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Original Study Article

# Assessment of comparative parameters of leg length discrepancy in children using temporary epiphysiodesis with 8-plates

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***BACKGROUND:*** Epiphysiodesis is used to correct the leg length discrepancy in children. The results of the effectiveness in different studies using epiphysiodesis with 8-plates. Forecasting is a fundamental provision of the methodology to apply epiphysiodesis.

***AIM:*** To determine the comparative effectiveness of temporary epiphysiodesis with 8-plates in correcting the difference in size of the lower limbs in children, depending on the age of the patient and the segment of epiphysiodesis.

***MATERIALS AND METHODS:*** We included data from a retrospective analysis of the results of correcting the leg length discrepancy using the method of guided growth in 94 patients. The technique included the use of two 8-plates. The calculation of comparative indicators was used, while the difference in the ratios of lengths of the epiphysiodesed and paired segments before epiphysiodesis and at the time of completion of guided growth (removal of metal structures) was determined as an indicator of the effectiveness of treatment.

***RESULTS:*** The maximum efficiency was observed with epiphysiodesis of the femur in children of the younger age group (a change of 7.59% in the length of the bone), the minimum was observed with epiphysiodesis of the tibia in children of the older age group (a change in length of 2.04%). The decrease in the effectiveness of femoral epiphysiodesis depending on age was linear, while that between the efficiency indicators in the younger and middle groups was 1.85%, and between the middle and older groups was 2.8%. In epiphysiodesis of the tibia, the difference between the efficiency indicators in the younger and middle age groups was 2.42%, and that between the middle and older age group was 0.34%.

***CONCLUSIONS:*** Temporary epiphysiodesis with 8-plates is effective in correcting the LLDs in children. The use of the comparative efficiency indicators obtained in different age groups allows us to plan the intervention more accurately and avoid unnecessary operations.

**Keywords:** temporary epiphysiodesis; leg length discrepancy (LLD); 8-plates.

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Оригинальное исследование

# Оценка относительных параметров разновеликости нижних конечностей у детей при использовании временного эпифизеодеза 8-образными пластинами

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***Обоснование.*** Методику эпифизеодеза используют для коррекции разновеликости нижних конечностей у детей. Результаты исследования эффективности эпифизеодеза 8-образными пластинами при этой патологии неоднозначны. Прогнозирование коррекции — принципиальное условие применения методик эпифизеодеза.

***Цель*** — определение относительной эффективности методики временного эпифизеодеза 8-образными пластинами для коррекции разновеликости нижних конечностей у детей в зависимости от возраста пациента и эпифизеодезируемого сегмента.

***Материалы и методы.*** В исследование включены данные ретроспективного анализа результатов коррекции разновеликости нижних конечностей методом управляемого роста 94 пациентов. Методика хирургического лечения предусматривала применение двух 8-образных пластин. Рассчитывали относительные показатели, при этом в качестве показателя эффективности лечения определяли разницу процентных соотношений длин эпифизеодезируемого и парного интактного сегментов до эпифизеодеза и на момент завершения лечения методом управляемого роста (удаления металлоконструкций).

***Результаты.*** Максимальная эффективность наблюдалась при эпифизеодезе бедренной кости у детей младшей возрастной группы (изменение на 7,59 % длины кости), минимальная — при эпифизеодезе большеберцовой кости у детей старшей возрастной группы (изменение длины на 2,04 %). Снижение эффективности эпифизеодеза бедренной кости в зависимости от возраста носило линейный характер, при этом разница между показателями эффективности в младшей и средней группах составила 1,85 %, а между средней и старшей — 2,8 %. При эпифизеодезе большеберцовой кости разница между показателями эффективности в младшей и средней возрастных группах составила 2,42 %, а между средней и старшей — 0,34 %.

***Заключение.*** Временный эпифизеодез 8-образными пластинами эффективен при коррекции разновеликости нижних конечностей у детей. Использование полученных нами относительных показателей эффективности в различных возрастных группах позволяет более точно планировать вмешательство и избежать неоправданных операций.

**Ключевые слова:** временный эпифизеодез; разновеликость нижних конечностей; 8-образные пластины.

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ЭКО•ВЕКТОР

## BACKGROUND

Lower limb length discrepancy, also known as anisomelia, is a condition in which paired limbs have a clinically significant measurable length inequality [1]. Lower extremity length discrepancy is a common orthopedic problem, with 40%–90% incidence in the population, according to different authors [1, 2]. The variability of anisomelia is largely determined by the diagnostic criteria. Back pain, lower extremity pain, and lower extremity large joints degenerative changes have traditionally been associated with leg length discrepancy and necessitated its correction [1, 3]. Length discrepancy correction has conservative and surgical methods, and the indications for their use vary depending on the length discrepancy severity and the patient's age. Surgical correction methods, in turn, are divided into techniques aimed at lengthening a shorter segment and methods that involve longer segment shortening, as well as a combination of several techniques [4].

The Pediatric Orthopedic Society of North America recommends using compensatory shoe inserts, epiphysiodesis, or surgical longer segment shortening in case of leg length discrepancy of 2–5 cm in pediatric patients [5].

The epiphysiodesis technique, which involves limiting the growth of the segment due to the influence on the growth zone, was developed in 1933 by Phemister and has undergone several changes over the past 90 years, and in our opinion, the most significant of them, which contribute to the spread of the method, are associated with the development of 8-shaped plates by Peter Stevens. This method is used to correct axial deformities and length discrepancy of the lower extremities in pediatric patients [6]. The treatment results of 34 patients aged 7–16 years (mean age 12.5 years) revealed that femoral epiphysiodesis enables to correct the length discrepancy by 10 ± 7.3 mm, that of the tibia by 0.4 ± 6 mm, and in combination by 10 ± 10 mm [7]. Subsequent researchers expressed doubts that the temporary epiphysiodesis technique using 8-shaped plates is effective in correcting the leg length discrepancy. After temporary epiphysiodesis of the proximal tibial growth zone, Lauge-Pedersen and Hagglund stated a relatively low correction rate, which was 6.7 and 5.6 mm in 1.5 years in two treated patients; therefore, the authors concluded that the technique was ineffective [8].

Stewart et al. presented the comparative study results on the efficiency of epiphysiodesis with 8-shaped plates and permanent epiphysiodesis (reaming of the growth zone), which was 4.0 mm for 592.6 days of follow-up in the temporary epiphysiodesis versus 15.5 mm for 798.9 days in the permanent epiphysiodesis group [9].

Gaumetou et al. published the study results on the analysis of the efficiency of 8-shaped plates. The study included 32 pediatric patients (40 growth zones) with an average age of 12.5 years at the time of surgery. The follow-up was performed until the closing of the growth zones [10]. The authors did not calculate linear correction at a constant rate, as in previous studies, but estimated the difference between the possible and actual segment length at the end of treatment. They concluded that femoral epiphysiodesis was effective by 63% and tibial epiphysiodesis was only 42% effective from the maximum possible correction value. Additionally, the influence of the screw positions on the correction efficiency was studied, which revealed that the parallel screw position and the screw position for discrepancy do not significantly affect the length discrepancy correction.

The femoral length changed by 10.1 ± 3.0 mm and the tibial length by 5.4 ± 2.5 mm using a temporary epiphysiodesis and 12.1 ± 1.7 and 4.7 ± 2.3 mm using a permanent epiphysiodesis in the study of the comparative efficiency of the techniques after 2 years of follow-up. Concurrently, the authors did not reveal a statistically significant difference between the obtained results [11].

A study analyzed the results of temporary epiphysiodesis using 8-shaped plates, Blount braces, and transphyseal screws and revealed the average total correction rate per year of 1.11, 1.22, and 0.59 cm, respectively. There were no statistically significant differences in the correction rate [12]. Demirel monitored 7 patients aged 6–11 years and revealed an average correction rate for temporary epiphysiodesis of 0.48 mm per month [13].

Several authors report more significant correction rates using 8-shaped plates, namely 1.1 cm per year [14] or 1.52 mm per month [15]. Russian specialists estimated the temporary epiphysiodesis efficiency as 0.9 ± 0.4 cm per year in a group of 13 pediatric patients aged 2.5–12 years [16].

A single available study determined the relative efficiency indicators as changes in the ratio of segment lengths to each other expressed as a percentage. They presented data from 19 patients, where temporary epiphysiodesis was performed in 10 pediatric patients using Blount braces and 8-shaped plates in 9 patients (mean age of patients was 12.1 and 12.4 years, respectively). The efficiency of 8-shaped plates for length discrepancy correction was low. Concurrently, the difference in segment lengths decreased by 3.6% in Blount braces and 1.8% in 8-shaped plates over 2 years [17].

Predicting the correction rate is a fundamental condition for epiphysiodesis techniques. Most authors use metric correction parameters (centimeters per year, millimeters per month, etc.) as evidenced by previous studies. The method of controlled growth with leg length discrepancy mainly aimed to achieve equal leg length. The available correction prediction methods for pediatric orthopedists are based on the metric indicator assessment by direct limb length discrepancy measurement [18]. Hence, the fundamental

limitations of this calculation method are quite obvious. Firstly, there is a significant result variability in pediatric patients of different heights (and, accordingly, with different constitutional lengths of the lower limbs), and secondly, there is the impossibility of an objective and unconditional use of the method for epiphysiodesis of an elongated limb. Additionally, the technical aspects of metric calculations should also be considered due to the measurement error from X-ray patterns [19]. The use of relative length discrepancy parameters avoids the aforementioned difficulties and can improve the measurement accuracy in predicting and evaluating the treatment outcomes. However, the data on the relative efficiency of epiphysiodesis presented in the literature do not have age gradations, which does not enable their unambiguous extrapolation to all age groups.

We hypothesized that the relative efficiency of the length discrepancy correction using temporary epiphysiodesis with 8-shaped plates may vary depending on the child's age and the limb segment, which can significantly affect the treatment results.

**The work aimed** to determine the relative efficiency of temporary epiphysiodesis with 8-shaped plates for correcting the leg length discrepancy in pediatric patients, depending on the patient's age and the segment corrected using epiphysiodesis.

## MATERIALS AND METHODS

The present study included data from a retrospective analysis of the leg length discrepancy correction results using the method of controlled growth in 94 patients (102 epiphysiodesis), including 56 male and 38 female patients who received treatment from 2015 to 2020. The median of the clinically determined leg length discrepancy was 3.0 cm (Me) ($Q_1$ was 2.5 cm; $Q_3$ was 4.5 cm). The study analyzed high-quality panoramic radiographs of the lower extremities in patients' upright positions in the electronic format of the DICOM standard before and after treatment. Table 1 shows the anatomical segments and duration of epiphysiodesis in patients of the studied group.

**Table 1.** Anatomical regions at the time of surgery and duration of epiphysiodesis

| Epiphysiodesis segment | | Age subgroups | | |
|---|---|---|---|---|
| | | 2–5 years old | 6–9 years old | 10–14 years old |
| Femur | Number of surgeries | 16 | 21 | 27 |
| | Average duration of epiphysiodesis, days Me ($Q_1$; $Q_3$) | 742 (665.25; 842) | 770 (726; 854) | 707 (642.5; 792) |
| Tibia | Number of surgeries | 6 | 11 | 21 |
| | Average duration of epiphysiodesis, days Me ($Q_1$; $Q_3$) | 834.5 (734; 904.25) | 731 (713; 857) | 761 (686; 902) |

**Table 2.** Nosological causes of length discrepancies

| Diagnosis | Number of patients |
|---|---|
| **Congenital causes** | |
| Congenital lower limb malformation, accompanied by its shortening (congenital femoral and tibial malformations) | 34 |
| Congenital lower limb malformation, accompanied by its lengthening (hemihypertrophy and gigantism of the limb) | 24 |
| **Acquired pathology** | |
| Post-traumatic and idiopathic lower limb shortening | 10 |
| Postoperative congenital clubfoot condition | 9 |
| Postoperative congenital hip dislocation and Perthes disease conditions | 5 |
| Sequellae of acute hematogenous osteomyelitis | 2 |
| **Neurological diseases** | |
| Infantile cerebral palsy | 6 |
| Charcot-Marie-Tooth disease | 1 |
| Hypomelanosis of Ito | 1 |
| Paralytic deformity | 1 |
| Arthrogryposis | 1 |

Table 2 shows the information about the cause of length discrepancies.

The surgical treatment technique included the use of two bilaterally placed 8-shaped plates (medial and lateral) on the femoral and/or tibial bone.

The treatment duration depended on the achievement of the desired correction, the appearance of secondary deformities, and data from previous studies that indicate the need to stop temporary epiphysiodesis when the surgical hardware operational life was >2 years [20, 21].

We analyzed panoramic radiographs of the lower extremities in the anteroposterior projection, performed in the upright position, to plan the treatment and evaluate its results. This study evaluated the radiographs taken before the treatment initiation and at its completion (before the surgical hardware removal). Radiography was performed on Philips devices with further image post-processing using stitching software and segment measurement using the IntelliSpace PACS DCX Viewer R3.2 SP1 program (Philips Healthcare, the Netherlands). X-ray parameters were studied according to the method proposed by Helms and McCarthy [22]. Measurements were made segment by segment, namely, from the upper point of the femoral head to the lower point of the medial condyle for the femur and from the lower point of the medial part of the tibial plateau to the distal part of the epiphysis for the tibia (Fig. 1). All measurements were performed by one researcher.

Absolute length values were used to calculate relative indicators while determining the difference in the percentage ratios of the lengths of the epiphysiodesis and paired intact segments before the epiphysiodesis and at the end of treatment by the controlled growth method (surgical hardware removal) (formula in Fig. 2). The indicator presented the relative efficiency of the temporary epiphysiodesis technique.

Patients were distributed into three age subgroups, namely 2–5, 6–9, and 10–14 years, for further analysis.

Descriptive statistics methods were used for statistical analysis. The median was calculated to determine the average values, considering the small number of cases and the sample heterogeneity, and the values of the first and third quartiles (Me [$Q_1$; $Q_3$]) were calculated to estimate the variance. The obtained data were processed using the IBM Statistical Package for the Social Sciences version 23 software package (IBM SPSS, USA).

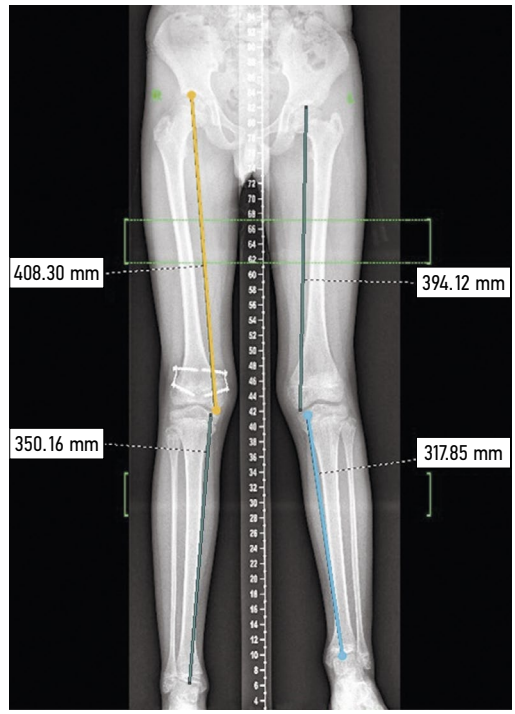


**Fig. 1.** Scheme of the segment measurement technique. The yellow line indicates the femoral length measurement and the blue line indicates the tibial length measurement

## RESULTS

The surgery was most often performed in patients of the older age group (47% of the total number) and less often in the middle and younger groups (33% and 20%, respectively), as presented in Table 1. Femoral epiphysiodesis was more often performed (60% of surgeries), and that of the tibia and both bones of the limb (32% and 8%, respectively) was less often performed. Lower limb congenital abnormalities were the most common cause of length discrepancy.

Evaluating the epiphysiodesis results in terms of changes in the proportionality of the segments revealed a decreased efficiency with age. The maximum efficiency was registered with femoral epiphysiodesis in pediatric patients of the younger age group (change by 7.59% in the bone length), and the minimum efficiency was noted with tibial epiphysiodesis in pediatric patients of the older age group (change in length by 2.04%), as presented in Figure 3. The decreased efficiency of femoral epiphysiodesis depending on age was linear, while the difference was 1.85% between the efficiency indicators in the younger and middle age groups, and 2.8% between

$$\underbrace{\left(\frac{\text{Epiphysiodesis segment}}{\text{Paired segment without epiphysiodesis}} \cdot 100\ \%\right)}_{\text{After treatment}} - \underbrace{\left(\frac{\text{Epiphysiodesis segment}}{\text{Paired segment without epiphysiodesis}} \cdot 100\ \%\right)}_{\text{Before treatment}} = \text{Efficiency of epiphysiodesis of this segment, \%}$$

**Fig. 2.** Formula for calculating the relative efficiency of the temporary epiphysiodesis method

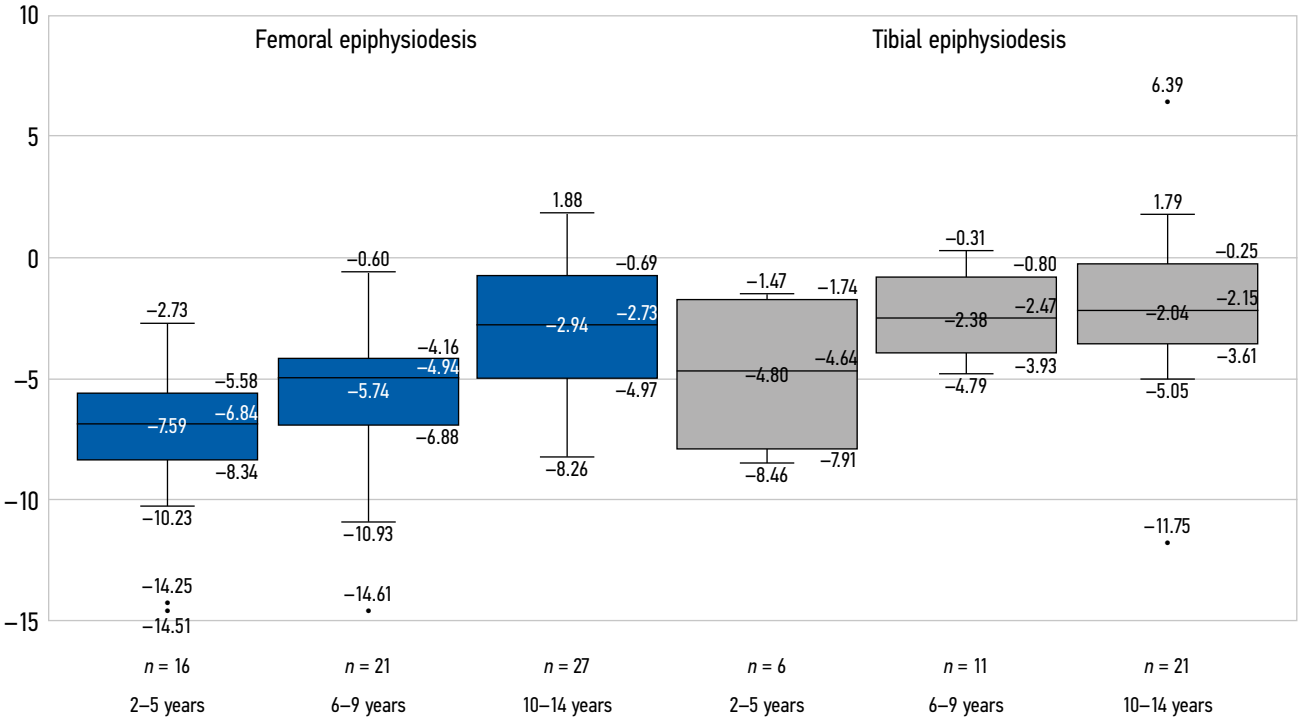


**Fig. 3.** Relative parameters of leg length discrepancy correction in pediatric patients during temporary epiphysiodesis with 8-shaped plates

the middle and older age groups. The difference between the efficiency indicators in the younger and middle age groups was 2.42% and that between the middle and older age groups was 0.34% in tibial epiphysiodesis. The relative efficiency was lower in tibial epiphysiodesis in the middle age group than that calculated for the femur in patients of the middle age group. Concurrently, most femoral interventions were performed in pediatric patients of the middle and younger age groups (37 of 64), while the tibial epiphysiodesis was used in more than half of the cases in patients of the older age group (21 of 38), as shown in Table 1.

The epiphysiodesis segment was longer than the paired intact segment because the length ratio in this situation exceeded 100% in most cases. The percentage ratio decreased in epiphysiodesis efficiency after the treatment completion; therefore, the larger value was subtracted from the lower value when calculating the final results, and the efficiency indicator was negative in value. Contrarily, a positive value of the difference indicated that the temporary epiphysiodesis method with 8-shaped plates was ineffective in a particular patient.

The correction was 2–2.5 cm with a femoral length of 27–34 cm, and 1–1.3 cm with a tibial length of 21–27 cm for the entire treatment period if the relative values (percentages) are converted into absolute values (centimeters) in the younger age subgroup. The correction was 2–2.3 cm with a femoral length of 35–40 cm and 0.7–0.8 cm with a tibial length of 28–32 cm in the middle age subgroup. The correction was 1.2–1.4 cm with a femoral length of 42–48 cm and 0.7–0.8 cm with a tibial length of 34–39 cm in the older age subgroup.

## DISCUSSION

An analysis of a small number of published studies evaluating the efficiency of epiphysiodesis showed the absence of a unified approach to segment measurement methods, which some researchers do not even mention. There is no single approach to evaluating epiphysiodesis efficiency; therefore, the results of studies cannot be compared. The literature revealed that the absolute rate of correction using a temporary epiphysiodesis varies from 0.28 mm [8] to 1.52 mm per month [15], that is, the data differ by >5 times. None of the available studies provide quantitative data on the efficiency of temporary epiphysiodesis depending on the patient's age. Concurrently, considering the non-linear growth rate of the child, expecting this indicator to be different in different age groups would be reasonable. Traditionally, the highest absolute growth rates are associated with periods of "growth spurts," while the highest growth rates are typical for females aged 12.05–13.26 years and males aged 12.20–12.83 years [23]. Methods of controlled growth for deformity correction also suggest the highest rates of correction during the most intensive growth periods [24]. A shorter segment (shortened in cases of shortening of various etiologies or healthy in cases of length discrepancy due to segment elongation) is considered to be most probably

subjected to the general patterns of linear growth when using epiphysiodesis to correct limb length discrepancy. Therefore, the rate of length discrepancy correction will be determined not only by the effective blocking of the growth zone but also by the growth zone function on the non-epiphysiodesized segment.

Studies in this area indicate higher efficiency of permanent epiphysiodesis despite ongoing discussions regarding the efficiency of 8-plate epiphysiodesis compared to permanent epiphysiodesis [9]. Concurrently, temporary epiphysiodesis has undoubted advantages, namely a reversible nature, which avoids excessive segment shortening due to inaccurate time calculation for growth zone destruction with permanent epiphysiodesis. Additionally, the temporary epiphysiodesis technique can be applied to young children. The temporary epiphysiodesis technique using 8-shaped plates is one of the most high-demand nowadays since it does not lead to direct damage to the growth zone (unlike transphyseal screws) and provides high stability of the structure (unlike Blount braces). Moreover, several authors question the efficiency of 8-shaped plates for correcting the size discrepancy [8, 11]. Thus, predicting the surgical results is of fundamental importance.

The scientific literature presents only generalized data regarding the efficiency of epiphysiodesis with 8-shaped plates, while most authors evaluated the absolute correction rate value (in millimeters per month or year of epiphysiodesis). The only study is known to us that used relative efficacy rates (versus the contralateral segment) as the main method of evaluation included a small number of cases, wherein 10 patients underwent 13 brace surgeries (9 on the femur and 4 on the tibia) and 9 patients had 14 surgeries using 8-shaped plates (7 on the femur and 7 on the tibia). Concurrently, assessing the effect of age was impossible, when the surgery was performed and on its outcome due to the small number of patients [17].

Our study reviewed the treatment results of the largest group of patients (based on the available literature) who underwent temporary epiphysiodesis with 8-shaped plates with leg length discrepancy. This enabled us to present the age patterns of the technique efficiency. We have demonstrated a general decrease in the correction efficiency with age, while the femoral epiphysiodesis efficiency in all age groups was higher than the tibial epiphysiodesis efficiency. Additionally, the tibial epiphysiodesis efficiency was characterized by the greatest decrease with age, while the minimum indicators were recorded in pediatric patients over 9 years of age. In particular, this can explain the literature data on the extremely low efficiency of epiphysiodesis with 8-shaped plates in pediatric patients in general. The tibial epiphysiodesis was most often performed in pediatric patients over 9 years of age both in our study and in the literature, with minimal efficiency. Therefore, using the epiphysiodesis method with 8-shaped plates (at least its classical version) is not advisable in pediatric patients of this age with a difference in segment length of >2%. For example, the expected effect of aligning the lengths of the limbs using a temporary epiphysiodesis with 8-shaped plates will be an average of 5 mm if the length of the longer tibia in a child over 9 years of age is 25 cm. The surgery is performed for a more significant result in most cases. Concurrently, our data are consistent with the above literature data and indicate inflated expectations in specific clinical cases rather than the method inefficiency, considering the age pattern presented by us.

Opinions regarding the low technique efficiency are usually based on data obtained in the older age group, and the expected result of the tibial epiphysiodesis should often be insignificant. Thus, we should consider more accurate planning of the method, rather than its inefficiency.

Concerning the study limitations, it is noteworthy that the impact of a particular pathology on the efficiency of the temporary epiphysiodesis technique cannot be assessed due to the small group of patients. Additionally, the age groups differed in the number of patients. However, we noted important general trends that may optimize the indications for the use of the technique and realistically schedule the intervention depending on the patient's age, and a universal evaluation method in the form of a relative efficiency indicator is presented.

## CONCLUSION

Our study findings conclude that temporary epiphysiodesis with 8-shaped plates is effective in correcting the leg length discrepancy in pediatric patients. Its efficiency is higher when correcting the length discrepancy of the thighs compared to that of the lower legs. With age, the correction efficiency naturally decreases, being more pronounced with tibial length discrepancy. The intervention can be planned more accurately based on the relative performance indicators obtained in different age groups, and unnecessary surgeries can be avoided in cases when the correction result is unachievable.

For the first time, our study not only focused on the problem of using metric indicators to predict the results of correcting the leg length discrepancy in pediatric patients with temporary epiphysiodesis using 8-shaped plates but data are presented to level out the shortcomings of the described methods at this stage. A regular dependence of the change in the relative segment length with age was revealed, namely the younger the child, the greater the expected value of the length discrepancy correction. Concurrently, for the bones of the tibia, the absolute expected values will be much lower, considering the lengths of the segments, although the relative values may not be significantly lower compared to the femur.

In our opinion, the proposed approach has several indisputable advantages over the direct metric assessment of the length discrepancy, which makes further and more detailed development of the methodology very promising. Higher accuracy in predicting the treatment outcomes can be expected with the accumulation of clinical material.

## ADDITIONAL INFORMATION

**Funding.** The study had no external funding.

**Conflict of interest.** The authors declare no conflict of interest.

**Ethical considerations.** The study on the evaluation of the efficiency of the temporary epiphysiodesis technique was approved by the local ethical committee of the Turner Scientific and Research Institute for Children's Orthopedics (protocol No. 19-2 dated 12/04/2019).

The consent of the patients (their representatives) was obtained for the processing and publication of non-personalized data.

**Author contributions.** *D.A. Petrova* reviewed the literature, collected and processed the data, prepared the tables and illustrations, and wrote the initial version of the article. *V.M. Kenis* provided methodological support and edited the text of the article.

All authors made a significant contribution to the study and preparation of the article, as well as read and approved the final version before its publication.

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