no obvious signs of impaired motor functions of the donor foot.

Conclusion. It was objectively confirmed that the non-vascularized toe phalanx transfer to the hand does not significantly affect the shape and statodynamic function of the foot in the long-term follow-up period, despite the shortening of the donor toes.

Keywords: hand, congenital anomalies, autografts, free bone grafting, phalanx transfer, toes, non-vascularized graft, biomechanical examination, children.

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Оценка состояния стопы после заимствования некровоснабжаемых фаланг пальцев для аутотрансплантации на кисть

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Актуальность. Аутотрансплантация некровоснабжаемых фаланг пальцев стопы является одним из доступных методов реконструктивно-пластической хирургии для лечения недоразвитий кисти. Актуален вопрос влияния заимствования фаланг на внешний вид и функциональность донорской стопы в отдаленном периоде.

Цель — объективная оценка внешнего вида, формы и функционального состояния стопы в отдаленном периоде после заимствования некровоснабжаемых фаланг пальцев и последующей пересадки для замещения дефекта пальцев кисти при врожденных и приобретенных патологиях.

Материал и методы. Обследовано 40 пациентов, которым в возрасте от 8 мес. до 11 лет были выполнены в совокупности 54 пересадки фаланг по поводу редукционных аномалий кисти. В качестве трансплантата использовали проксимальные или средние фаланги IV и II пальцев стопы. Для оценки состояния стоп в отдаленном периоде всем пациентам проводили клинико-рентгенологические исследования. 12 пациентам в возрасте от 3 до 13 лет проведены компьютерные плантография, подометрия и бародинамоплантография.

Результаты. При осмотре стоп оперированных пациентов в отдаленном периоде у многих было выявлено линейное укорочение донорских пальцев стопы по сравнению с контралатеральной стопой, что для доказательности фиксировали компьютерным планто-подометрическим методом. Бародинамоплантографическое исследование не показало значимых признаков снижения опороспособности стопы, которые можно было бы связать с пересадкой некровоснабжаемой фаланги пальца стопы. При ходьбе не наблюдалось явных признаков нарушения двигательных функций оперированной стопы.

Заключение. Объективно подтверждено, что заимствование некровоснабжаемых фаланг пальцев стопы для их последующего перемещения на кисть не оказывает существенного влияния на форму и статодинамическую функцию стопы в отдаленном периоде наблюдения, несмотря на укорочение донорских пальцев стопы.

Ключевые слова: кисть, пороки развития, аутотрансплантация, свободная костная пластика, транспозиция фаланги, пальцы стопы, некровоснабжаемый трансплантат, биомеханическое исследование, дети.

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BACKGROUND

The reported literature presents various methods of reconstructive plastic surgery that are used in the treatment of congenital hand underdevelopment (brachydactyly, ectrodactyly, and hypoplasia) and acquired hand deformities, characterized by decreased linear and volumetric parameters and decreased number of hand segments, which lead to significant functional and cosmetic upper limb disorders [1]. Reconstruction methods include microsurgery [2], compression-distraction osteosynthesis [3, 4, 5, 6], various types of skin, tendomuscular, and bone grafting [6, 7], and prosthetics [8]. Concurrently, a less common, but effective and affordable variant of bone grafting for restoring hand functionality and cosmetic condition is known, which includes autografting of non-vascularized toe phalanges [9, 10, 11, 12].

The method for autografting of non-vascularized toe phalanges gained popularity in the early 20th century. The phalanges of the fingers deformed due to tuberculosis infection or enchondroma were resected and replaced with non-vascularized toe phalanges, and grafts from the costal cartilage were transplanted into the resulting defects in the donor areas of the toes. During the follow-up examination of patients after a year, there were no major cosmetic or functional defects in the donor's toes and recipient's fingers, the position of the bone grafts was satisfactory on the radiographs, the epiphyses in the formed fingers were congruent, and no signs of resorption were noted [9, 10]. New cases of finger reconstruction using the toe phalanges have also been reported in some studies [11, 12, 13].

The method for autografting of non-vascularized toe phalanges in congenital hand maldevelopment became more widely known in 1990 after the study of 57 patients who had undergone 97 phalanx transplantations since 1976 [14, 15].

Gradually, new studies on the transplantation of non-vascularized toe phalanges to the hand have been conducted. These studies revealed that autografting of non-vascularized toes in the case of the hand underdevelopment improves its appearance and function [16, 17, 18, 19], provides an opportunity for toe growth due to the growth zone of the transplanted phalanx [18, 20, 21, 22], is characterized by low-injury rate for the donor foot [16, 22, 23] and has a minimal resorption risk of the transplanted graft [21, 22, 23, 24].

Concurrently, the long-term effect of phalanx transplantation on the appearance and functionality of the donor foot remains relevant. Several have reported the clinical studies on donor feet of patients after harvesting non-vascularized phalanges [16, 17, 22, 25]. Donor toe shortening, flexibility, and instability were registered in several cases. However, we did not find any information about the study of the feet, which would enable us to objectively assess (using instrumental methods) the degree of phalanx transplantation affecting the change in the shape and function of the foot after harvesting phalanges for autografting to the hand.

The study objectively assessed the appearance, shape, and functional state of the foot at the long-term period after harvesting non-vascularized finger phalanges and their subsequent transplantation to replace the defects of the fingers in congenital and acquired pathologies.

METHODS

Study design

This prospective single-center observational study of the effect of harvesting non-vascularized toe phalanges (for transplantation into a finger defect) on the anatomical and functional state of the foot was conducted at the clinic of the G.A. Albrecht Federal Scientific Center of Rehabilitation of the Disabled of the Ministry of Labor of Russia.

Patients

This study examined 40 patients (21 boys and 19 girls), who underwent 54 phalanx transplantations for hand underdevelopment (ectrodactyly, brachydactyly, and hypoplasia) and acquired hand deformities from 2013 to 2022 at the ages of 8 months to 11 years, including 2 children aged under 1 year, 22 pediatric patients aged 1–3 years, 11 patients aged 3–7 years, and 5 children aged 7–11 years). Proximal or middle phalanxes of the toes IV or II were used for transplantation, focusing on linear and volumetric dimensions of the suspected defect in the recipient zones (Table 1). Table 2 presents the distribution of recipient zones in patients by localization on the hand.

Table 1

Distribution of donor zones during transplantation of non-vascularized toe phalanges to the hand

Toe	Localization of donor zones		Total
	Proximal phalanges	Middle phalanges	
II	2	7	9
IV	26	19	45
Total	28	26	54

Table 2

Localization of the recipient zone during transplantation of non-vascularized phalanges of the toes to the hand

Hand ray	Localization of recipient zones			Total
	Metacarpal bones	Proximal phalanges	Middle phalanges	
I	8	8	–	16
II	–	5	7	12
III	–	6	4	10
IV	–	3	6	9
V	–	5	2	7
Total	8	27	19	54

Results assessment

We performed a clinical examination, the Oxford Ankle Foot Questionnaire Children (OAFQ-C) for subjective assessment of the patient's foot postoperatively and the identification of complaints of impaired support ability [26, 27]. We also performed an X-ray examination to assess their foot condition in the long-term period. The long-term follow-up period ranged from 1 to 8 years postoperatively (49 of 54 cases of harvesting of the toe phalanges), with an average of 3.04±1.20 years, up to 3 years in 18 cases, 3–6 years in 28 cases, and ≥6 years in 3 cases.

The following instrumental studies were conducted on 12 patients aged ≥3 years, who underwent surgery at least 6 months before the examination [28]:

– computer plantography and podometry by the three-coordinate optical plate scanning method of the feet using the hardware and software package (HSP) Scan (registration certificate No. FSR 2010/07441 dated 04/22/2010) with the calculation of parameters reflecting the foot shape;

– barodynamic plantography on the HSP with matrix underfoot pressure meters in the form of insole HSP DiaSled (registration certificate No. FSR 2009/06416 dated 26.02.2010) to assess the statodynamic function of the foot.

Among 12 patients, 4 had previously undergone phalanx transplantation of both feet. One patient underwent transplantation of the main phalanges of toe IV, two patients of the middle phalanges of toe IV, one patient of the main phalanx of toe IV of the left foot and the middle phalanx of toe IV of the right foot, one patient of the middle phalanx of toe II of the right foot, three patients of the main phalanx of toe IV, and seven patients of the middle phalanx of toe IV. Concurrently, one patient underwent plantography and podometry twice, which was a year after the middle phalanx transplantation of toe IV of the right foot, and 2 years after the examination and a year after the middle phalanx transplantation of toe IV of the left foot.

The effect of autografting of non-vascularized toe phalanges on the statodynamic function of the foot was studied using the barodynamic

plantography method using the HSP DiaSled under static conditions (standing) and when walking in standard shoes. Patients with a foot size of at least 190 mm were examined for the available size range of measuring sensors in the form of insoles with pressure sensors. Therefore, 7 of 12 patients were examined using the DiaSled complex who underwent plantopodometry. The measuring sensors were inserted into the shoes for the examination, which minimally affected the foot function.

Statistical analysis

Descriptive statistics of quantitative indicators were calculated using the IBM Statistical Package for the Social Sciences version 23.0 system for the entire traditional set of characteristics (mean value, scatter of data [standard deviation], minimum, maximum, median, and quartiles, as well as coefficients of variation of the study characteristics for a group of patients were examined by biomechanical methods).

RESULTS

Forty operated patients were distributed into four groups based on the degree of shortening of the donor toes compared with the contralateral foot by performing physical examination of the feet (Fig. 1). The middle phalanx of toes II or IV was harvested in 78% of children without shortening or with minor shortening of the donor toes. One child underwent middle phalanx transplantation of toe II, while the rest of the proximal phalanges of toe II (1 patient) or toe IV (6 patients), in the group of patients with moderate shortening of the donor toe (8 children). The main phalanx of toe IV was previously harvested in the 11 children with a pronounced toe shortening (by >1 nail plate).

The distribution of 49 cases according to the degree of shortening of donor toes after harvesting of non-vascularized phalanges for transplantation to the hand revealed nil, minimum, moderate, and pronounced shortening in 12 (24.5%), 18 (36.7%), 8 (16.3%), and 11 (22.5%) patients, respectively.

Questionnaire score

None of the patients or their parents expressed regret after the surgery despite the noted toe shortening. They did not notice any visible changes in gait after the treatment. During the Oxford Ankle Foot Questionnaire, parents of 4 children (one 1-year-old boy and three 6–10-year-old girls) noted a little discomfort by the foot appearance.

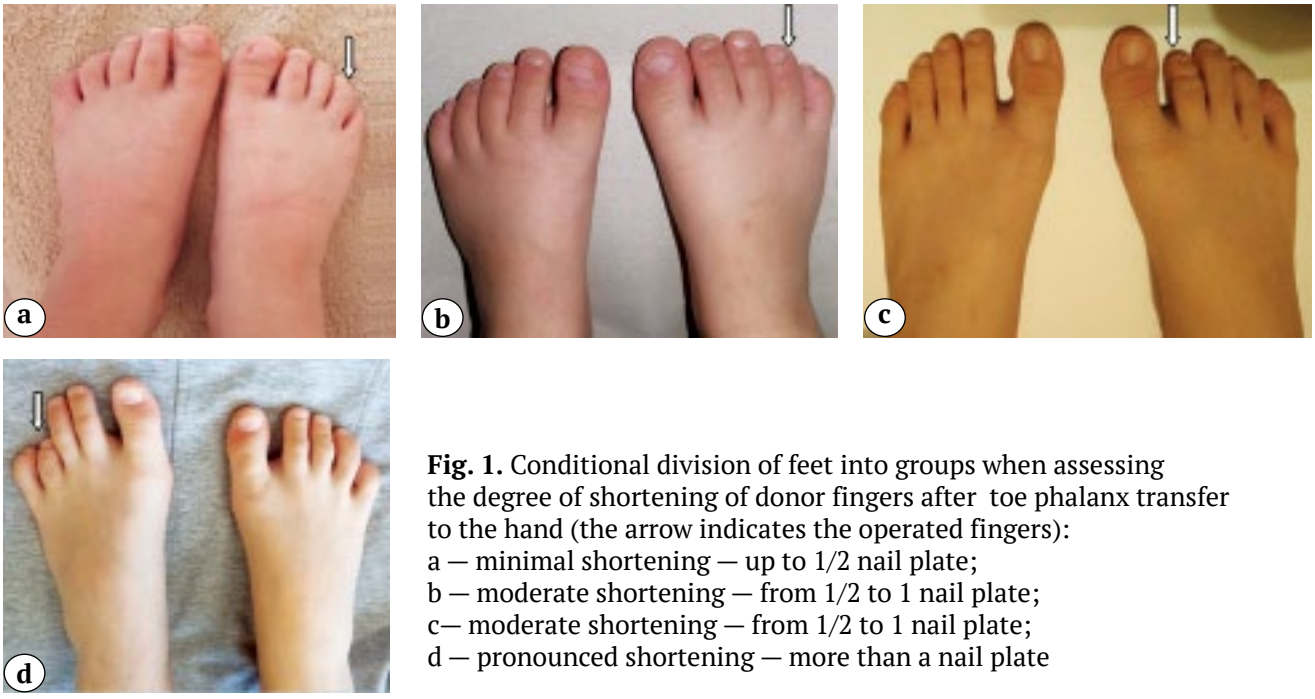


Fig. 1. Conditional division of feet into groups when assessing the degree of shortening of donor fingers after toe phalanx transfer to the hand (the arrow indicates the operated fingers):
a — minimal shortening — up to 1/2 nail plate;
b — moderate shortening — from 1/2 to 1 nail plate;
c— moderate shortening — from 1/2 to 1 nail plate;
d — pronounced shortening — more than a nail plate

Planto-podometric study

To assess the foot shape in 12 pediatric patients, using the planto-podometric study based on the graphic calculation analysis of the plantogram (an imprint of the plantar surface, reflecting the inclusion of foot zones in the perception of static load, as well as signs of local overloads of the plantar surface) and podometric images in projection onto three orthogonal planes, the following parameters characterizing the foot shape were evaluated (Fig. 2):

1) *Chopart joint angle* (α_1) characterizes the lateral deviation of the midfoot, formed by two rays originating from a point located on the outer contour of the foot image below at the level of 0.36-foot length from the heel (which corresponds to the level of the calcaneocubital joint). One of which is directed forward and passes through the most laterally protruding point of the foot contour in the bundled region, and the other is directed backward and passes through the most protruding point of the foot contour in the heel region;

2) *Angle of the toe I deviation* (α_2) characterizes the presence and severity of hallux valgus and represent an angle between the tangent to the contour of the main part of the foot on the medial side and the tangent to the toe contour on the same side;

3) *Forefoot coefficient* (k_1) characterizes the forefoot position (adduction or abduction) relative to the hindfoot and is calculated as the ratio of the width of the medial part of the line of bundles to the width of the lateral part of this line;

4) *Coefficient of the forefoot flatness* (k_2) characterizes the degree of the forefoot flattening and is calculated as the ratio of the foot width at the level of bundles to the foot length;

5) *Height of tuberosity of the navicular bone* (G′) characterizes the height of the internal longitudinal arch, but it reflects the arch pronouncement only indirectly because it also depends on the foot length, which correlates with the patient's age and is defined as the distance from the plane of support to the lower edge of the navicular bone tuberosity;

6) *Podometric index* (p) characterizes the pronouncement of the internal longitudinal arch of the foot; calculated as the ratio of the height of the navicular bone tuberosity to the foot length;

7) *Angle of valgus or varus deviation of the hindfoot* (β) characterizes the position of the hindfoot in the frontal plane and is calculated as the angle between the vertical and the median line of the hindfoot, connecting the middle of the Achilles tendon and the middle of the supporting surface of the heel.

A more detailed definition of these HSP Scan parameters is presented in the methodological manual [28].

The coefficient of interlimb asymmetry of the foot shape was calculated by correlating the parameter value obtained when measuring one foot with the value of the contralateral foot for each of these parameters. Here, the lower value was always divided by the larger one for a more demonstrational comparison of the obtained results when examining different patients (Table 3).

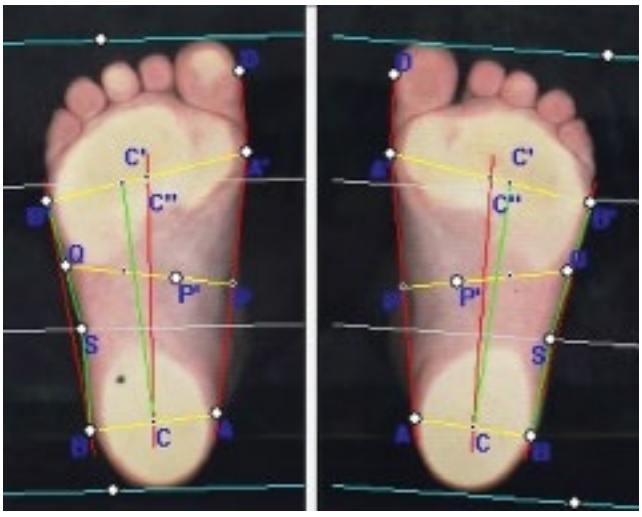


Fig. 2. A plantogram combined with a podometric image of the feet from below, of patient at the age of 5, 3.5 years after the middle phalanx of the IV finger of the right foot transfer and 1 year after a similar surgery on the left foot: no signs of the feet shape asymmetry were revealed

Table 3

Descriptive statistics of the assessment of interlimb asymmetry of the foot shape in the group of operated patients, n = 12

Statistical parameter	Coefficient of interlimb asymmetry of planto-podometric parameters						
	$K_{\alpha 1}$	$K_{\alpha 2}$	K_{k1}	K_{k2}	$K_{G'}$	K_p	K_β
Mean value ($\bar{M}$)	0.99	0.55	0.79	0.98	0.85	0.84	0.68
Standard deviation (m)	0.02	0.35	0.21	0.02	0.14	0.14	0.19
Median (Me)	0.99	0.53	0.90	0.98	0.88	0.88	0.71
Coefficient of variation (Cv), %	1.6	64.5	27.1	1.8	16.1	16.3	28.0

A significant asymmetry of the plantographic and podometric parameters of the donor and contralateral feet in the group of patients was revealed only for two parameters, including the angle of deviation of the toe I (α_2) and the angle of the frontal deviation of the hindfoot (β). Such asymmetry of these parameters in the group ($\bar{M}[K_{\alpha 2}] = 0.55$; $\bar{M}[K_\beta] = 0.68$) is accompanied by their pronounced variability ($Cv[K_{\alpha 2}] = 64.5\%$; $Cv[K_\beta] = 28.0\%$). A particularly pronounced asymmetry of the angle of deviation of the toe I of the donor and non-operated foot in a case was due to the congenital syndactyly of rays I-II of the donor foot in the patient. The patients' data were evaluated individually and in the group to clarify whether the detected asymmetry of the foot shape on an average was associated with the previous surgery (Table 4).

Table 4

Results of planto-podometric examination of patients

No.	Donor foot		Age, years	α_1, deg.			α_2, deg.			k_1			k_2			G′, mm			p, %			β, deg.		
	L	R		L	R	Cs	L	R	Cs	L	R	Cs	L	R	Cs	L	R	Cs	L	R	Cs	L	R	Cs
1		+	4	176	168	0,95	-2	-2	1,00	1,65	1,00	0,61	0,42	0,41	0,97	Unmeasurable						4	3	0,75
2		+	4	170	163	0,96	9	9	1,00	0,59	0,67	0,89	0,43	0,42	0,96	19	19	1,00	11,31	11,52	0,98	4	5	0,80
3	+	+	5	171	173	0,99	11	10	0,91	1,63	1,47	0,90	0,45	0,46	0,98	23	22	0,96	12,04	11,46	0,95	11	11	1,00
4		+	5	169	171	0,99	7	**14**	**0,50**	1,22	1,23	0,99	0,41	0,39	0,95	36	22	0,61	21,3	12,72	0,6	7	8	0,88
5	+	+	5	170	171	0,99	**12**	9	**0,75**	0,79	0,87	0,91	0,45	0,43	0,97	26	18	0,69	14,77	10,17	0,69	3	2	0,67
6	+		6	172	171	0,99	**11**	2	**0,18**	0,76	0,77	0,98	0,42	0,41	0,98	49	45	0,92	24,26	22,39	0,92	5	4	0,80
7	+		7	169	169	1,00	**-4**	1	**0,25**	1,11	1,05	0,95	0,39	0,41	0,97	25	26	0,96	12,69	13,27	0,96	2	5	0,40
8	+	+	7	170	168	0,99	1	9	0,11	0,92	1,00	0,92	0,36	0,36	1,00	38	28	0,74	18,27	13,27	0,73	5	4	0,80
9	+		9	170	170	1,00	9	**16**	0,56	1,08	0,95	0,89	0,42	0,42	1,00	38	33	0,87	18,54	15,79	0,85	5	2	0,40
10	+	+	9	176	173	0,98	-2	-1	0,50	0,7	1,33	0,52	0,4	0,4	1,00	8	7	0,88	3,09	2,71	0,88	5	3	0,60
11		+	10	173	173	1,00	9	11	0,82	0,5	1,13	0,44	0,38	0,38	1,00	37	38	0,97	16,59	17,04	0,97	2	1	0,50
12	+		13	171	171	1,00	2	0	0,00	0,38	0,84	0,46	0,4	0,41	0,99	27	19	0,70	11,64	7,98	0,69	7	4	0,57

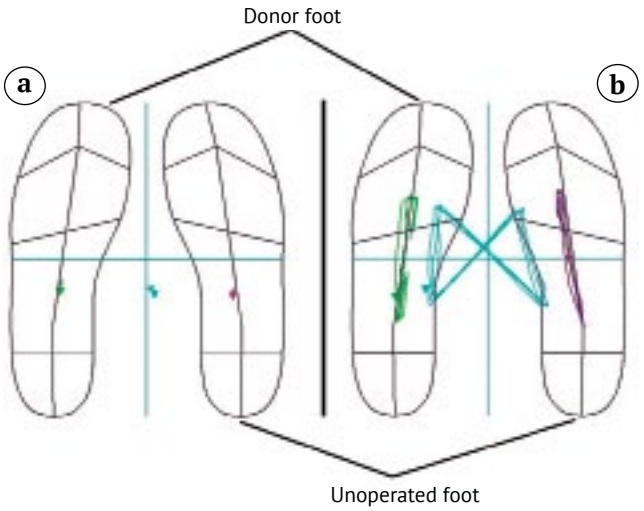
L — left foot; R — right foot; Cs — symmetry coefficient; bold font indicates the values of the operated foot parameters that are beyond the normal range in case there is also a significant asymmetry of the parameter when comparing both feet.

We paid special attention to the cases when the parameter values of the operated foot were beyond the normal range with the presence of asymmetry compared with the contralateral foot, which could indicate a pathological change as a result of surgery.

Data of patients 4 and 7 were noteworthy when analyzing the results of the deviation angle of the toe I. Valgus deviation of toe I on the operated foot was noted in patients 4 and 6, both the feet were donors in pediatric patient 5, and the deviation was on one of them (up to 12°). Varus deviation (up to 4°) was noted in toe I of patient 7 instead of valgus deviation. Additionally, patient 9 had a valgus deviation in toe I up to 16° on the contralateral foot. However, this is not regarded as a negative impact of surgery on the foot shape because a deviation from the norm for these patients was detected in the donor and contralateral limbs.

An analysis of the deviation parameters of the hindfoot showed that the results were within the reference values in most patients and slightly exceeded the norm in some cases.

A planto-podometric study of the operated and contralateral feet did not reveal any changes in other parameters (Chopart joint angle, arch height, coefficients and flattening of the forefoot, and podometric index), which could be directly related to the transplantation of the non-vascularized toe phalanges.



Barodynamic and plantographic examinations

The position and migration of the trajectory of the underfoot pressure center were analyzed during the examinations (Fig. 3).

The assessment in statics identified the displacement of the general load center in the frontal plane, which characterizes the support function of the lower limb. Concurrently, we did not reveal a support preference for a healthy limb, which would indirectly indicate a decrease in the static support ability of the donor foot.

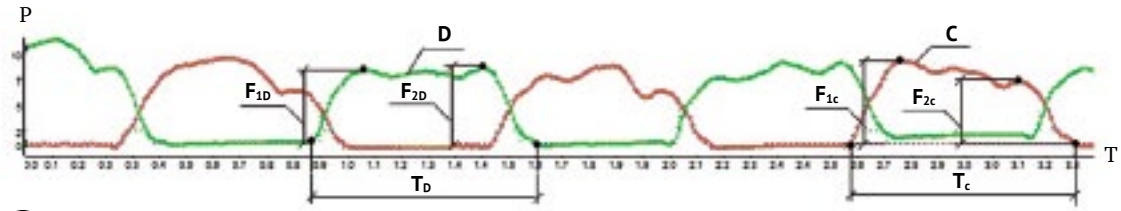
The study of patients' gait also included the measurement and analysis of asymmetry of the duration of the rolling motion on the donor (T_d) and contralateral feet (T_c), the anterior push forces (F_{1d} and F_{1c}), and the posterior push forces (F_{2d} and F_{2c}) (Fig. 4).

The interlimb asymmetry was assessed by correlating the parameter value obtained for the donor foot to the value of the contralateral one for each of the biomechanical parameters.

The barodynamic and plantographic examination results are presented individually because of the small group of examined patients (Table 5).

In 5 out of 7 pediatric patients examined, one foot was donor and the other foot was intact, which enabled us to compare them with each other to identify changes in the biomechanical characteristics of the operated foot. A decrease in the forces of the anterior and posterior push in the rolling motion (F_1 and F_2) and the rolling duration (T) of the donor foot was detected and compared with the contralateral one in 2 (No. 1 and No. 3) out of these 5 patients; whereas the reverse presentation was noted in 1 patient (No. 2). Concurrently, no significant decrease was found in the involvement of the donor forefoot (no decrease in the trajectory length of the pressure center in the forefoot area was detected), as well as a zonal or local overload of the operated or contralateral forefoot.

Fig. 3. Load distribution in the supporting contour of the feet of patient B. at the age of 9 years, 3 years after the the middle phalanx of the IV finger of the left foot transfer:
a — the position of the pressure centers in static;
b — migration of the trajectory of the pressure center when walking



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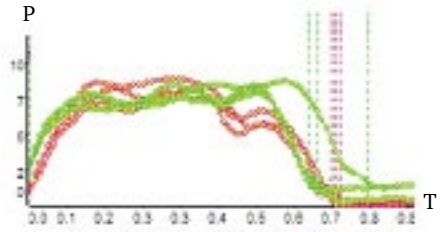


b

Fig. 4. Measurement of the load on the feet when walking patient at the age of 9 years, 3 years after the middle phalanx of the 4th toe of the left foot transfer:
a — in the mode of viewing the sequential display of graphs of the integral load on the feet in time by steps;
b — in the mode of transposition (overlapping) graphs of the integral loads in steps.
Designations: T — duration of rolling over the foot, sec; F_1 — force of anterior thrust; F_2 — posterior; D — donor foot; C — contralateral foot; P — pressure under the feet, conventional units

DISCUSSION

Autografting of non-vascularized toe phalanges improves the appearance and function of the hand by restoring the finger anatomy by transplanting the toe phalanx into the finger defect; however, according to some authors, it negatively impacts the appearance of the donor feet, worsens the quality of life due to difficulties with the selection and wearing of shoes and causes emotional problems [17, 25]. Concurrently, changes in gait, associated with toe phalanges transplantation, were not observed [16, 22].

An interesting clinical and radiological study by Garagnani et al., showed that changes in donor sites in 40 patients with underdevelopment of the fingers after 136 toe phalanges transplantations with extensor tendon restoration after the phalanx harvesting was performed from 1991 to 2007. The Oxford Ankle Foot Questionnaire study, which reflects the degree of satisfaction of patients and their parents was carried out, and X-rays were examined. Patients reported a tendency to hide their feet, where >80% of patients and their legal representatives reported some degree of emotional problems related to their feet and >60% of patients noted problems with the selection and wearing of the shoes. From a clinical perspective, the shortening of donor toes was individual, and excessive mobility was registered in 76%–100% of cases; thus, the increase in clinical deformity of the donor feet was expected during the harvest of several phalanges from one foot. X-ray examination also revealed hypoplasia of the surrounding bone structures, including the distal phalanx, the middle phalanx, and the metatarsal. One patient underwent amputation of toe IV of both feet due to their instability and to improve the appearance of the feet [25].

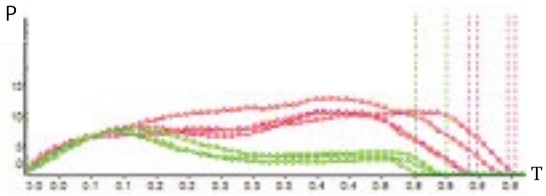
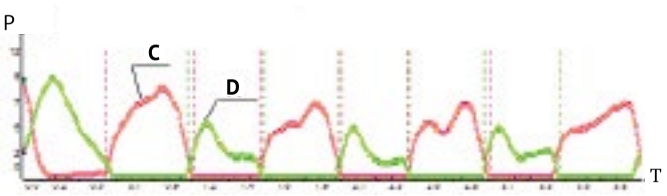
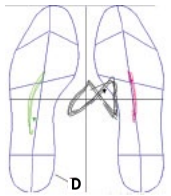
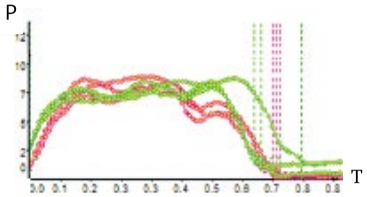
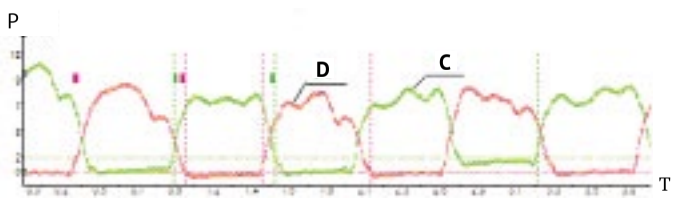
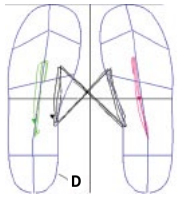
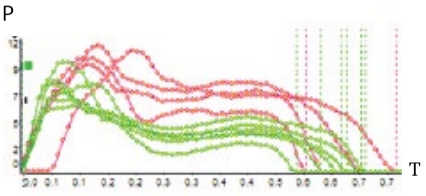
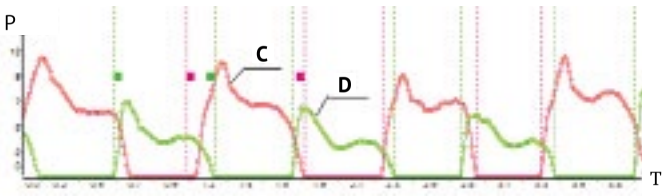
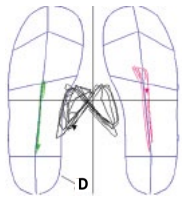
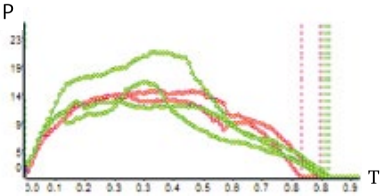
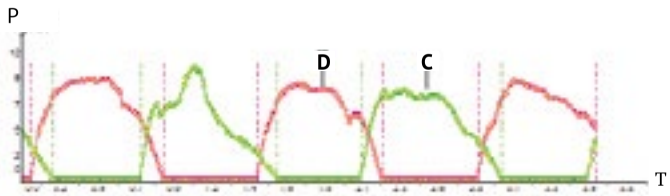
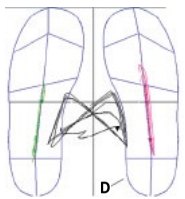
Bone autografting of the formed defect [10, 15, 16, 17], as well as suturing together the flexor and extensor tendons of the toe [14], or fixation of the toe for 4–5 weeks with preservation of diastasis, was performed to prevent donor toe shortening and deformity [14, 17]. Concurrently, the foot is compromised to the least extent during bone autografting; however, there is a risk of graft lysis, and an absence of mobility in the toe is also noted [16, 17].

Unglaub et al. followed up cases of linear shortening of donor toes in the previously operated patients, who did not significantly affect their gait [22].

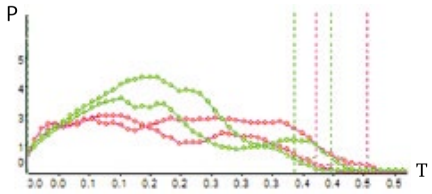
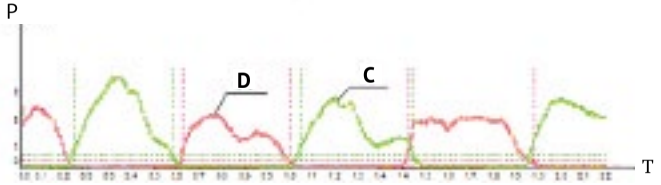
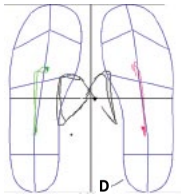
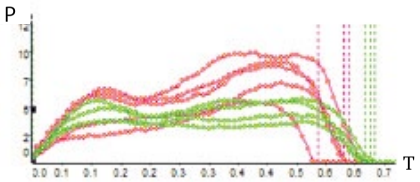
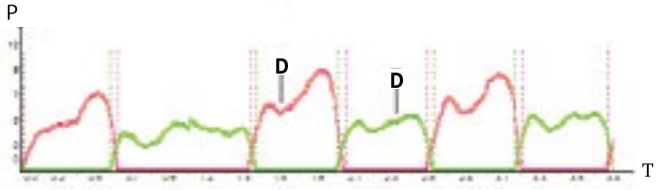
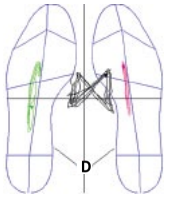
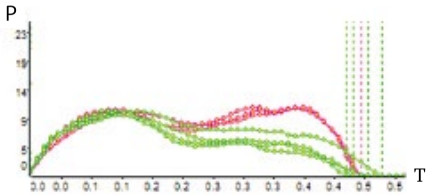
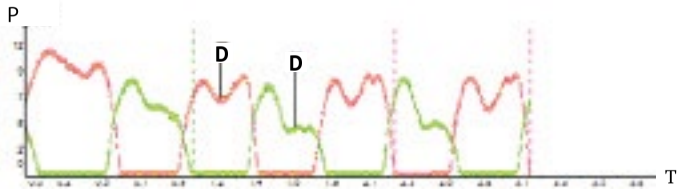
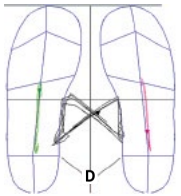
In reliance on the literature available, we conducted a study of the state of the donor feet in patients in the long-term period postoperatively after the harvesting of non-vascularized phalanges.

Table 5

Results of barodynamic and plantographic examination of 7 patients aged 6–13 y.o.

No.	Age at the time of examination	Time after surgery	Graphs of the integral load in the superposition mode by steps	Change in the total load on the feet when walking	Migration of the pressure center trajectory
1	13 years	2 years			
2	9 years	3 years			
3	6 years	4 years			
4	7 years	7.5 years			

End of the table 5

No.	Age at the time of examination	Time after surgery	Graphs of the integral load in the superposition mode by steps	Change in the total load on the feet when walking	Migration of the pressure center trajectory
5	10 years	9 years			
6	9 years	One year on the left foot, 6 months on the right foot			
7	7 years	3 years on the right foot, 2 years on the left foot			

D — donor foot; C — contralateral foot; P — pressure under the feet, conventional units; T — duration of rolling over the foot, sec.

A survey of patients and their legal representatives using the Oxford Ankle Foot Questionnaire did not reveal complaints about impaired support and gait, pain, limitations in wearing shoes, and emotional problems due to the appearance of toes although our clinical and radiological examination confirms the authors' findings on the linear shortening of the donor toes (more significant shortening was detected in those pediatric patients whose proximal phalanx was harvested). Our study was supplemented by an instrumental biomechanical assessment of donor and contralateral feet and revealed no significant changes in their shape and statodynamic function in the long-term period after harvesting the toe phalanges for autografting to the hand.

Study limitations

The result interpretation of the biomechanical examination of the patients' feet was small sample size. Also, limited data availability (four reported studies) determined the relevance of further studies of this issue.

CONCLUSION

The computer plantography and podometry results showed that the data obtained on the effects of non-vascularized phalanx transplantation of the toes on pathological changes in the longitudinal arch, adduction/abduction of the middle or anterior segments, flattening of the anterior segment, or valgus/varus angulation of the posterior segment of the operated foot were not statistically significant. Additionally, no significant changes were revealed in the statodynamic function of the operated foot in the long-term period after harvesting the toe phalanges for transplantation to the hand, according to the barodynamic and plantographic examination results.

The method for autografting of non-vascularized toe phalanges can be used for finger reconstruction without the risk of pronounced impairment in the statodynamic function of the donor zones. However, the data array available for examination, which is less due to the low incidence of pathology and its surgical treatment using the study method, makes it expedient to further follow-up the condition of the feet in a larger number of patients and for longer periods postoperatively.

DISCLAIMERS

Author contribution

Matveev P.A. — research conception and design, literature review, the collection and processing of data, data statistical processing, text writing and editing.

Shvedovchenko I.V. — the collection and processing of material, text writing and editing.

Smirnova L.M. — research conception and design, processing of data, text writing and editing.

Koltsov A.A. — the collection and processing of data, text writing and editing.

All authors have read and approved the final version of the manuscript of the article. All authors agree to bear responsibility for all aspects of the study to ensure proper consideration and resolution of all possible issues related to the correctness and reliability of any part of the work.

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Competing interests. The authors declare that they have no competing interests.

Ethics approval. The study was approved by the local ethics committee of Federal Scientific Center of Rehabilitation of the Disabled named after G.A. Albrecht, protocol No 1, 02.06.2022.

Consent for publication. Written consent was obtained from legal representatives of children for publication of relevant medical information and all of accompanying images within the manuscript.

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