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TREATMENT OF PEDIATRIC PATIENTS WITH LOWER LEG DEFORMITIES ASSOCIATED WITH PHYSEAL ARREST: ANALYSIS OF 28 CASES

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Aim. To retrospectively analyze the results of two treatment methods for lower leg deformities associated with partial growth arrest.

Materials and methods. Group I comprised 15 children who underwent osteotomy, acute overcorrection, and external fixation by Ilizarov with subsequent lengthening of the segment. Group II comprised 13 patients who underwent epiphysiodesis of the healthy part of the growth plate by drilling, osteotomy with external fixation by use of an Ortho-SUV Frame, and subsequent gradual deformity correction and lengthening.

Results. In group I, overcorrection of varus deformities by mechanical axis deviation (MAD) was 18.28 ± 5.25 mm, overcorrection by mechanical medial proximal tibial angle (mMPTA) was 14.86 ± 4.45°, and overcorrection by mechanical lateral distal tibial angle (mLDTA) was 12.85 ± 3.02°. Overcorrection of valgus deformities according to MAD was 15.12 ± 8.28 mm, overcorrection by mMPTA was 10.38 ± 2.77°, and overcorrection by mLDTA was 7.5 ± 3.9°. Recurrence of the deformity was observed in 11 (73%) cases (range, 5–16 months).

In group II, the accuracy of correction (AC) in varus deformities for MAD was 98% and 94% for mMPTA and mLDTA. For valgus deformities, AC for MAD was 90% and 96% for mMPTA and mLDTA. The AC for anatomical proximal posterior tibial angle and anatomical anterior distal tibial angle was 96% for procurvation deformities and that for recurvation deformities was 92%. Deformity recurrence was observed in only one case within 6 months after frame removal. In 2 cases, repeat limb length discrepancy correction surgeries were performed.

Conclusion. Use of epiphysiodesis of the healthy portion of the growth plate in combination with osteotomy, computer-assisted external fixation with subsequent gradual deformity correction, and lengthening in patients with deformities associated with partial physeal arrest significantly decreased the number of deformity recurrences.

Keywords: epiphysiodesis; deformity correction; hexapods; software-based external fixation; six-axis frames; Ortho-SUV Frame.

ДЕФОРМАЦИИ КОСТЕЙ ГОЛЕНИ У ДЕТЕЙ ВСЛЕДСТВИЕ ПОВРЕЖДЕНИЯ ЗОНЫ РОСТА: АНАЛИЗ ХИРУРГИЧЕСКОГО ЛЕЧЕНИЯ 28 ПАЦИЕНТОВ (ПРЕДВАРИТЕЛЬНОЕ СООБЩЕНИЕ)

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Цель работы — ретроспективно проанализировать результаты двух методов лечения детей с деформациями голени, являющимися следствием парциального синостоза зоны роста.

Материалы и методы. Группу I составили 15 пациентов, которым выполняли остеотомию с одномоментной гиперкоррекцией деформации и чрескостный остеосинтез аппаратом Илизарова с последующим дозированным удлинением сегмента. Группу II составили 13 пациентов, которым выполняли гемиэпифизиодез функционирующей порции поврежденной зоны роста, остеотомию, чрескостный остеосинтез аппаратом Орто-СУВ с последующей коррекцией деформации и удлинением сегмента во времени.

Результаты. В группе I выявлено, что при коррекции варусных деформаций гиперкоррекция по девиации механической оси (ДМО) составила 18,28 ± 5,25 мм, гиперкоррекция по мМПрББУ (механическому медиальному

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проксимальному большеберцовому углу) — 14,86 ± 4,45°; по мЛДББУ (механическому латеральному большеберцовому углу) — 12,85 ± 3,02°. При коррекции вальгусных деформаций гиперкоррекция по ДМО составила 15,12 ± 8,28 мм, гиперкоррекция по мМПрББУ — 10,38 ± 2,77°; по мЛДББУ — 7,5 ± 3,9°. В 11 случаях (73 %) отмечался рецидив деформации. При этом минимальные сроки рецидива деформации составили 5 месяцев, максимальные — 16 месяцев.
В группе II точность коррекции (ТК) варусных деформаций по ДМО составила 98 %, по мМПрББУ и мЛДББУ — 94 %; для вальгусных деформаций по ДМО — 90 %, по мМПрББУ и мЛДББУ — 96 %. ТК антекурвационных деформаций по анатомическому заднему проксимальному большеберцовому углу (аЗПББУ) и анатомическому переднему дистальному большеберцовому углу (аПДББУ) составила 96 %, рекурвационных — 92 %. Только в одном случае через 6 месяцев после демонтажа аппарата отмечался рецидив деформации. В 2 случаях по мере роста ребенка потребовалось повторное оперативное вмешательство, направленное на устранение неравенства длин конечностей.
Заключение. Использование методики эпифизиодеза неповрежденной порции зоны роста в сочетании с остеотомией и чрескостным остеосинтезом на базе компьютерной навигации с последующими дозированными коррекцией деформации и удлинением достоверно снижает частоту рецидивов у пациентов с деформациями голени на фоне физарных синостозов.

Ключевые слова: эпифизиодез; компьютерная навигация; гексапод; аппарат Орто-СУВ; коррекция деформации; гиперкоррекция.

Introduction

A distinctive feature of the pediatric skeleton is the presence of functioning growth zones. Damage to a growth zone as a result of trauma or pathological process (e.g., tumor, infection, or dystrophy) often leads to the formation of a partial physeal synostosis. As the child grows, the healthy part of the growth zone continues to function while the synostotic region does not, with unequal growth leading to deformity and/or shortening of the segment [1–3].

Axial deformities of the tibia cause biomechanical disorders that underlie the development of osteoarthrosis of the knee [4], ankle, and subtalar joints [5, 6]. Thus, children with tibial deformities must be treated surgically. Several surgical approaches are used to treat tibial deformities that result from damage to the growth zone. A number of authors advocate resection of the synostotic portion of the growth zone and filling of the defect with a material that prevents the recurrence of synostosis (fat, wax, methyl methacrylate) [7]. This procedure has also been combined with corrective osteotomy [8]. This method has several limitations: the angular deformity should not exceed 10 degrees; the area of the synostosis should not exceed 50% of the area of the growth zone; active growth of the child is required; and it is ineffective in the presence of a significant shortening, since the length of the segment is not restored [7]. In addition, a high frequency of relapse of synostosis is reported [8].

The standard method for treating deformities accompanied by shortening is osteotomy of the segment in conjunction with transosseous osteosynthesis. This procedure enables elimination of the deformity with simultaneous elongation of the segment over time in a dose-dependent manner through the formation of a distraction regenerate [9–11]. However, osteotomy in combination with transosseous osteosynthesis does not guarantee a positive outcome in children. In the absence of intervention on the growth zone, further growth of the child naturally leads to a relapse of the deformity. This problem has prompted a number of orthopedists to perform hypercorrection in cases of deformities accompanied by physeal synostosis [12] to delay relapse of the deformity. The optimal magnitude of the hypercorrection and its feasibility have not been proven.

One study reports a positive effect using the combination of osteotomy of the damaged segment, epiphysiodesis of an intact portion of the growth zone by reaming, and transosseous osteosynthesis [13]. In this case, both the deformity and the overelongation of the damaged segment were corrected. The magnitude of overelongation is calculated using prediction techniques [14]. However, we found no reliable data on the efficacy of this technique in the literature. The use of hexapods, which use computer navigation, as a transosseous device is highly recommended because they have a high accuracy of deformity correction [15–18].

This study **aims** to analyze retrospectively the results of two surgical methods for treating pediatric patients with tibial deformities caused by partial synostosis of the growth zone.

Materials and methods

This study included 28 patients treated between 2009 and 2015. An obligatory condition was the signed informed consent of the parents (or guardians) of the pediatric patients to participate in the clinical study and surgery. All patients had deformities of the tibia associated with shortening of the damaged segment. The main condition for patient inclusion in the study was the presence of deformities of the tibia, with X-ray signs of partial synostosis of the growth zone.

Group I comprised 15 patients who underwent osteotomy of the tibia bone in combination with transosseous osteosynthesis. No surgical intervention was performed on the growth zone. Correction of the deformity was performed simultaneously or dosed by transosseous osteosynthesis. In this case, the tibias were imparted with a hypercorrection position in the angle and length.

Group II consisted of 13 patients who underwent epiphysiodesis of an intact portion of the growth zone by reaming under the control of an electron-optical transducer, osteotomy of the tibia, and transosseous osteosynthesis. The deformity was corrected using the Ortho-SUV unit. The aim of the correction was to restore the normal values of the reference lines and angles (RLA) [19] and overelongation of the segment. The amount of overelongation was calculated using the PaleyGrowth program.

Group I comprised 6 boys and 9 girls. The average patient age at the time of treatment was 11.0 ± 2.6 years (range, 6–15 years). The cause of the deformity was trauma (4 cases), Blount disease (5 cases), and infancy hematogenous osteomyelitis (IHO) (6 cases). The deformity was caused by damage to the proximal growth zone in 5 cases and the distal growth zone in 10 cases. The deformity was classified according to the classification of deformities of long bones [20] as complex (CD) in 8 cases, of moderate severity (MSD) in 5 cases, and simple (SD) in 2 cases.

Group II comprised 7 girls and 6 boys. The average patient age at the time of treatment was 10.6 ± 2.9 years (range, 7–14 years). The cause of the deformity was injury (7 cases), Blount disease (4 cases), and IHO (2 cases). The deformity was caused by damage to the proximal growth zone in 7 cases and the distal growth zone in 6 cases. The deformities were classified as CD (6 cases), MSD (6 cases), and SD (1 case).

For group I, the elongation value, size of the elongation, deformity correction period (CP), amount of hypercorrection, index of external fixation (IEF), and the number and nature of the complications were evaluated. The value of the hypercorrection was evaluated by comparing the RLA values as a result of correction with the extreme value from the normal range. For group II, the elongation value, magnitude of overelongation, CP, correction accuracy, IEF, and the number and nature of the complications were evaluated. When analyzing the accuracy of correction, the RLS parameters were evaluated.

Results

The primary results are presented in Tables 1 and 3.

Group I

When correcting the varus deformities, hypercorrection according to the deviation of the mechanical axis (DMA) was 18.28 ± 5.25 mm, that according to the mechanical medial proximal angle of the tibia (mMPAT) was 14.86 ± 4.45°, and that according to the mechanical lateral angle of the tibia (mLDAT) was 12.85 ± 3.02°. When correcting the valgus deformities, hypercorrection according to the DMA was 15.12 ± 8.28 mm, that according to the mMPAT was 10.38 ± 2.77°, while that according to the mLDAT was 7.5 ± 3.9°. In 12 cases, the segment was over elongated. In 3 cases, overelongation was deliberately avoided because the preoperative shortening of the segment was more than 6 cm. It should be noted that the deformity correction period indicated in Table 1 for Group I was calculated only for the five patients who received the correction in dosed fashion. In all other cases, the deformity correction was one-stage and was performed intraoperatively.

We observed the following complications. During elongation and deformity correction, inflammatory changes were noted in all cases in the area of the exit sites of one or more transosseous elements. Antibiotic therapy for the management of the inflammatory process was used only in 3 patients. An ankle contracture occurred in the course of distraction in 4 patients, and a knee joint contracture occurred in 3 patients. None of

Table 1

Reference lines and angles in Group I

Indicator	Normal values	Before surgery	After the correction
Frontal plane			
Varus			
DMA	0 ± 9.7 mm inside	36.8 ± 9.9 mm inside	18.3 ± 7.7 mm outside
mMPAT	85–90°	76 ± 6.7°	99.8 ± 4.4°
mLDAT	86–92°	100.7 ± 5°	79.1 ± 3°
Valgus			
DMA	0 ± 9.7 mm inside	31.8 ± 8.9 mm outside	15.2 ± 8.3 mm inside
mMPAT	85–90°	100.1 ± 6.5°	79.6 ± 2.7°
mLDAT	86–92°	74.2 ± 6.4°	97.5 ± 3.9°
Sagittal plane			
Recurvation			
aPPAT	77–84°	95.1 ± 5.1°	82.7 ± 3.9°
aADAT	78–82°	70.4 ± 3.9°	83.6 ± 5.6°
Antecurvation			
aPPAT	77–84°	68.3 ± 6.2°	86.1 ± 5.5°
aADAT	78–82°	88.7 ± 6.5°	75.7 ± 2.7°

Note: mMPAT, mechanical medial proximal angle of the tibia; mLDAT, mechanical lateral distal angle of the tibia; DMA, deviation of the mechanical axis; aPPAT, anatomical posterior proximal angle of the tibia; aADAT, anatomical anterior distal angle of the tibia.

Table 2

Reference lines and angles in Group II

Indicator	Normal values	Before surgery	After the correction
Frontal plane			
Varus			
DMA	0 ± 9.7 mm inside	27.4 ± 6.7 mm inside	2.5 ± 8.8 mm inside
mMPAT	85–90°	72.8 ± 8.5°	86.2 ± 3.8°
mLDAT	86–92°	102.7 ± 8.4°	87.6 ± 4.5°
Valgus			
DMA	0 ± 9.7 mm inside	44.3 ± 10.2 mm outside	0.6 ± 5.2 mm inside
mMPAT	85–90°	104.5 ± 8.5°	89.5 ± 6.8°
mLDAT	86–92°	74.2 ± 6.4°	97.5 ± 3.9°
Sagittal plane			
Recurvation			
aPPAT	77–84°	95.1 ± 5.1°	82.7 ± 3.9°
aADAT	78–82°	70.4 ± 3.9°	83.6 ± 5.6°
Antecurvation			
aPPAT	77–84°	68.3 ± 6.2°	86.1 ± 5.5°
aADAT	78–82°	88.7 ± 6.5°	75.7 ± 2.7°

Note: mMPAT, mechanical medial proximal angle of the tibia; mLDAT, mechanical lateral distal angle of the tibia; DMA, deviation of the mechanical axis; aPPAT, anatomical posterior proximal angle of the tibia; aADAT, anatomical anterior distal angle of the tibia.

Table 3

Comparison of outcomes between Groups I and II

Indicator	Group I	Group II
Elongation, mm	46.4 ± 7.2	54.1 ± 9.3
Overelongation, mm	18.6 ± 6.2	22.4 ± 8.2
Time of distraction, days	48.3 ± 7.3	46.3 ± 12.2
Correction period, days	12.4 ± 6.1	14.4 ± 4.2
Index of external fixation, days/cm	34.4 ± 8.2	28.3 ± 10.1

these complications required surgical treatment. In 1 case, the formation of a false joint was noted; repair involved grafting with an autobone and repeated external fixation. A relapse of the deformity occurred in 11 cases (73%). The minimum time until relapse of the deformity was 5 months, while the maximum was 16 months. In all of these cases, a repeated surgical intervention was performed. All 4 patients who had no relapse of the deformity were older than 13 years at the time of treatment.

Group II

The main treatment outcomes for Group II patients are presented in Tables 2 and 3. The accuracy of the correction of varus deformities was 98% on DMA and 94% on mMPAT and mLDAT; that of valgus deformities was 90% on DMA and 96% on mMPAT and mLDAT. The accuracy of correction of antecurvation deformities along the anatomical posterior proximal angle of the tibia (aPPAT) and anatomical anterior distal angle of the tibia (aADAT) was 96%, while that of recurrent deformities was 92%.

The following complications were observed. Inflammatory changes of soft tissues in the area of the exit sites of transosseous elements were noted in all cases. In 2 cases, antibacterial therapy was required for the management of superficial infection; one case required removal of the transosseous element. Contractures of the knee joint (2 cases) and ankle joint (3 cases) were seen. In all cases, the physiological amplitude of movements in the joint was achieved with the help of mechanotherapy during the fixation period and in the first month after dismantling the external fixation device. In one case, a deformity relapse occurred 6 months after dismantling the device. In 2 cases, repeated elongation of the damaged segment was required as the child grew.

Discussion

Deformities of the tibial bones in children resulting from damage to the growth zone are characterized by a high frequency of relapse because of the presence of the physeal synostosis, which prevent even bone growth. With early detection and short extension of the synostosis, resection provides good results in 40–70% of cases [7, 21]. Timely detection of synostosis is complicated by a number of factors. In trauma with damage to the growth zone, adherence to all treatment standards (anatomic repositioning and stable fixation) does not guarantee a good treatment outcome. The tendency toward synostosis on the consolidation of the fracture is not immediately evident. Often, the formation of synostosis can be determined only when deformity and shortening occur.

With a considerable duration of physeal synostosis in a growing child, treatment appears to be a complex, often intuitive process. None of the guidelines reviewed by us provide a single standard of treatment. Clearly, the aim of treating a child is to eliminate the deformity: that is, to restore the normal values of the reference lines and angles and to equalize the length of the limbs. However, a number of studies report “hypercorrection” [12, 22, 23], which essentially means “deformity in the opposite direction.” We also came across the view that hypercorrection should be performed in young children, while in adolescents it is more appropriate to adhere to the normal values of reference lines and angles when correcting deformity [24]. We found no information regarding the proper magnitude of hypercorrection. This lack of specifications is because the growth of a child is difficult to predict, and it is especially difficult to predict the development of the damaged growth zone. The tendency of orthopedists to perform hypercorrection is explained by their reluctance to destroy the functioning portion of the growth zone. A number of authors state that the presence of physeal synostosis serves as a guarantee of a relapse of deformity, regardless of whether correction is performed in accordance with normal values of the RLA or with hypercorrection [13, 24]. Our results do not support the unequivocal inconsistency of this method. However, our observed 70% relapses of deformity rate within 5 to 16 months suggest that indications for the use of hypercorrection may require revision. In addition, we believe that the basis of hypercorrection is the shift of the axial load to another yet "uncompromised" region of the joint. We assume that overloading the healthy part of the joint, even for 5–16 months, cannot positively affect the duration of the joint.

Horn et al. report good outcomes in 5 patients with posttraumatic deformities of the lower extremities with physeal synostosis treated with the combination of drill epiphysiodesis of an intact portion of the growth zone, osteotomy, and transosseous osteosynthesis [13]. Several reports recommend this method [17], but we could not find a clinical study of this method that used a reliable sample of patients. One source cites data from a study of treatment combining corrective osteotomy and resection of a healthy portion of the growth zone for epiphysiodesis in 21 patients with post-traumatic deformities of long bones [25]. The author claims that resection of the preserved portion of the growth zone with the subsequent creation of epiphysiodesis is a rational component in the complex surgical treatment of children with posttraumatic deformities of the limbs, since it prevents the recurrence of deformities and helps to reduce the frequency of surgical interventions during the growth of the child.

Modern computer-assisted transcutaneous devices (so-called 'hexapods') enable the placement of bone fragments in 3 planes and with 6 degrees of freedom. The high accuracy of these devices in correcting deformities has been demonstrated [15, 16, 18, 26]. In our study, we used the Ortho-SUV apparatus, which is the only Russian hexapod currently available. This device, in fact, is not a transcutaneous device, but a repository unit based on computer navigation that can be used with external supports for almost all circular devices [18, 26]. However, to date, there is very little information on the use of this device in pediatrics [27]. Our analysis reveals that the accuracy of deformity correction using the Ortho-SUV unit is 90 to 98%, depending on the plane of deformity. Our results demonstrate that the correction of deformity by transosseous osteosynthesis based on computer navigation in combination with the epiphysiodesis of the growth zone and the segment overelongation provides good outcomes. Only one patient experienced a relapse of deformity. In a detailed analysis of this case, it was found that the desired epiphysiodesis of the non-synostosis portion of the growth zone was not achieved, likely because of the imprecision of the epiphysiodesis technique.

Should the correction of deformities in children be performed simultaneously or by methods of transosseous osteosynthesis in a dosed manner over time? Our data indicate that in the patients treated with dosed correction of the deformity had a significantly lower index of external fixation than did those treated with simultaneous correction and subsequent distraction.

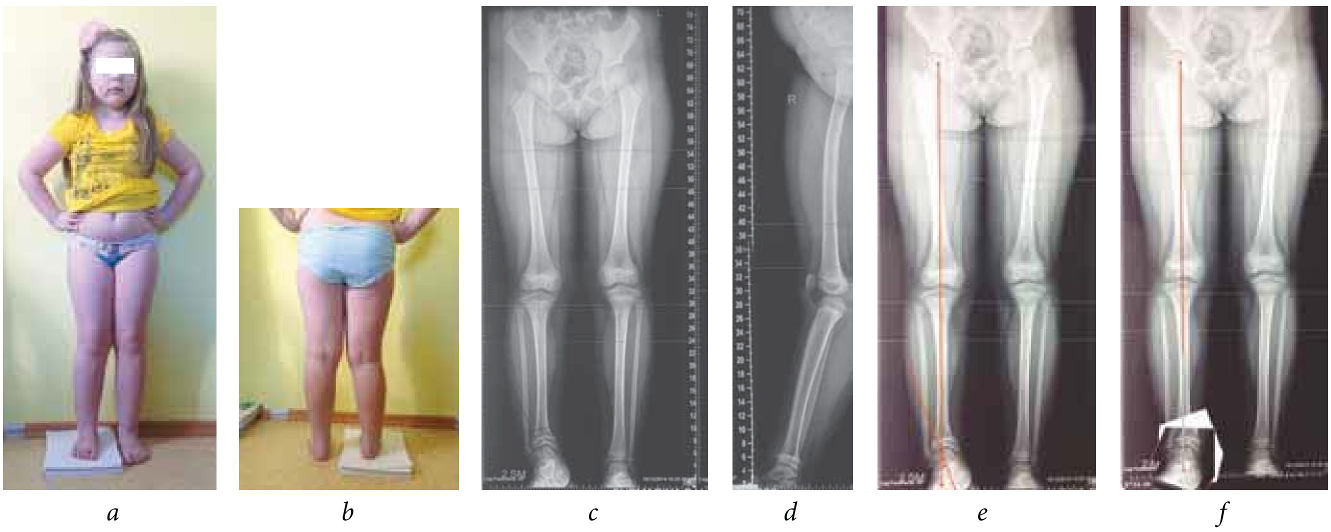
Segment overelongation should also be discussed. Several methods are presently used to predict growth, including the arithmetic method [28], the Moseley graphical method [29], the Green-Anderson method [30], and the Multiplier method [31]. In our work, we used the Multiplier method, which is the basis of the computer application for the iPhone PaleyGrowth. According to Paley et al., this method determines the inequality in limb length after reaching bone maturity [32]. We calculated the size of the overelongation using the real length of the segment and the predicted length of the healthy segment at bone maturity. In 3 cases, we were unable to perform overelongation to the required extent because the extension exceeded 6 cm (the amount we assume as the maximum elongation in cases involving injuries and acquired diseases). In 2 patients, the prediction was not accurate enough; after these children reached bone maturity, the defective segments had shortened by 25 and 30 mm. This observation is confirmed by Lee et al. [14], who evaluated the accuracy of the present methods for predicting growth and came to the conclusion that none is absolutely accurate. To repair the resulting defect, one of our patients underwent elongation of the defective tibia; the other patient underwent shortening osteotomy of the healthy tibia. A limitation of this study is that of the 13 patients in the cohort, only 7 have reached bone maturity. Thus, we cannot say with certainty that the remaining 6 patients will not need further treatments to repair inequality of limb lengths.

Clinical case

Patient B., 6 years old, was hospitalized as per plan with the diagnosis of posttraumatic deformity of the right tibia, with shortening of the right lower limb. Anamnesis reveals that the trauma occurred 2 years before the hospitalization as a result of a fall from height. The patient was treated conservatively, and plaster immobilization was used. At admission, the girl complained of a deformity of the lower leg, shortening, and lameness. She had no previous surgery. The child's parents noticed an increase in the deformity 4 months after the trauma.

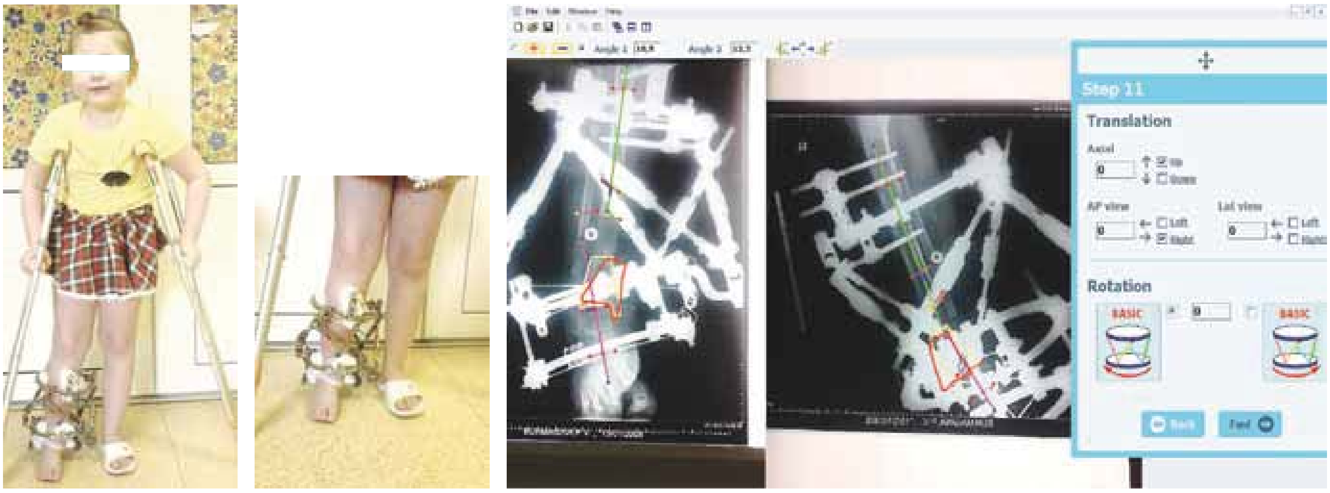
Clinical examination and analysis of panoramic radiographs (Fig. 1, *a*, *b*) indicate that the child had a complex varus-antecurvation deformity of the right tibia with partial synostosis of the medial portion of the distal right tibial growth zone exceeding 50% of its area. The RLA data before correction were as follows: proximal medial mechanical angle of the tibial bone, 90°; distal lateral mechanical angle of the tibial bone,116°; anatomical posterior proximal tibial angle, 79°; anatomical anterior distal tibial angle, 86°; angle of the varus deformity, 26°; angle of recurvation deformity, 6°; and angle of the external tibia torsion (according to CT), 15°. Standard planning of the deformity correction was performed (Fig. 1, *c*, *d*).

Surgical treatment was performed as follows: epiphysiodesis of the external portion of the distal growth zone by reaming, osteotomy of the right lower leg bones in the lower third, combined transosseous osteosynthesis (Fig. 2, *a*, *b*). Given the height of the osteotomy, the ankle joint was immobilized. Elongation was performed along the bars of the Ilizarov apparatus with their subsequent replacement with the Ortho-SUV unit for the deformity correction period. Calculation of the deformity correction using the computer navigation program for the Ortho-SUV unit is shown in Fig. 2, *c*. In this case, a standard procedure was performed in which the axes of the proximal and distal fragments and skiagrams were constructed using the program tools on the direct and lateral radiographs. The correction rate was chosen as 1 mm/day. At the same time, using the Ortho-SUV unit telescopic struts (so-called strats), the correction was performed fractionally 4 times a day following the Ilizarov standards of distraction. The period of distraction was 46 days, and the deformity correction period was 15 days. The deformity was eliminated (Fig. 3, *a*, *b*). The cumulative elongation (measured from panoramic radiographs) amounted to 52 mm: the elongation value was 35 mm, and the overelongation value was 17 mm. One month after the end of deformity correction, the foot support was dismantled (the ankle joint was unlocked). Exercise therapy and mechanotherapy were conducted later.



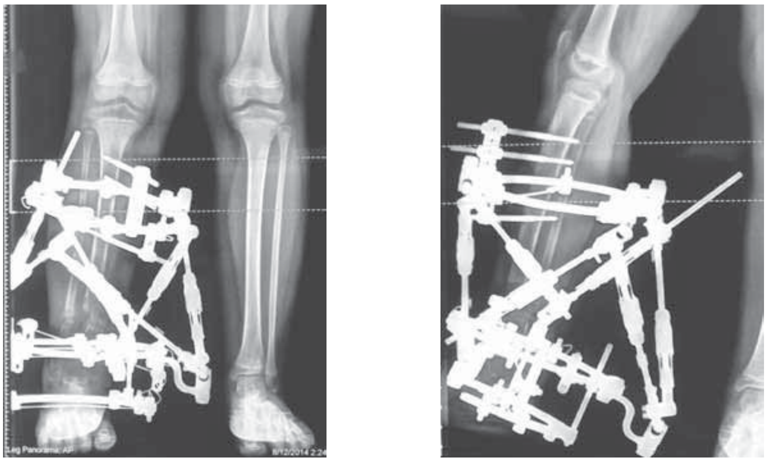
a *b* *c* *d* *e* *f*

Fig. 1. Patient B. before treatment: *a, b* — appearance; *c, d* — teleroentgenograms of the lower extremities; *e* — X-ray shows the mechanical axes of the proximal and distal bone fragments, and the vertex and deformity angle were found; *f* — a 'simulating' osteotomy of the skiagram at the vertex level was performed in the BoneNinja program; the deformity was eliminated



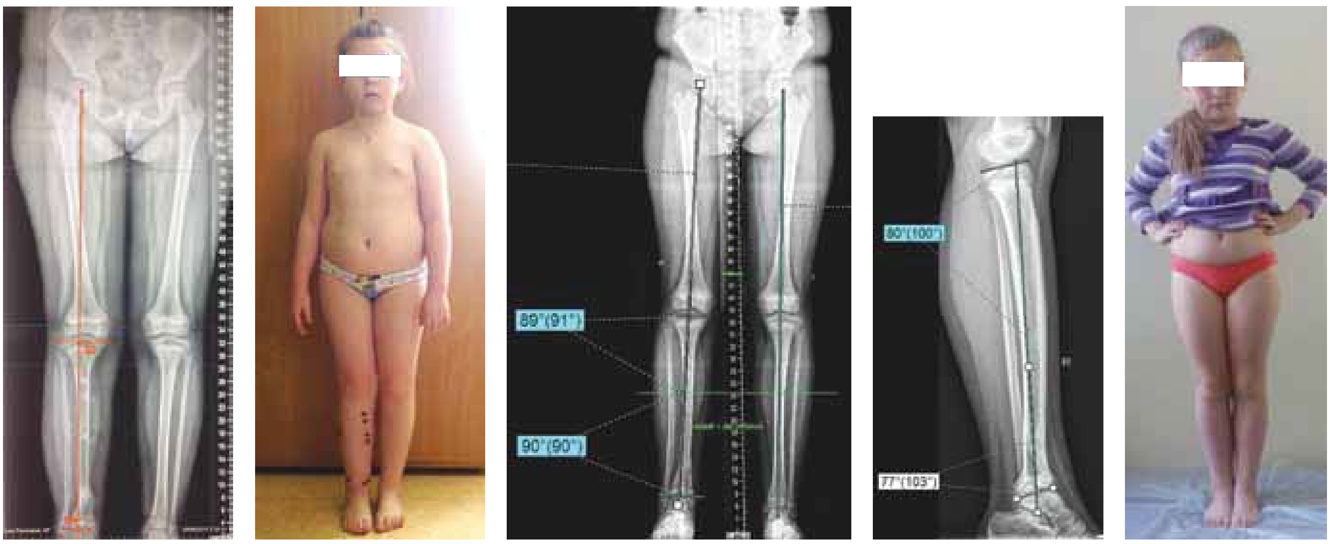
a *b* *c*

Fig. 2. Patient B. after surgery: *a, b* — the appearance of the child and the limb after the surgery; *c* — calculation of the deformity correction using the program of the Ortho-SUV apparatus at stage 11; yellow contour, skiagram of the distal bone fragment at the time of calculation; red contour, expected final position of the distal bone fragment after deformity correction



a *b*

Fig. 3. Patient B.: *a, b* — radiograph after deformity correction



a *b* *c* *d* *e*

Fig. 4. Patient B.: *a, b* — photographs and panoramic radiographs after dismantling the external fixation device; *c, d, e* — photographs and roentgenograms 2 years after dismantling the Ilizarov apparatus

The device was dismantled 198 days after the surgery (Fig. 4, *a*, *b*). The index of external fixation was 26.3 days/cm. The following parameters of the reference lines and angles were achieved: proximal medial mechanical angle of the tibia, 89°; distal lateral mechanical angle of the tibia, 89°; anatomical posterior proximal angle of the tibia, 80°; and the anatomical anterior distal angle of the tibia, 77°.

At the control examination 2 years after dismantling the external fixation device for limb length (Figure 4, *c*, *d*, *e*), the deformity correction was preserved, and the limbs were of equal length.

Conclusions

Use of the epiphysiodesis method on an intact portion of the growth zone in combination with osteotomy and transosseous osteosynthesis followed by dosed correction of deformity and elongation reliably reduces the relapse rate in patients with tibial deformities with synostosis. The use of transosseous devices based on computer navigation provides high-accuracy correction of tibial deformities in children.

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Author B.A. Vilensky declares that he is an employee of the company Ortho-SUV LLC.

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