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Bone-Periosteal-Muscle Flap for Ulnar Lengthening in Children with Congenital Radial Club Hand

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Background. Congenital radial club hand is characterized by the underdevelopment of all forearm structures. Ulnar bone shortening ranges from 24.7% to 50.0% compared to the intact limb.

The aim of the study was to evaluate the outcomes of ulnar lengthening by distraction osteogenesis in patients with congenital radial club hand type IV who underwent osteotomy with the formation of a bone-periosteal-muscle flap, and to compare these results with the treatment outcomes of the patients who had standard (oblique) ulnar osteotomy.

Methods. The main group consisted of 20 patients who underwent osteotomy with the formation of a bone-periosteal-muscle flap during ulnar lengthening between 2019 and 2022. The control group included 19 patients (22 forearms) who underwent oblique ulnar osteotomy between 1998 and 2018. The following indicators were evaluated: length of the regenerate, distraction time, correction period, fixation index, osteosynthesis index, and complications.

Results. A lengthening of 4.1 cm was achieved (30.7% of the initial ulnar bone length). The correction of angular deformity was 71.4%. Greater correction was achieved with osteotomy in the proximal ulna. In the subgroup with proximal segment osteotomy, the distraction and osteosynthesis indices were 25.6 and 25.7 days/cm, respectively. In the mid-third osteotomy group, these indices were 42.3 and 42.6 days/cm, respectively. Complications were limited to inflammatory phenomena in 30% of cases. All patients in the main group exhibited successful regenerate formation. Thus, the bone fragment with a periosteal-muscle pedicle serves as an additional source of osteogenesis during distraction.

Conclusions. This study demonstrates the appropriateness of osteotomy with the formation of a bone-periosteal-muscle flap in children with congenital radial club hand. This technique allows for greater deformity correction, a shortened regenerate formation period, and a reduction in complications.

Keywords: congenital radial club hand, children, ulnar lengthening, compression-distraction osteosynthesis, bone-periosteal-muscle flap, Ilizarov method.

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Использование костно-надкостно-мышечного лоскута при удлинении локтевой кости у детей с врожденной лучевой косорукостью

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Реферат

Введение. Врожденная лучевая косорукость характеризуется недоразвитием всех структур предплечья. Укорочение локтевой кости составляет в среднем 24,7–50,0% по сравнению с интактной конечностью.

Цель исследования — оценить результаты лечения пациентов с врожденной лучевой косорукостью IV типа методом дистракционного остеосинтеза, которым выполняли остеотомию с формированием костно-надкостно-мышечного лоскута, и сравнить их с результатами стандартной (косой) остеотомии локтевой кости.

Материал и методы. Основную группу составили 20 пациентов (период лечения с 2019 по 2022 г.), которым выполняли остеотомию с формированием костно-надкостно-мышечного лоскута при удлинении локтевой кости. Контрольная группа включала 19 пациентов (22 предплечья), которым с 1998 по 2018 г. выполняли косую остеотомию локтевой кости. Проводили оценку следующих показателей: длина полученного регенерата, время дистракции, период коррекции, индекс фиксации, индекс остеосинтеза, осложнения.

Результаты. Получено удлинение на 4,1 см (30,7% от исходной длины локтевой кости). Коррекция угловой деформации составила 71,4%, при этом большую коррекцию удалось получить при выполнении остеотомии в проксимальном отделе. Индексы фиксации и остеосинтеза в подгруппе остеотомии в проксимальном отделе составили 25,6 и 25,7 дней/см соответственно, при остеотомии в средней трети — 42,3 и 42,6 дней/см. Из осложнений зафиксированы воспалительные явления в 30% случаев. В 100% случаев у пациентов основной группы получено формирование регенерата. Таким образом, фрагмент костной ткани с надкостно-мышечной ножкой является источником дополнительного костеобразования при дистракции.

Заключение. Проведенное исследование доказало целесообразность использования остеотомии с формированием костно-надкостно-мышечного лоскута у детей с врожденной лучевой косорукостью. Применение данной методики позволяет получить большую коррекцию деформации, сократить сроки формирования регенерата и количество осложнений.

Ключевые слова: врожденная лучевая косорукость, дети, удлинение локтевой кости, компрессионно-дистракционный остеосинтез, костно-надкостно-мышечный лоскут.

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INTRODUCTION

In congenital radial club hand (CRH), also known as radial longitudinal deficiency, hypoplasia of all structures of the upper limb is observed. The underdevelopment of the radius and first finger is the most common manifestation [1]. The classification proposed by L.G. Vaupei and M.S. Klug, which divides CRH into four types based on the extent of radial underdevelopment, is commonly used [2]. Radial hypoplasia leads to radial deviation of the wrist and hand, often necessitating primary correction [3]. The most common surgical treatments include centralization and its modifications (such as radialization and ulnarization), the creation of a "fork" of the wrist joint through microsurgical autotransplantation of the foot joint, and splitting the distal part of the ulna in the sagittal plane [4, 5, 6]. The correction of the forearm deformity using various methods of hand stabilization on the ulna allows for better function of the forearm and hand, as well as for the aesthetic appearance of the upper limb [7]. Additionally, patients often undergo various reconstructive procedures on the hand to achieve a bipedal grip, including first metacarpus formation, tendon grafting, and pollicization of the second finger [8, 9, 10].

Along with the described symptoms, children with RCH experience forearm shortening due to the underdevelopment and "saber-like" deformity of the ulna. This presents a significant aesthetic and functional problem for patients, particularly in cases of unilateral lesions [11, 12]. Forearm shortening compared to the intact upper limb typically ranges from 24.7% to 50.0% [1, 12, 13, 14]. In unilateral lesions, the quality of life is generally close to normal, though patients may face challenges in choosing clothing. The most difficult aspect for the child and their family is often the emotional distress of being different from other children. In cases of bilateral lesions, in addition to the emotional burden, there are limitations in self-care and simple household tasks (such as performing hygiene procedures, finding clothes, tying shoelaces, buttoning buttons, and cooking). Moreover, as patients age, they may encounter difficulties in choosing a profession. Therefore, in unilateral lesions, lengthening is primarily performed for cosmetic reasons, while in bilateral lesions, it is done for functional reasons [7, 11, 15]. It has been mathematically proven that performing a corrective osteotomy with simultaneous correction of the "saber-like" deformity of the ulna does not lead to significant lengthening, even when multiple osteotomies are performed [16]. This is why patients with RCH require limb lengthening using compression-distraction osteosynthesis.

In 1995, Professor A.P. Pozdeev proposed a limb-lengthening method at the H. Turner National Medical Research Center for Children's Orthopedics and Trauma Surgery. This method involved performing a transverse osteotomy along with an additional osteotomy in the shape of a rectangle, positioned perpendicularly and symmetrically to the main osteotomy. This shaped osteotomy creates a vascularized periosteal-muscle flap, which serves as an additional source of bone formation during distraction (patent of the Russian Federation No. 2106826). A.P. Pozdeev and E.V. Bukharev later presented the results of using this method, with a modification of the flap into a semicircle, in the correction of lower limb deformities (Figure 1). Based on substantial clinical evidence, the authors demonstrated that this technique reduces the remodeling time of the distraction regenerate and shortens the period of external fixation. This allows for earlier weight-bearing on the limb [17]. However, in our search for publications, we did not find any that described the use of this method for treating children with upper limb pathology.

Figure 1. Formation of a bone-periosteal-muscle flap during femoral lengthening in patients [17]

The aim of the study was to evaluate the outcomes of ulnar lengthening by distraction osteogenesis in patients with congenital radial club hand type IV who underwent osteotomy with the formation of a bone-periosteal-muscle flap, and to compare these results with the treatment outcomes of the patients who had standard (oblique) ulnar osteotomy.

METHODS

Between 2019 and 2022, in the Department of Reconstructive Microsurgery and Hand Surgery of the H. Turner National Medical Research Center for Children's Orthopedics and Trauma Surgery ulna lengthening was performed on 20 patients (20 forearms) with Bayne and Klug type IV congenital radial club hand. The study included 13 boys and 7 girls. Their mean age was 8.8±3.5 years (5 to 15 years). Twelve patients underwent ulnar lengthening for the first time, 8 had already undergone length correction, and due to persisting shortening, a decision was made to perform a second operation. These patients formed the main group.

The control group included 19 patients (22 forearms) with Bayne and Klug type IV congenital RCH. There were 13 boys and 6 girls, with a mean age of 6.9±3.0 years (3 to 14 years), who underwent ulnar lengthening with oblique osteotomy between 1998 and 2018 [11].

Given the previously obtained good results for elbow lengthening in the distal part of the ulna [11], it was decided not to use this technique in the lower third of the ulna. Instead, the patients in both groups were divided into two subgroups based on the level of osteotomy. The determination of the osteotomy level depended on the location of the apex of the ulna deformity. If the apex of the deformity was located in the proximal region, the osteotomy was performed in the upper third of the ulna (subgroup I). If the angular deformity was located in the diaphysis, the osteotomy was performed in the middle third (subgroup II).

All patients of the main and control groups underwent various forearm interventions (one- or two-stage centralization surgery, and in 95% of patients - reconstructive operations to form a bilateral grip) before inclusion in the study.

Methods of patient examination

All patients underwent a clinical examination that included an assessment of the range of motion in the elbow joint and the joints of the fingers. X-rays of the forearm, hand, and elbow joint were taken in two views. The radiographs were used to measure the length of the ulna, the percentage of ulna shortening compared to the intact limb, and the angle of ulnar deformity.

Surgical technique

Ulna lengthening using percutaneous osteosynthesis was performed as follows:

1) under fluoroscopy, two half-pins were inserted into the proximal and distal sections of the ulna and fixed to two ring supports;

2) a dorsolateral incision, approximately 3-4 cm long, was made at the planned lengthening site on the forearm;

3) the posterior edge of the ulna was exposed from the dorsal side without separating the periosteum;

4) the ulna was perforated with a 1.5 mm drill bit to create a semicircular bone-periosteal-muscle flap, measuring 1.5-3.0 cm depending on the initial bone length (average 1.7±0.5 cm), involving half the diameter of the ulna;

5) the palmar cortical layer of the ulna was cut with a chisel, forming a bone-periosteal-muscular flap that remained attached to the periosteum and muscle (ulnar extensor of the hand);

6) a transverse osteotomy was performed on the remaining half of the ulna's diameter;

7) the percutaneous ring supports were connected with three rods, and if necessary, deformity correction was performed simultaneously at the osteotomy level;

8) a wire was inserted through the II-V metacarpal bones, fixing the hand to the external supports.

In three patients with elbow joint instability, two crossed wires were additionally placed in the lower third of the humerus and fixed to the external support to prevent forearm dislocation. The frame elements in the shoulder and proximal forearm were connected by two rods with hinges at a 90° angle at the elbow joint.

Distraction began on the 7th day after surgery, with a rate of 0.25 mm three times per day. Massage and physical therapy were conducted 4-5 times daily for 15-20 minutes to maintain movement in the elbow joint (with temporary unlocking of the hinges) and in the fingers to prevent contracture formation. One month after the distraction phase ended, partial disassembly of the external fixator (removing supports from the humerus and hand) was performed. Once the distraction regenerate reached phase IIIB, according to V.I. Sadofieva's radiological criteria [18], the external fixator was fully removed, and the upper limb was immobilized in a circular cast for one month.

In the control group, the external fixator was applied in the same manner as in the main group. However, an oblique osteotomy was performed

at the planned lengthening site, followed by correction of any ulnar angular deformity, if necessary. The timing of the beginning of distraction and rehabilitation procedures was comparable to that of the main group.

Evaluation of outcomes

The following parameters were assessed when analyzing the treatment outcomes in the main group: 1) length of the regenerate obtained; 2) distraction time; 3) correction period; 4) fixation index; 5) osteosynthesis index 6) complications (analyzed according to the J. Caton classification) [19]. All parameters were compared with the control group to evaluate the effectiveness of this osteotomy method in patients with congenital RCH. No assessment of limb function before and after treatment was performed.

Statistical analysis

The patient database was divided into groups based on the osteotomy level and organized in Excel spreadsheets. The results of the main and control groups were compared using the previously defined parameters. Calculations were performed using SPSS v.6 and Statgraphics 18 software. Descriptive statistics were used to calculate the arithmetic mean (M), standard deviations (SD), median (Me) with 25th and 75th percentiles [Q1; Q3], minimum and maximum values, as well as Student's t-test and Fisher's F-test. For parameters that did not follow a normal distribution, nonparametric tests were used, including the Mann-Whitney U-test and the Wilcoxon test. A critical significance level of 0.05 was set, meaning null hypotheses were rejected at $p < 0.05$.

RESULTS

The results of the study for the main group are presented in Table 1. The range of motion in the elbow joint, both pre- and postoperatively, did not differ significantly in any of the patients. Flexion-extension contracture was observed (flexion: 144.8±9°, extension: 7.8±2.6°). No statistically significant differences were found between the main and control groups in this regard ($p \geq 0.05$).

The preoperative shortening of the ulna relative to the intact limb averaged 32.7±10.5%, which decreased to 12.9±10.9% postoperatively. The ulna was lengthened by an average of 30.7% (compared to 36% in the control group) relative to its initial length. There were no statistically significant differences between the main and control groups in the pre- and postoperative periods ($p = 0.25$ and $p = 0.11$, respectively). Thus, the type of osteotomy did not affect the degree of lengthening. However, comparing pre- and postoperative parameters within the main group using the Wilcoxon test showed significant improvement ($W = 40.0$; $p = 0.0001$), confirming the effectiveness of the performed surgical treatment (Table 2).

Table 1

Comparative assessment of radiological and time parameters before and after surgery in the main group, M±SD (min-max)

Parameter	Subgroup I (the upper third of the ulna), n=9		Subgroup II (the middle third of the ulna), n=11	
	Before	After	Before	After
Radiological				
Ulna shortening compared to the intact limb, %	30.1±3 (14.3-47.1)	12.5±10.8 (0.5-32.5)	33.6±8.5 (24.9-51.3)	12.4±11.5 (0.0-35.2)
Angle of ulna deformation, deg.	15± 13.8 (2-45)	3 ±1.7 (1-5)	25 ± 8.6 (5-35)	7.2 ± 4.9 (1-15)
Time				
Correction period, days	46.7±11.6 (54-91)		64.5±13.8 (30-82)	
Length of the regenerate obtained, cm	4.1±0.9 (3.1-5.5)		4.1±0.7 (3.9-5.2)	
Obtained lengthening of the ulna as a percentage of its initial length	29.1±8.6 (20.9-38.0)		32.3±13.6 (17.5-49.2)	
Fixation index, days/cm	25.6±6.4 (19.9-39.4)		24.8±7.9 (14.9-35.9)	
Osteosynthesis index, days/cm	43.3±10.7 (29.8-64.8)		41.2±10.4 (27.9-58.8)	

When comparing different subgroups, no statistically significant differences were observed between the osteotomy with flap formation and the oblique osteotomy in the proximal ulna (W = 62.5; p = 0.6096). However, in the middle third of the ulna, lengthening after the correction of deformity was greater in the main group (W = 6.5; p = 0.0087), indicating the appropriateness of the osteotomy with the bone-periosteal-muscular flap in this region.

The preoperative angle of ulnar deformity in the main group was 20.5° (17.1° in the control group), and postoperatively, it decreased to 5.3° (7.6° in the control group). Comparing the pre- and postoperative medians within the main group showed significant improvement (W = 52.5; p = 0.0001), with a correction rate of 71.4% (Table 3).

No statistically significant differences were found in the angle of deformity in the proximal ulna between the main and control groups (W = 74.5; p = 0.9092). However, the osteotomy with a bone-periosteal-muscle flap provided greater correction than the oblique osteotomy (W = 117.0; p = 0.0081). There were no differences in the angle of deformity in the middle part of the ulna between the main and control groups, both preoperatively (W = 33.5; p = 1.0) and postoperatively (W = 31.5; p = 0.9186) (Table 4).

Table 2

Ulnar bone shortening in the pre- and postoperative periods in the main and control groups, %

Statistical indicator	Before surgery		After surgery	
	Main group	Control group	Main group	Control group
M±SD	32.7±10.5	36.2±13.0	12.9±10.9	16.0±10.5
[Q1;Q3]	[25.4;41.2]	[29.7;46.0]	[2.3;19.8]	[6.7;21.4]
min-max	2-45	2-40	1-5	2-30

Table 3

Obtained lengthening following osteotomy in the upper and middle thirds of the ulna, M±SD [Q1;Q3] (min-max)

Level of ulnar osteotomy	Main group	Control group
The upper third, cm	4.1±0.9 [3.4;5.1] (3.1-5.5)	3.8±1 [2.9;4.7] (1.5-5.0)
The middle third, cm	4±0.7 [3.5;4.7] (3.9-5.2)	2.4±0.9 [1.5;3.5] (1.3-3.7)

Table 4

Analysis of the obtained ulnar deformity correction in patients from the main and control groups, M±SD [Q1;Q3] (min-max)

Level of ulnar osteotomy	Before surgery		After surgery	
	Main group	Control group	Main group	Control group
The upper third, deg.	15±13.8 [3.5;23.5)] (2-45)	15.1±11.8[5;20)] (2-40)	3±1.7 [1.5;5.5)] (1-5)	8.1±8 [5;9.3] (2-30)
The middle third, deg.	24.9±8.7 [22;32] (5-35)	22.5±16 [4.3;37.8] (2-40)	7.2±4.9 [2;10] (1-15)	6.5±4.5 (1.5;10] (2-10)

When comparing the medians of the fixation and osteosynthesis indices using the Mann-Whitney U-test, no statistically significant differences were found between the main and control groups (p = 0.08 and p = 0.06, respectively), indicating similar consolidation times for both osteotomy methods. However, in the middle third of the ulna, statistically significant differences in the fixation index were observed, showing the effectiveness of this method (p = 0.04). When comparing the values, no difference was found in the osteosynthesis index (p = 0.12) (Table 5).

The lack of differences in the osteosynthesis index in the second subgroups can be explained by the fact that only 3 patients (50%) in the control group had sufficient regenerate formation to allow for the removal of the external fixator. In the other cases, an atrophic regenerate was formed, requiring bone grafting to replace the defect. Osteosynthesis index in these patients was equal to 0. In the main group, a bone regenerate was formed in 100% of cases, allowing for the removal of the external fixator.

The number of complications in the main group was lower than in the control group, However, no statistically significant differences were observed (t = -0.7727; F = 1.7368). In the main group, only soft tissue inflammation at the pin sites was noted (classified as first-degree complications according to Caton). The inflammatory process was managed with dressings and oral antibiotics (Table 6).

Table 5

Fixation index and osteosynthesis index in patients from the main and control groups, M±SD [Q1;Q3] (min-max)

Level of ulnar osteotomy	Fixation index		Osteosynthesis index	
	Main group	Control group	Main group	Control group
The upper third, days/cm	25.6±6.4 [19.4;28.5] (19.9–39.4)	22±10 [17.1;22.8] (94.7-50.7)	43.3±10.7 (33.7;49.3) (29.8-64.8)	35.4±10.5 (31;36.1) (19.4-64.0)
The middle third, days/cm	25.7±8.2 [17.4;34.2] (14.9-35.9)	47.4±21.5(29.7;56.1) (29.7-71.3)	42.6±10.6(33.1;53.3) (27.9-58.8)	75.5±45.6(40.5;97.1) (40.5-127.1)

Table 6

Complications in ulnar lengthening in patients from the main and control groups, n (%)

Complication	Main group	Control group
Soft tissue inflammation at the pin sites	6 (30)	2 (9.1)
ПPin fractures	0 (0)	2 (9.1)
Joint contractures	0 (0)	0 (0.0)
Formation of an atrophic regenerate or a nonunion	0 (0)	6 (27.3)
Elbow joint dislocation	0 (0)	2 (9.1)
Recurrence of hand deviation	0 (0)	1 (4.5)
In total	6 (30)	13 (59.1)

DISCUSSION

The shortening of the forearm in cases of RCH is a significant clinical and aesthetic problem for patients. If surgical treatment begins at a very young age, repeated interventions may be required to maintain balanced forearm length due to the recurrence of deformity [12, 20]. Our study included patients with an average age of 8.8±3.5 years. Additionally, in some cases, repeated lengthening was performed, which is consistent with findings in the literature [1, 12, 21].

Some authors suggest that up to 7 cm of regenerate can be achieved, but excessive lengthening may lead to complications due to the limitation of soft tissue elasticity [16]. Even when the expected length is achieved, the affected

bone may shorten again over time, so complete correction of the forearm length discrepancy is not always necessary for a successful outcome [21, 22]. This was confirmed by our results, as 8 patients in the main group had previously undergone ulnar lengthening, yet significant forearm shortening persisted as they grew. In our study, the ulna was lengthened by an average of 4.1 cm, which aligns with the results reported in the literature [23]. At the same time, greater lengthening was achieved using a bone-periosteal-muscle flap in the middle part of the ulna.

In addition to correcting the length discrepancy, the main objective in treating patients with RCH is to correct ulnar deformity. According to S. Farr et al., the average angle of deformity is 25.6°, and even after intraoperative correction, it persists in the long term, averaging 17° [24]. In our study, we achieved correction of the ulnar deformity, but it persisted with growth.

Unfortunately, only a small number of studies address complications in the treatment of RCH, particularly in limb lengthening. When correcting forearm deformities in patients with RCH using compression-distraction osteosynthesis, the incidence of complications can reach 100%. The most frequently reported complications include soft tissue inflammation, atrophic regenerate formation, joint contractures, and ulnar fractures after the removal of the external fixator [1, 24, 25]. In our study, we observed inflammatory processes in 30% of cases in the main group.

Excessive lengthening can lead to elbow joint dislocation and the development of flexion contractures in the ulnar-wrist joint and fingers [20]. In our study, 2 patients in the control group experienced elbow joint dislocation. We assessed clinical elbow joint instability along with radiological findings, including underdevelopment of the coronoid process and olecranon. If instability was evident, the fixation of the humerus was performed during the correction period to prevent elbow joint dislocation.

According to the literature, physiotherapeutic treatment, including physical therapy aimed at improving the range of motion, and external fixation of the hand during the correction period can prevent flexion contractures of the ulnocarpal joint and fingers. Additionally, even if lengthening is performed for cosmetic reasons, an increase in muscle strength and improved grip are observed after these procedures [7, 11]. In our study, all patients underwent percutaneous hand fixation and physiotherapeutic treatment, which helped to prevent the aforementioned complications.

The formation of an atrophic regenerate is reported in 12.5–20.0% of cases [21, 24, 26]. In the control group, the most common complication following oblique osteotomy was atrophic regenerate formation (27.3%). This complication was particularly prevalent in patients with deformity correction in the middle third of the ulna (50% of cases in this subgroup). Reducing the distraction rate and increasing the fixation period did not lead to the maturation of the regenerate. The causes of this complication may include congenital microcirculation disorders due to the hypoplasia or aplasia of the radial artery, endosteal damage, and reduced intraosseous blood flow due to previous multiple surgical interventions [27, 28]. When lengthening the lower limbs with standard osteotomy, A.P. Pozdeev and E.V. Bukharev describe the depletion of bone tissue's regenerative capacity, which leads to the formation of an atrophic regenerate. However, under the stimulating influence of a well-vascularized bone fragment, the regeneration process proceeded evenly [17]. In our study, using osteotomy with the formation of a bone-periosteal-muscular flap at a standard distraction rate, positive results were achieved in 100% of cases within timelines comparable to those reported in the literature. Thus, this osteotomy technique is effective in patients with congenital RCH, particularly when performing osteotomy in the middle third of the ulna, due to the stimulating effect of osteoplastic intervention.

The absence of complications such as elbow dislocation and recurrence of hand deviation in the main group is related to the analysis of previous lengthening procedures in the control group. In several patients, additional fixation of the elbow joint was performed when clinical examination revealed instability and a possible tendency for dislocation. The recurrence of hand deviation in the control group was observed when osteotomy was performed in the proximal region without the external fixation of the hand. This complication was avoided in the main group due to the fixation of the hand in all patients, regardless of the osteotomy site.

In the main group, the fixation index averaged 25.1±7.1, and the osteosynthesis index averaged

42.1±10.3. These results are comparable to those reported in the literature, which confirms the feasibility of the application of this method [20, 21, 24]. However, when performing this type of osteotomy in the middle third of the ulna, the fixation index was 45% lower compared to the control group. When lengthening the lower limbs using a bone-periosteal-muscle flap, it was found that the phase of primary bone tissue formation occurred 6.1 days earlier per centimeter of lengthening [17]. Thus, the data indicate that the use of such a flap in the upper limbs is effective.

CONCLUSIONS

The results of this study have shown the effectiveness of osteotomy with the formation of a bone-periosteal-muscle flap in children with congenital radial club hand, particularly when performed in the middle third of the ulna. This method enhances deformity correction, accelerates regenerate formation, and reduces the number of complications.

DISCLAIMERS

Author contribution

All authors made equal contributions to the study and the publication.

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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