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MINIMALLY INVASIVE COUNTER CORTICOTOMY OF THE DISTAL FEMUR IN PATIENTS WITH CONGENITAL LOWER LIMB DISORDERS (WITH PRESERVATION OF MEDULLARY CANAL STRUCTURES)

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Summary.

The increasing demand for orthopaedic correction calls for the refinement of surgical techniques that maximize bone regeneration while minimizing iatrogenic trauma to the medullary canal.

Aim of the study: *to evaluate the outcomes of a novel dual-approach femoral corticotomy in patients with hypochondroplasia and achondroplasia.*

Materials and methods. *A prospective dynamic active study enrolled 40 patients. The cohort was divided into a comparison group (Group 1, n=20) and a study group (Group 2, n=20), comprising pediatric patients aged 7-18 years with polysegmental deformities and lower limb shortening of genetic etiology. Group 1 underwent conventional single-approach corticotomy, while Group 2 received femoral corticotomy through two sequential approaches–minimally invasive counter corticotomy via anteromedial followed by anterolateral access–with mandatory final stabilization using an external fixation system with tension rods or hinge assemblies. Treatment outcomes were assessed according to four parameters: achieved segment lengthening, absence of residual deformity, preserved limb and joint function, and patient-reported satisfaction metrics. The study protocol received ethical approval from the Republican Specialized Scientific and Practical Medical Center of Traumatology and Orthopaedics (Approval No. 8-2023, dated 15 August, 2023). All procedures were conducted in accordance with the World Medical Association's Declaration of Helsinki (2000 amendments). Statistical analysis was performed using Microsoft Excel 2013. Given the sample sizes in the groups, non-parametric statistics were applied with a significance level set at $p \leq 0.05$. Quantitative sample characteristics are presented in the table as the median (25th-75th percentiles) and the number of observations (n), corresponding to the number of step cycles. The statistical significance of differences was determined using the unpaired Wilcoxon test.*

Funding: *This work was carried out within the framework of the research plan of the Bukhara State Medical Institute (05.2022 DSc.135) entitled «Development of new approaches to early diagnosis, treatment, and prevention of pathological conditions affecting the health of the population of the Bukhara region after COVID-19 (2022-2026)».*

Results of the study. *In Group 1 (n=20), where classical corticotomy in the distal third of the femur was performed via an anterolateral approach, outcomes were excellent in 85% of patients, good in 5%, and satisfactory in 10%. In Group 2 (n=20), where a dual-approach counter corticotomy preserving the medullary canal was used, outcomes were excellent in 90%, good in 5%, and satisfactory in 5%.*

Conclusion. *Both techniques achieved careful preservation of the medullary canal structures and yielded a high rate of satisfactory outcomes. The novel dual-approach femoral corticotomy proved to be a viable and effective alternative to the classical technique for patients with hypochondroplasia and achondroplasia.*

Keywords: *Vdistraction Osteosynthesis; Ilizarov Method; Osteotomy; Corticotomy; Counter Corticotomy; Polysegmental Osteosynthesis.*

Introduction

Contemporary trauma and orthopaedic surgery is witnessing a steady increase in the number of surgical procedures, driven by a rising incidence of both post-traumatic conditions and congenital musculoskeletal disorders. Achondroplasia, a systemic skeletal dysplasia caused by impaired endochondral growth of long and short tubular bones, is well-characterized in the clinical, radiological, and genetic literature [1-4]. This condition also frequently necessitates surgical management. The critical need for increasing stature in patients with achondroplasia stems from a significant discrepancy between chronological age and height [5-7]. Multidisciplinary research into height augmentation for these patients has concluded that surgical limb lengthening currently remains the only viable treatment option [8-11]. As these procedures involve bone resection, the number of osteotomies performed continues to grow.

The modern orthopaedic operating theatre is equipped with a vast array of osteotomes and chisels of various designs, featuring different blade widths, instruments for low-impact osteotomy, and chisels with protective guards to prevent penetration of the medullary canal [12, 13].

Surgical preference is given to techniques that mitigate risk, enhance outcome predictability, and reduce operating time. Consequently, the development of new instruments and surgical methods remains a priority, with a focus on performing osteotomies that maximize the preservation of the medullary canal structures and the bone marrow, with its rich vascular and neural network.

A meticulously performed femoral osteotomy is crucial for the successful correction of deformities, limb lengthening, and the management of bone defects [14-16]. However, a purely mechanical approach to distraction-compression osteosynthesis using an external fixator, which fails to account for the biology of osteogenic tissues

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and causes damage to the bone marrow, often results in compromised outcomes. These include delayed union, non-union, and pseudarthrosis, typically requiring unplanned revision surgeries. This necessitates additional time, financial resources, and healthcare utilization to achieve the desired therapeutic goal [17-20].

Aim of the study: to evaluate the outcomes of a novel dual-approach femoral corticotomy in patients with hypochondroplasia and achondroplasia.

Materials and Methods

The study protocol received ethical approval from the Institutional Review Board of the Republican Specialized Scientific and Practical Medical Center of Traumatology and Orthopaedics (Approval No. 8-2023, dated 15 August, 2023). All procedures were conducted in accordance with the World Medical Association's Declaration of Helsinki (2000 amendments). Statistical analysis was performed using Microsoft Excel 2013. Given the sample sizes in the groups, non-parametric statistics were applied with a significance level set at $p \leq 0.05$. Quantitative sample characteristics are presented in the table as the median (25th-75th percentiles) and the number of observations (n), corresponding to the number of step cycles. The statistical significance of differences was determined using the unpaired Wilcoxon test.

This prospective dynamic active study enrolled 240 patients. A total of 120 patients were assigned to the comparison group (Group 1) and 120 to the study group (Group 2).

The cohort comprised patients aged 7-18 years with polysegmental lower limb deformities secondary to systemic musculoskeletal genetic disorders. All patients received treatment at the Bukhara Regional Multidisciplinary Medical Center and the G. A. Ilizarov National Medical Research Center for Traumatology and Orthopaedics.

Group 1 (n=20) underwent conventional single-approach femoral corticotomy in the distal third via an anterolateral approach. Approximately three-quarters of the femoral circumference were transected. To complete the corticotomy, mechanical manipulation was employed: either wedging the bone wound with a key or redressing the fragments using the apparatus supports to disrupt the integrity of the remaining quarter of the femoral circumference.

Group 2 (n=20) underwent a dual-approach counter corticotomy designed to preserve the medullary canal structures. This technique involved preliminary sequential drilling of aligned perforations along the planned osteotomy line through both cortical plates. An osteotome with a guiding spike on its cutting edge was then engaged into these pilot holes to sequentially connect them, ensuring precise division of the cortical bone between perforations while avoiding intrusion into the medullary canal.

Notably, in some patients with systemic skeletal dysplasias, physeal closure in long tubular bones occurred 3-4 years earlier than in individuals with normal osteogenesis.

Patient distribution by age is presented in Table 1, and by diagnosis in Figure 1. Achondroplasia and pseudoachondroplasia were the most prevalent diagnoses, while hypochondroplasia was confirmed in only two of the fort y cases (5%).

Table 1

Age Distribution of Patients in the Study Groups

Indicators Group 1		7-10 years		11-14 years		15-18 years	
		Group 2	Group 1	Group 2	Group 1	Group 2	
Number of Patients	abs.	7	6	5	7	8	7
	%	35	30	25	35	40	35
Mean Age		8.6±1.3	8.6±1.3	12.1±1.6	12.1±1.6	15.4±0.8	15.4±0.8

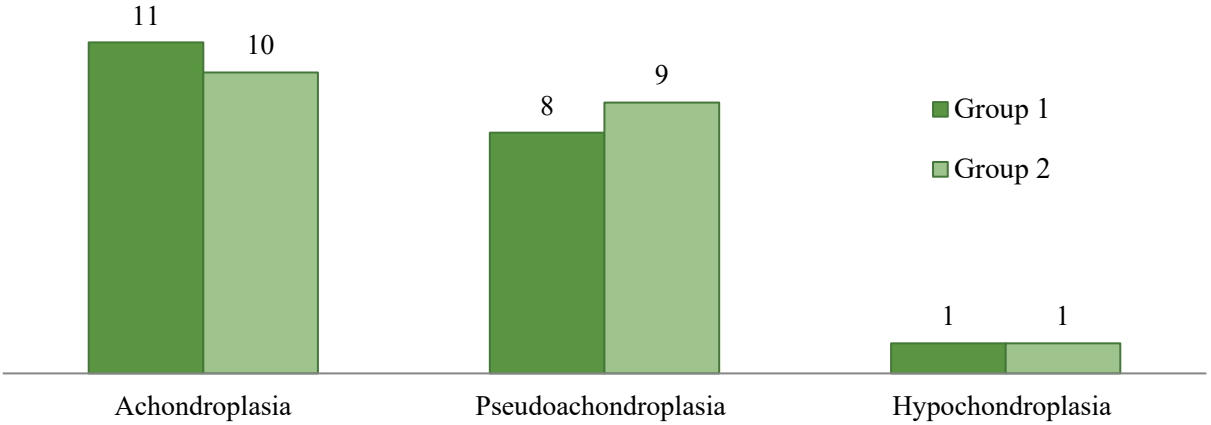

Fig. 1. Distribution of patients by nosology.

The corticotomy technique was refined at National Ilizarov Medical Research Center for Traumatology and Orthopaedics to address limitations identified through retrospective analysis. Performing a dual-approach counter corticotomy in the distal femoral third requires standard orthopaedic operating room equipment. The essential instrumentation includes a scalpel, a set of elevators, an orthopaedic hammer, osteotomes or chisels, a power tool (medical drill), drills and trocars of various diameters for corticoperforations.

Surgical Protocol for Dual-Approach Counter Corticotomy of the Distal Femur

As with conventional corticotomy, minimally invasive counter corticotomy begins with femoral osteosynthesis using an external fixation device, with mandatory final frame stabilization employing tension rods or hinge assemblies. Following frame application, the counter corticotomy level is identified and marked on the skin. Threaded rods in the distal frame segment are temporarily removed during the corticotomy, enabling accurate determination of complete corticotomy across the entire perimeter of the cortical plate. The corticotomy is performed sequentially through two approaches: first via a medial approach, then via a lateral approach. Longitudinal stab incisions up to 8-10 mm are made with a scalpel along the projection of the corticotomy, and access to the femur is created bluntly using an elevator. Prior to the medial corticotomy, corticoperforations are made perpendicular to the bone with a 2.5-3.5 mm drill along the anterior, medial, and posterior surfaces of the cortical plate, avoiding penetration of the drill into the medullary canal (Figure 2).

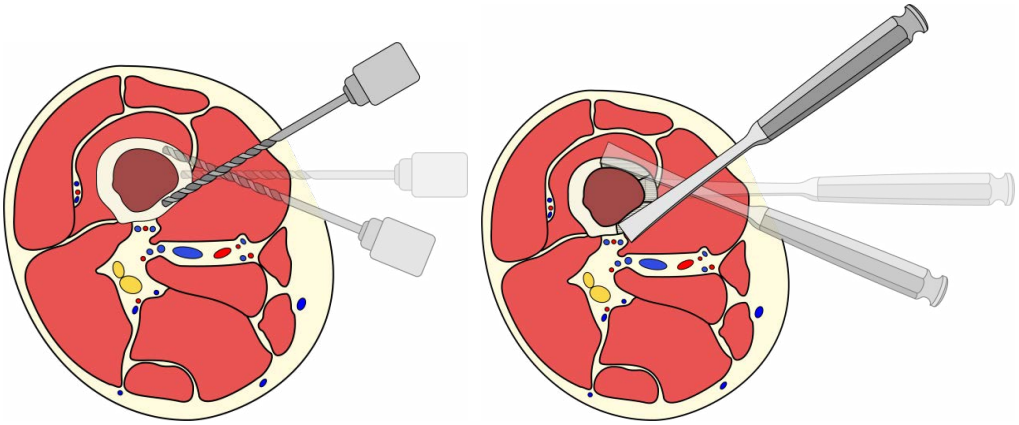

Figure 2. Medial approach for the femoral counter corticotomy technique

Corticoperforation defines the trajectory for the subsequent counter corticotomy, reduces cortcal resistance to the osteotome, and prevents undesirable and uncontrolled cortical fracture. Following drilling, a suitably sized osteotome (10-20 mm width, depending on the patient's age) is inserted into the formed access, parallel to the muscle fibers, until it is in full contact with the bone surface. Maintaining tight contact with the bone, initial shallow scoring cuts are made along the cortical plate (in pediatric patients, this maneuver facilitates access under the periosteum and subsequent subperiosteal work). The osteotome is then repositioned perpendicular to the bone, and controlled, short hammer strikes are used to sequentially transect the cortical plates following the previously drilled trajectory – anterior, medial, and posterior – while preserving the medullary canal. The technique of transecting the cortical plates is similar to the technique of cutting glass or ceramic tiles: initial superficial scoring in all three planes is followed by gradual, deeper osteotome advancement until complete transection of only the cortical plates of the medial part of the femur. This controlled approach prevents osteotome impaction and minimizes the risk of uncontrolled femoral splitting with aberrant fracture propagation.

Following complete medial corticotomy, a corresponding lateral incision is made directly opposite the medial portal along the anterolateral thigh, guided by the skin marking and matched to the medial incision length and the working part of the selected osteotome (Figure 3).

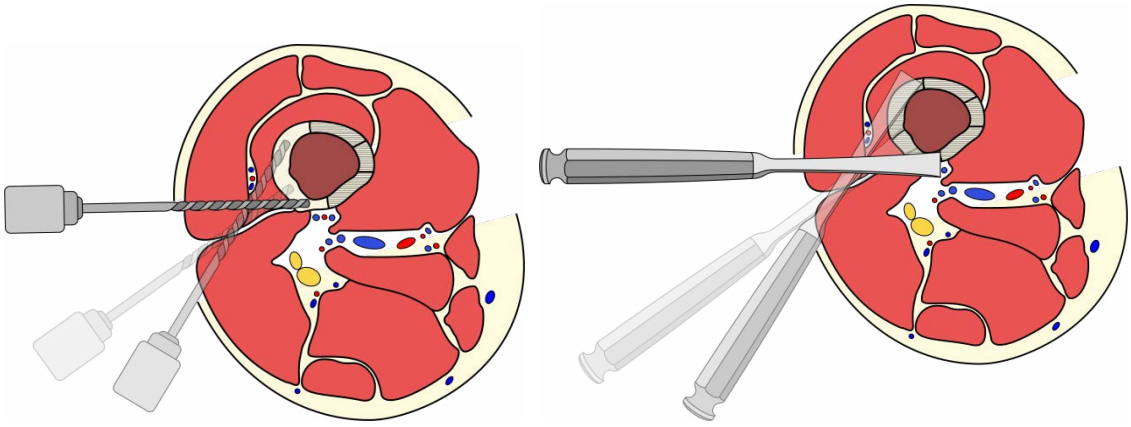

Figure 3. Surgical technique for the anterolateral femoral counter corticotomy

The anterolateral approach mirrors the medial procedure. Blunt dissection with an elevator establishes access to the surface of the femur. A 2.5-3.5 mm drill is used to create corticoperforations perpendicular to the bone along the anterior, lateral, and posterior surfaces of the cortical plate, preserving the medullary canal. The osteotome is inserted following the known rules: first parallel to the muscle fibers until contact with the bone surface, then several cutting movements on the surface of the cortical plate, after which the blade of the osteotome is turned perpendicular to the bone surface. Controlled hammer strikes initiate grooving of the anterior, lateral, and posterior cortical plates, followed by progressive deepening of the osteotomy. The counter corticotomy is usually achieved without a wedging turn of the osteotome with a wrench. The operating surgeon tactilely confirms successful cortical discontinuity through acquired fragment mobility. Verification of the completeness of the counter corticotomy by turning the osteotome with a wrench or by applying counter-rotation to the supports is strongly discouraged, as such maneuvers inevitably traumatize medullary structures and compromise controlled osteogenesis. If incomplete counter corticotomy is suspected, a narrow elevator should be used to identify the area of doubt, followed by careful targeted osteotome application in this location until subtle fragment mobility provides definitive confirmation of the corticotomy completion. Finally, the temporarily removed fixation rods are reinstalled, minimizing the period of fragments instability and preventing their displacement. The pre-contoured rods facilitate automatic reduction if minor displacement has occurred.

Treatment outcomes were categorized as excellent, good, and poor (unsatisfactory). An excellent result required a predictable osteotomy performed along the intended line, with the expected duration, without fragments or cracks, and without complications; achievement of the planned lengthening objective without residual deformity; full preservation of limb function and joint mobility; and complete patient satisfaction with the treatment results. A good result was assigned when a predictable osteotomy without fragmentation achieved the planned lengthening, but was associated with a prolonged procedure, minor joint stiffness (5-10°), residual or acquired segment deformity (3-5°), and partial patient dissatisfaction. A satisfactory outcome described a predictable osteotomy along the planned line, with prolonged duration and formation of minor fragments and/or cracks, but without complications; the achieved lengthening measured up to 75% of the planned amount, accompanied by joint movement limitation up to 10-15° and/or segment deformities up to 5-10° with the patient expressing partial satisfaction with the treatment outcome. A poor result was defined by an aberrant osteotomy line with the formation of fragments and/or cracks, failure to achieve 75% of the planned lengthening objective, significant joint contracture exceeding 15°, deformity greater than 10°, and patient dissatisfaction.

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Results

In Group 1 (n=20) treated with conventional single-approach femoral corticotomy, outcomes were distributed as follows: 85% excellent, 5% good, and 10% satisfactory.

In Group 2 (n=20) treated with the dual-approach counter corticotomy with preservation of medullary canal structures, outcomes were distributed as follows: 90% excellent, 5% good, and 5% satisfactory. The treatment outcome data for both study groups are presented in Table 2.

Table 2.

Treatment Outcomes

Study Group	Number of Patients							
	Excellent		Good		Satisfactory		Poor	
	abs.	%	abs.	%	abs.	%	abs.	%
Group 1 (*n*=20)	17	85	1	5	2	10	0	0
Group 2 (*n*=20)	18	90	1	5	1	5	0	0

The combined excellent and good outcomes comprised 90% (18/20) of Group 1 and 95% (19/20) of Group 2. Notably, two patients (10%) in Group 1 with objectively satisfactory outcomes subjectively rated their results as excellent. No poor outcomes were recorded in either group.

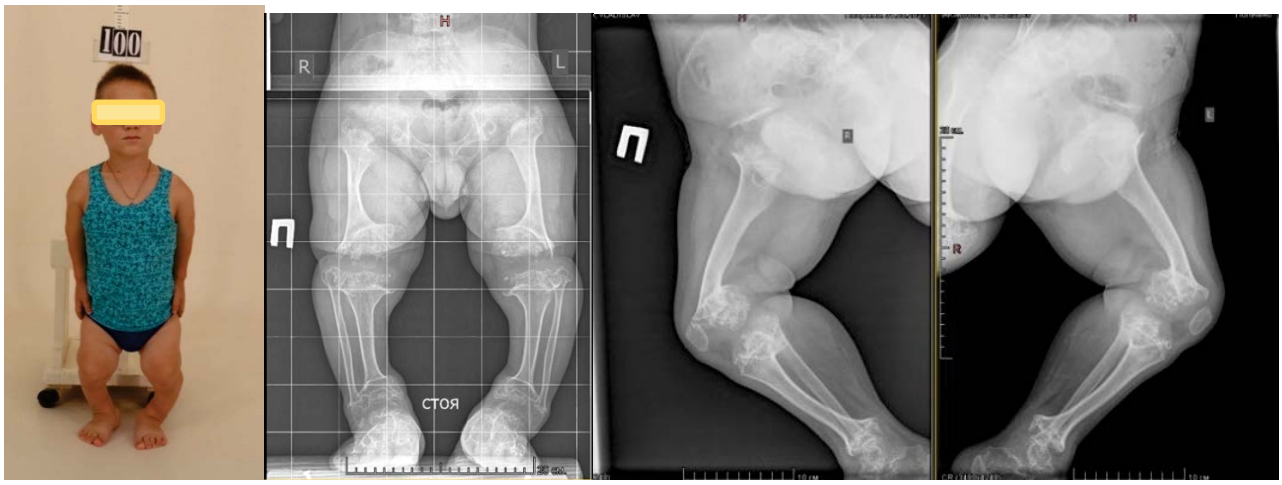
Clinical Case Report.

A 13-year-old male (Patient Y., Group 2) presented with pseudoachondroplasia, short stature (100 cm height), and multiplanar lower limb deformities. Clinical assessment revealed combined hip and knee joint contractures, bilateral tibial varus, and disproportionate shortening of all extremities (Figure 4a). To restore height, correct deformities, and improve anatomical proportions, the patient underwent a two-stage limb lengthening protocol using variants of hemilateral single-stage femoral and tibial distraction osteogenesis, with two sequential procedures separated by a one-year interval.

During the initial stage, simultaneous lengthening of the left femur (4.7 cm) and left tibia (5.2 cm) was achieved (Figure 4b). The distraction phase, using bilocal osteosynthesis, lasted 44 and 50 days for the femur and tibia, respectively, followed by a 134-day consolidation period with external fixation.

In the subsequent stage, the right lower limb was addressed using the same methodology, achieving symmetrical limb length (Figure 4c). Distraction required 46 days for the femur

and 56 days for the tibia, with consolidation period of 117-120 days. The comprehensive treatment resulted in a total height increase of 20 cm while preserving full hip and knee joint function throughout the rehabilitation process (Figure 5).



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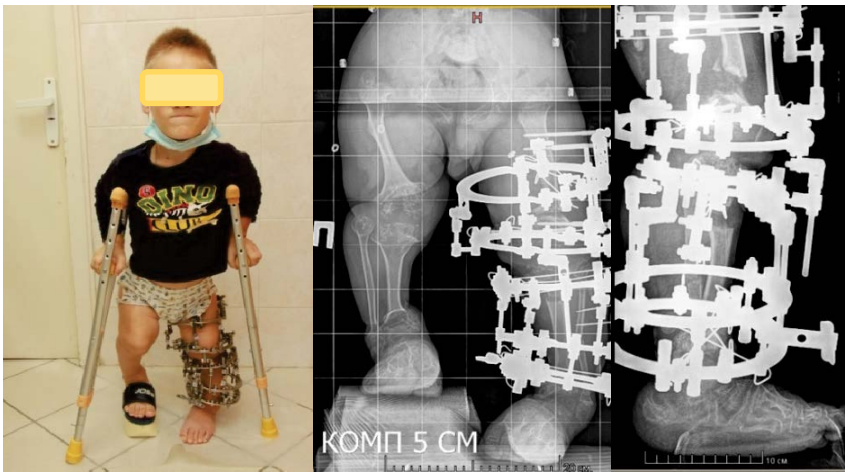

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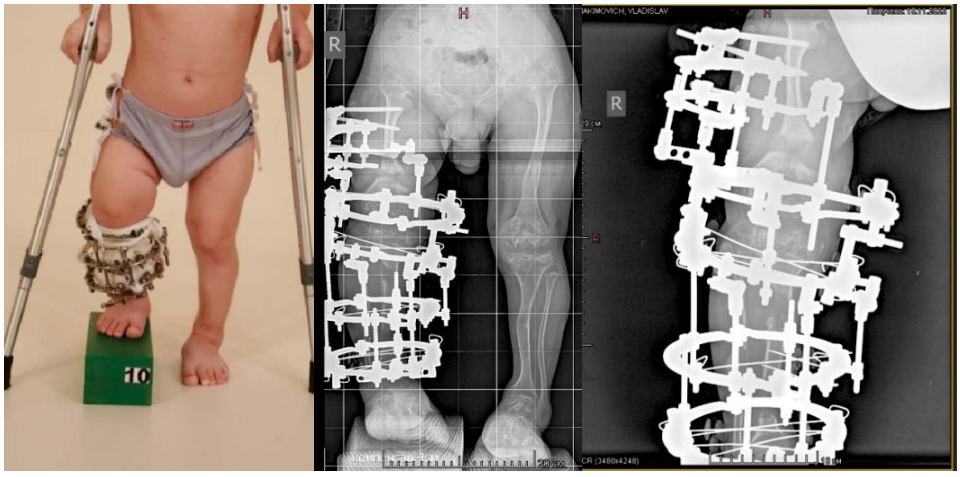

c

Figure 4. Photographs and radiographs of the thighs and tibiae of patient Y.: a – before treatment; b – during the first stage of height increase; c – during the second stage of femoral and tibial lengthening

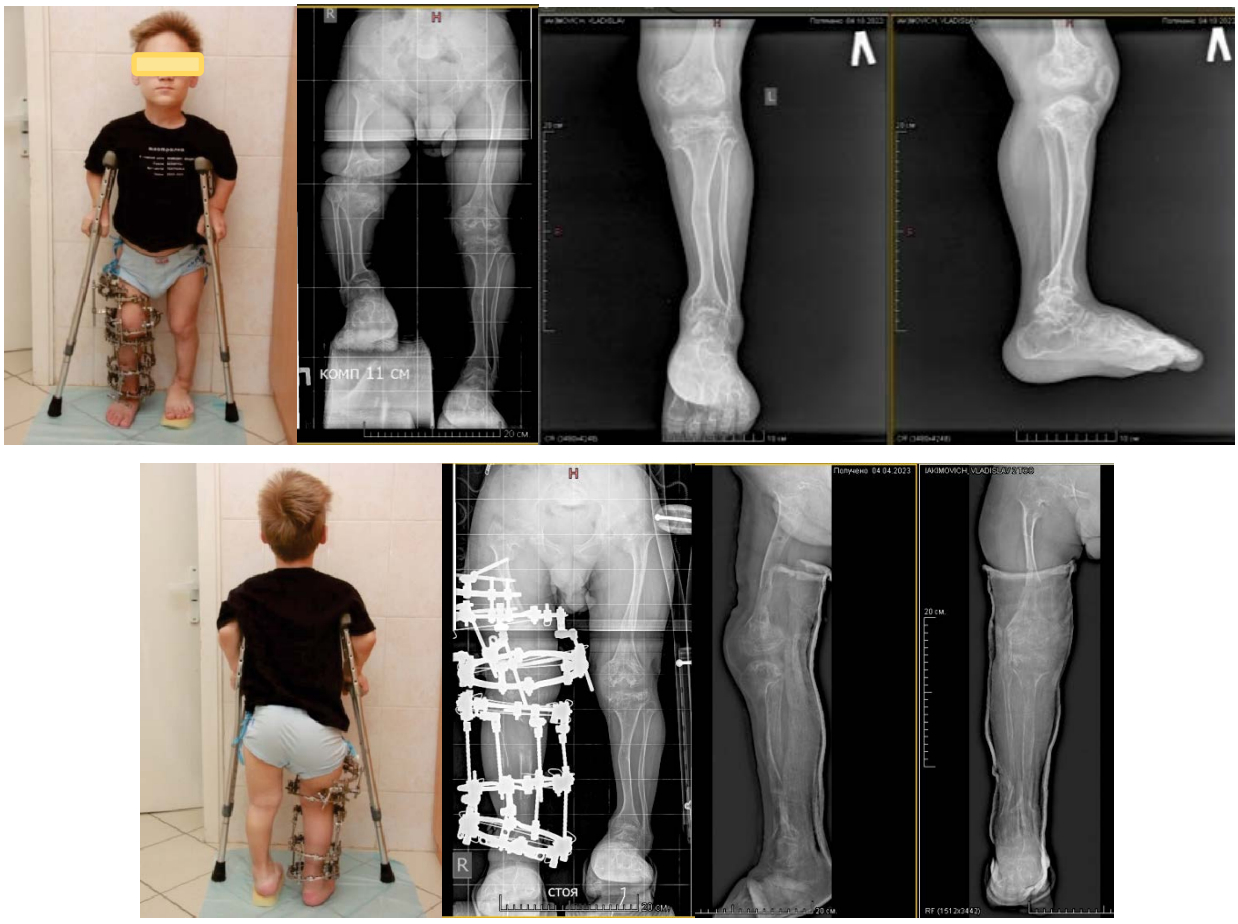

Figure 5. Photographs and radiographs of the thighs and tibiae of patient Y. after lengthening of the lower limb segments

Discussion

No previous literature has described the application of dual-approach corticotomy in patients with hypochondroplasia and achondroplasia. Furthermore, this study represents the first comparative analysis between the novel double-approach counter corticotomy technique and conventional femoral corticotomy in this patient population.

A complete osteotomy at the distal femoral third requires surgical exposure and circumferential cortical transection along anterolateral, posterolateral, anteromedial, and posteromedial surfaces using osteotomes or chisels. This approach inevitably causes significant damage to medullary canal structures and bone marrow.

The Ilizarov corticotomy [21, 22] involves mounting the supports of an external fixation device onto the femur and creating an access on the anterolateral surface of the thigh in the distal third of the femur. Using an instrument (a surgical chisel or an osteotome), the cortical plate is transected along the anterolateral and partially along the posterolateral surface of the femur. The anteromedial and posteromedial portions of the cortical plate on the femoral surface remain intact. Subsequently, a fracture of the remaining untransected bone portion (osteoclasis) is performed by rotating the supports of the external fixation device in opposite directions.

The Ilizarov corticotomy preserves bone marrow integrity but does not always result in a predictable fracture line of the femur; there is a risk that the untransected part of the bone will fracture along a line different from the planned one.

Thus, the limitation of existing bone dissection techniques lies in the risk of an unpredictable fracture line during bone integrity disruption. Conversely, achieving the planned fracture line through complete cortical transection fails to preserve the bone marrow and other medullary canal structures.

The success of orthopaedic treatment using Ilizarov transosseous osteosynthesis depends on multiple factors, one of the most critical being maximal preservation of osteogenic structures in the corticotomy zone. Corticotomy in the distal third of the femur presents specific technical challenges due to anatomical constraints, frequently preventing complete circumferential control of cortical transection. During conventional anterolateral corticotomy at the distal femoral third, for example, the osteotome can access only adjacent cortical plates, enabling transection of approximately three-quarters of the femoral circumference. Completion requires mechanical manipulation using either a bone spreader to wedge open the osteotomy or the application of force through external fixator supports to redress fragments, thereby disrupting the integrity of the remaining quarter of the femoral circumference. The dual-approach counter-corticotomy enables complete circumferential cortical dissection while preserving medullary canal structures and maintaining their osteogenic potential. The bilateral access provides comprehensive procedural control, allowing the surgeon to precisely detect corticotomy completion through tactile feedback, so to speak, at the tip of the osteotome.

Since both fixation wires and osteotome do not penetrate the medullary canal, the predetermined fracture pattern is achieved without rotational osteoclasis or medullary trauma. This technique enables precise cortical transection at the planned location with controlled geometry.

Evaluation of the dual-approach femoral corticotomy in 20 patients with hypochondroplasia and achondroplasia demonstrates its potential to expand the surgical arsenal for bone integrity disruption. Furthermore, when performing the proposed minimally invasive counter corticotomy in the distal femoral third, it was possible in 90% of cases to reduce operative time, prevent conversion of corticotomy to complete osteotomy, decrease surgical trauma, preserve medullary canal structures, minimize risk to vascular and neural elements within the canal during corticotomy, and consequently maintain maximal osteogenic potential for bone regeneration.

Conclusion

Careful preservation of medullary canal structures during osteotomy was achieved in both Group 1 and Group 2, with a high rate of satisfactory outcomes. The new dual-approach femoral corticotomy technique demonstrates viability as an alternative to conventional femoral corticotomy in patients with hypochondroplasia and achondroplasia.

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НЕОНАТОЛОГІЯ, ХІРУРГІЯ ТА ПЕРИНАТАЛЬНА МЕДИЦИНА
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МІНІМАЛЬНО ІНВАЗИВНА КОНТРАКТОРКОТОТОМІЯ ДИСТАЛЬНОГО ВІДДІЛУ БЕДРЕННОЇ КІСТКИ У ПАЦІЄНТІВ ІЗ ВРОДЖЕНИМИ ПОРУШЕННЯМИ ФУНКЦІЙ НИЖНІХ КІНЦІВОК (ЗІ ЗБЕРЕЖЕННЯМ СТРУКТУР МЕДУЛЛЯРНОГО КАНАЛУ)

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Резюме.

Зростаючий попит на ортопедичну корекцію вимагає вдосконалення хірургічних технік, що максимізують регенерацію кісток і мінімізують ятрогенну травму медулярного каналу.

Мета дослідження: оцінити результати нової подвійної кортикотомії стегнової кістки у пацієнтів з гіпохондроплазією та ахондроплазією.

Матеріали та методи. У проспективному динамічному активному дослідженні взяли участь 40 пацієнтів. Когорту було розділено на групу порівняння (група 1, n = 20) та дослідну групу (група 2, n = 20), до складу яких входили пацієнти дитячого віку від 7 до 18 років з полісегментарними деформаціями та укороченням нижніх кінцівок генетичної етіології. Група 1 пройшла традиційну кортикотомію з одним підходом, а група 2 – кортикотомію стегнової кістки з двома послідовними підходами – мінімально інвазивну контркортикотомію через передньомедіальний, а потім передньолатеральний доступ – іе з обов'язковою кінцевою стабілізацією за допомогою системи зовнішньої фіксації з натяжними стрижнями або шарнірними вузлами. Результати лікування оцінювали за чотирма параметрами: досягнуте подовження сегмента, відсутність залишкової деформації, збереження функції кінцівки та суглоба, а також показники задоволеності пацієнтів. Протокол дослідження отримав етичне схвалення від Етичної комісії Республіканського спеціалізованого науково-практичного медичного центру травматології та ортопедії (схвалення № 8-2023 від 15 серпня 2023 року). Всі процедури проводилися відповідно до Гельсінської декларації Всесвітньої медичної асоціації (поправки 2000 року).Статистичний аналіз проводився за допомогою Microsoft Excel 2013. З огляду на розміри вибірки в групах, було застосовано непараметричну статистику з рівнем значущості, встановленим на рівні $p \leq 0,05$. Кількісні характеристики вибірки представлені в таблиці у вигляді медіани (25-75-й процентиль) та кількості спостережень (n), що відповідає кількості крокових циклів. Статистична значущість відмінностей була визначена за допомогою непарного тесту Вілкоксона.

Фінансування. Дане дослідження виконано в рамках плану науково-дослідних робіт Бухарського державного медичного інституту (05.2022 DSc.135) «Розробка нових підходів до ранньої діагностики, лікування та профілактики патологічних станів організму, що впливають на здоров'я населення Бухарського регіону після COVID-19 (2022-2026)».

Результати дослідження. У групі 1 (n=20), де класичну кортикотомію в дистальній третині стегнової кістки проводили через передньолатеральний доступ, результати були відмінними у 85% пацієнтів, добрими у 5% і задовільними у 10%. У групі 2 (n=20), де застосовувалася подвійна контра-кортикотомія із збереженням медулярного каналу, результати були відмінними у 90%, добрими у 5% і задовільними у 5%.

Висновок. Обидві техніки забезпечили ретельне збереження структур медулярного каналу і дали високий відсоток задовільних результатів. Нова двостороння кортикотомія стегнової кістки виявилася життєздатною і ефективною альтернативою класичній техніці для пацієнтів з гіпохондроплазією та ахондроплазією.

Ключові слова: дистракційний остеосинтез; метод Ілізарова; остеотомія; кортикотомія; контр-кортикотомія; полісегментарний остеосинтез.

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