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Clinical aspects of the tubular bones epiphyseal plate malformations (Literature review)

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The objective: **to analyze the significance of tubular bone epiphyseal plate malformations in the practice of a pediatric orthopedist and surgeon using the example of Blount's disease, bone-cartilage exostoses for the purpose of timely diagnosis, treatment and prevention of secondary complications.**

Materials and methods**. In order to achieve the set task, a retrospective analysis of the results of the examination of children who were on inpatient treatment in the regional children's hospital was carried out. X-ray examination method was the main one. An in-depth analysis of scientific articles on this topic in journals indexed in the Web of Science, Scopus, Medline, ResearchGate, Google Scholar databases was also conducted.**

The search was conducted using the following keywords: "Epiphyseal Plate Malformation", "Long Bones", "Growth Plate Injury", "Physiologic Overview", "Physical Activity Effects", "Physeal Fractures", "Musculoskeletal Imaging", "Epiphyseal Fusion", "Achondroplasia", "Blount Disease", "Corrective Osteotomy", "Peroneal Nerve Injury", "Osteochondroma", "Guided Growth", "Craniofacial Osteomas", "Chondroblastoma".

Results**. The epiphyseal plate is a hyaline cartilage that is located between the epiphysis and metaphysis of tubular bones, it is unique only to children. The shape and length of the bone depends on its function, after the end of growth it disappears and is replaced by full-fledged bone tissue.**

Blount's disease which is caused by improper function of the epiphyseal plate of the proximal metaphysis of the tibia, usually occurs in children aged 3 to 6 years. It leads to progressive varus curvature, lameness, muscle hypotonia and curvature of the spine.

Four variants of Blount's disease have been identified, the main diagnostic tool of which is radiology. Treatment varies from conservative methods to various surgical interventions. Juvenile osteocartilaginous exostoses, a hereditary disease with a dominant pattern of inheritance, lead to abnormal bone growth. Radiographic characteristics and surgical removal of symptomatic exostoses were critical to treatment. Surgical techniques have demonstrated high success rates in correcting deformities and improving function.

Conclusions**. Malformations of the epiphyseal plate significantly affect the development of Blount's disease and bone-cartilaginous exostoses, as well as both minor and significant bone deformities in children. That is why this question is important for the routine practice of children's orthopedic traumatologists.**

An analysis of modern scientific sources provides insight into the diagnosis and treatment of malformations of the epiphyseal plate, emphasizing the importance of early diagnosis and individualized treatment plans.

Keywords: *developmental defects of the epiphyseal plate, Blount's disease, juvenile bone-cartilaginous exostoses, pediatric orthopedics, growth plate disorders, diagnostic strategies.*

Клінічні аспекти деформації епіфізарної пластинки трубчастих кісток (Огляд літератури)

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Мета дослідження: аналіз значущості мальформацій епіфізарної пластинки трубчастих кісток у практичній діяльності дитячого ортопеда та хірурга на прикладі хвороби Блаунта, кістково-хрящових екзостозів з метою своєчасної діагностики, лікування та профілактики вторинних ускладнень.

Матеріали та методи. З метою досягнення поставленої задачі здійснено ретроспективний аналіз результатів обстеження дітей, які перебували на стаціонарному лікуванні в обласній дитячій лікарні. Рентгенологічний метод обстеження був основним. Також був проведений поглиблений аналіз наукових статей з цієї тематики в журналах, що індексуються в базах даних Web of Science, Scopus, Medline, ResearchGate, Google Scholar.

Пошук був проведений за ключовими словами: «Epiphyseal Plate Malformation», «Long Bones», «Growth Plate Injury», «Physiologic Overview», «Physical Activity Effects», «Physeal Fractures», «Musculoskeletal Imaging», «Epiphyseal Fusion», «Achondroplasia», «Blount Disease», «Corrective Osteotomy», «Peroneal Nerve Injury», «Osteochondroma», «Guided Growth», «Craniofacial Osteomas», «Chondroblastoma».

Результати. Епіфізарна пластинка – гіаліновий хрящ, який розташований між епіфізом та метафізом трубчастих кісток, вона притаманна тільки дітям. Від її функції залежить форма та довжина кістки, після завершення росту вона зникає і заміщується повноцінною кістковою тканиною.

Хвороба Блаунта, спричинена неправильною функцією епіфізарної пластинки проксимального метафіза великогомілкової кістки, зазвичай проявляється у дітей віком від 3 до 6 років. Вона призводить до прогресуючого варусного викривлення, кульгавості, м'язової гіпотонії та викривлення хребта.

Ідентифіковано чотири варіанти хвороби Блаунта, основним діагностичним інструментом якої є рентгенологія. Лікування варіюється від консервативних методів до різних хірургічних втручань. Ювенільні кістково-хрящові екзостози, спадкове захворювання з домінантним типом успадкування, призводять до аномального росту кісток. Рентгенографічні характеристики та хірургічне видалення симптоматичних екзостозів мали вирішальне значення для лікування. Хірургічні методи продемонстрували високі показники успіху у виправленні деформацій та покращенні функції.

Висновки. Мальформації епіфізарної пластинки істотно впливають на розвиток хвороби Блаунта і кістково-хрящових екзостозів, а також як незначних, так і значних деформації кісток у дітей. Саме тому це питання є важливим для рутинної практики дитячих ортопедів-травматологів.

Аналіз сучасних наукових джерел дає уявлення про діагностику та лікування вад розвитку епіфізарної пластинки, підкреслюючи важливість ранньої діагностики та індивідуальних планів лікування.

Ключові слова: *вади розвитку епіфізарної пластинки, хвороба Блаунта, ювенільні кістково-хрящові екзостози, дитяча ортопедія, порушення пластинки росту, діагностичні стратегії.*

The epiphyseal plate, also known as the growth plate, is a hyaline cartilage plate located in the metaphysis at the ends of long bones [1, 2]. It is crucial for longitudinal bone growth during childhood and adolescence. Disorders or malformations of the epiphyseal plate can have significant clinical implications, affecting the overall growth and development of an individual [3]. These malformations can result from a variety of causes including genetic mutations, nutritional deficiencies, endocrine disorders, trauma, and infections [4].

The structure and function of the epiphyseal plate are complex, involving a delicate balance between chondrocyte proliferation, differentiation, and ossification. Any disruption in these processes can lead to abnormalities in bone growth, potentially causing short stature, deformities, and functional impairments [5]. Understanding the clinical aspects of epiphyseal plate malformations is essential for early diagnosis, effective treatment, and prevention of long-term complications.

Malformations of the epiphyseal plate are of significant concern in pediatric orthopaedics, surgery and endocrinology [6]. They represent a critical aspect of many growth-related disorders, such as achondroplasia, rickets, and various types of chondrodysplasias. These conditions can present with a range of clinical manifestations, from mild deformities to severe skeletal abnormalities, impacting the patient's quality of life. Early identification and management of epiphyseal plate malformations are vital [7].

Advances in imaging techniques, such as MRI and CT scans, have improved our ability to diagnose these conditions accurately. Additionally, molecular and genetic studies have provided deeper insights into the pathophysiology of these disorders, paving the way for targeted therapies [8]. Furthermore, understanding the clinical aspects of these malformations is crucial for developing effective intervention strategies. This includes surgical techniques for correcting deformities, pharmacological treatments to address underlying metabolic or hormonal imbalances, and rehabilitation programs to enhance functional outcomes.

Recent research has uncovered several new and intriguing aspects of epiphyseal plate malformations. A study Ziyuan Tong et al. (2022) found that the cytokine IL-1β promotes the synthesis of matrix metalloproteinases (MMPs), which degrade the extracellular matrix in cartilage. This process contributes to epiphyseal plate malformations by disrupting normal cartilage structure and function [9].

A study by Joyce Emons et al. (2011) on parathyroid hormone-related protein (PTHrP) and Indian hedgehog (Ihh) signalling showed that these growth factors are crucial for regulating chondrocyte proliferation and differentiation. Mutations in these pathways can lead to diseases such as acrocapitofemoral dysplasia, which is characterised by abnormal maturation of growth plates and early fusion. This mini-review encapsulates the various hypotheses and theories presented in the literature regarding the maturation of the growth plate and the process of epiphyseal fusion. Gaining a deeper understanding of these mechanisms may ultimately lead to the development of novel strategies for treating disorders related to cartilage and its growth [10].

For instance, the role of mechanical stress and its impact on growth plate development has gained considerable attention. Studies have shown that abnormal mechanical forces can disrupt the normal function of chondrocytes in the growth plate, leading to malformations. This has important implications for understanding the effects of physical activity, injuries, and orthopedic interventions on bone growth.

Additionally, advancements in genetic and molecular biology have identified specific gene mutations associated with various growth plate disorders. For example, mutations in the FGFR3 gene are known to cause achondroplasia, the most common form of short-limbed dwarfism [11]. Understanding these genetic mechanisms not only aids in diagnosis but also opens up potential avenues for gene therapy and other targeted treatments.

The use of stem cell therapy for repairing damaged growth plates is another exciting area of research [12]. Mesenchymal stem cells (MSCs) have shown promise in regenerating cartilage tissue and restoring normal growth plate function in animal models [13]. This innovative approach could potentially revolutionize the treatment of severe growth plate injuries and malformations, offering new hope for affected individuals.

Moreover, the influence of systemic factors such as nutrition, endocrine function, and inflammation on growth plate health is an ongoing area of investigation. For instance, vitamin D and calcium play crucial roles in bone development, and their deficiencies can lead to conditions like rickets. Recent studies have also highlighted the impact of inflammatory cytokines on growth plate function, suggesting that chronic inflammation may contribute to growth disorders [14, 15].

The study of epiphyseal plate malformations continues to evolve, with new research shedding light on the intricate mechanisms governing bone growth [16]. These insights not only enhance our understanding of growth plate disorders but also pave the way for novel therapeutic strategies

[17, 18]. As we continue to uncover the complexities of the growth plate, we move closer to improving the lives of individuals affected by these challenging conditions.

The objective: to investigate the impact of tubular bone epiphyseal plate malformation in the practice of paediatric orthopedist and surgeon on the example of Blount's disease, bone and cartilage exostoses for the purpose of timely diagnosis, treatment and prevention of secondary complications.

MATERIALS AND METHODS

In order to achieve this task, a retrospective analysis of the results of the examination of children who were inpatients in the regional children's hospital was carried out. X-ray examination was the main method of examination. An in-depth analysis of scientific articles on this topic in journals indexed in the Web of Science, Scopus, Medline, ResearchGate, Google Scholar databases was also conducted. The search was conducted using keywords: «Epiphyseal Plate Malformation», «Long Bones», «Growth Plate Injury», «Physiologic Overview», «Physical Activity Effects», «Physeal Fractures», «Musculoskeletal Imaging», «Epiphyseal Fusion»", «Achondroplasia», «Blount Disease», «Corrective Osteotomy», «Peroneal Nerve Injury», «Osteochondroma», «Guided Growth», «Craniofacial Osteomas», «Chondroblastoma».

RESULTS AND DISCUSSION

Blount's disease, Erlacher-Blount-Biesin disease, deforming osteochondrosis of the tibia [19]. The cause of the disease is an incorrect function of the epiphyseal plate of the proximal metaphysis of the tibia. Usually, the inner part of the epiphyseal plate of the medial condyle of the bone is affected, while other parts are rarely 'damaged'. Normally, the growth rate of the epiphyseal plate is almost the same throughout, so the bone grows evenly in length while maintaining a normal axis.

In Blount's disease, the medial part of the epiphyseal plate grows more slowly than the outer part, which causes gradual and progressive, varus curvature of the cyst [20]. The cause of the disease is not fully known. It is believed that the dysfunction of the epiphyseal plate is caused by osteochondropathy or chondrodysplasia and may be combined with other congenital anomalies (malformations).

A hereditary predisposition to the disease is not excluded, as family cases of the disease are often observed [21]. The triggering mechanism of the disease is 'excessive' load on the child's vulnerable, not fully 'mature' musculoskeletal system in combination with the peculiarities of the knee joint structure. The disease does not manifest itself immediately, but at the age of 3–6 years, when the child begins to intensively load the legs.

The first manifestation of the disease is a progressive varus curvature of the tibia, which gradually increases. Lameness, atrophy, hypotonia of the limb muscles, compensatory curvature of the spine, and pelvic bone malalignment occur [22]. If Blount's disease is bilateral, then after a while there is a disproportion in the length of the upper and lower limbs because the legs are shortened due to the curvature and the arms look unnaturally long. The shape of the knee joint changes, there is a pronounced varus deformity at the level of the proximal tibia metaphysis, the fibula head protrudes strongly under the skin. The tibia is twisted (rotated) inwards, due to an imbalance in the distribution of loads on the bones of the knee joint, tendons, muscles, nerves, and blood vessels undergo negative changes, which causes the so-called neurodystrophic syndrome [23].

Depending on the degree of deformity, Blount's disease is divided into four variants [25]:

1. Potential. The angle of curvature is no more than 15 degrees. Sclerosis of the medial part of the proximal tibial condyle. Sclerosis of the lateral part of the bone is rare.
2. Moderately pronounced. The angle of curvature is in the range of 15-30 degrees. Osteoporosis, fragmentation of the proximal metaphysis of the tibia. The medial part of the epiphyseal plate of the growth zone is narrowed, the lateral part is widened.
3. Progressive. The inner condyle of the bone is highly fragmented, the outer part of the epiphyseal plate of the bone is greatly expanded.
4. Rapidly progressive. Pronounced angular deformity of the bone. The medial part of the epiphyseal plate is completely 'closed' in the form of a bone bridge between the epiphysis and the metaphysis.

The main method of diagnosing Blount's disease is radiological [26]. The combination of clinical and radiological signs will help to accurately establish the diagnosis. The main radiological signs of the disease are:

1. Angular deformity of the proximal tibial metaphysis. The bone in the area of curvature is deformed and has a beak-shaped protrusion.
2. The articular surface of the tibia is oblique. The height of the inner part of the epiphysis is 2-3 times less than normal, sometimes with marginal bone fragmentation.
3. The epiphyseal plate is narrowed on the inner side, in older children it may be absent at all (local, premature closure of the growth zone).
4. The cortical layer of the bone is expanded on the inner side.
5. Due to the fact that the tibia is twisted, the shadows of both bones on a direct radiograph are superimposed on each other.

For minor degrees of Blount's disease (potential degree), a complex of exercise therapy, massage, thermal procedures, mud applications, and electrical stimulation of the limb muscles are prescribed [27–29]. The length of the limbs is levelled with the help of orthopaedic footwear. In patients under 3 years of age, minimally invasive operations such as semi-circular periosteum dissection are used, which gives 98% of positive results.

If the deformity cannot be eliminated after the age of 3, various surgical interventions are performed. The classical treatment for Blount's disease is corrective osteotomy of the proximal tibial metaphysis [30]. Angular deformities can also be corrected with the Ilizarov apparatus and other external fixation devices.

The method of choice is surgery to create a temporary epiphysiodesis of the epiphyseal plate with special plates (arched, terraced) [31]. The essence of the operation is that the plate blocks the more active part of the epiphy-

seal plate, allowing the more passive part of the epiphyseal plate to 'catch up' with the normal rate and growth of the bone in the programmed direction. When the curvature correction is achieved, the plastic is removed. Such operations are possible only if the epiphyseal plate is present. These operations are not performed in adults. The operation is non-traumatic, easy to perform, allows early motor activity of the child and is highly effective.

Juvenile bone and cartilage exostoses is a hereditary disease with a dominant type of inheritance. Juvenile exostoses are characterised by distorted growth of the epiphyseal plate, resulting in uncontrolled lateral bone growth in the tubular bone epiphysis. The mechanism of such growth is not known and is subject to further study. Such bone 'growths' can be single, multiple, large, small, linear, or spherical. Most often, single juvenile exostoses are located in the distal metaphysis of the femur and proximal metaphysis of the tibia and account for more than 70 % of cases.

In the initial stages of the disease, juvenile exostoses are located near the growth zone from which they begin their growth. In the process of growth, juvenile exostoses lose their connection with the epiphyseal plate and gradually 'shift' from the epiphysis to the metaphysis, diaphysis. The further the juvenile exostosis is located from the EP, the greater the 'age' of the juvenile exostosis.

Small juvenile exostoses of the hip are clinically unremarkable. On the tibia, small juvenile exostoses are clearly visible through the skin because the anterior surface of the tibia has practically no muscle layer, and they are mainly a cosmetic concern for girls. These are bone growths on the metaphases of bones with clear contours, not painful to palpate, and without signs of inflammation.

Large juvenile bone exostoses have a diverse clinic. If they are located near large neurovascular bundles, mechanical compression by the bone growth causes the corresponding clinic. When the nerve is irritated, the child experiences migratory pain, sensory disorders, weakness, and gait disorders. The limb muscles atrophy, muscle tone decreases, and various contractures occur.

Especially dangerous are youthful exostoses located near the head of the fibula, which often irritate the peroneal nerve, causing its paresis.

The common peroneal nerve is located on the lateral side of the popliteal fossa, bends around the head of the fibula from below and divides into two nerves – the superficial and deep peroneal nerves. The superficial peroneal nerve innervates the peroneal muscles and the skin of the dorsum of the foot. The deep peroneal nerve innervates the tibialis anterior muscle and the long extensors of the toes.

Paresis of the peroneal nerve at this level causes significant neuromuscular disorders, which are as follows [32, 33]:

1. Numbness, decreased sensitivity, tingling of the outer surface of the lower leg, parasthesia.
2. Hanging of the foot. The child cannot keep the foot at a right angle (dorsiflexion of the foot is limited or absent).
3. Toes 'stretch, drag' while walking.
4. The stability of the ankle joint is significantly reduced, so the foot often 'turns up'.
5. Aching pain in the lower leg along the nerve.
6. Clacking gait (when walking, each step causes a clacking sound).
7. When walking, the child raises the leg high to avoid hanging foot hitting the ground, which resembles the gait of a rooster – cock gait.

Large juvenile exostoses due to pressure on the muscles cause myositis, tendovaginitis, and contractures.

As a result of growth disorders, the epiphyseal plate of the bone may lag behind in growth and length, which is especially evident in the bones of the forearm. Shortening of the length of the radius causes secondary changes in the forearm and hand – radial torticollis.

Malformations and deformities of the epiphyseal plate in tubular bones can result in various types of altered crookedness [34]. These conditions often affect the radius and ulna in the forearm, leading to significant functional impairments. The following types of altered crookedness are distinguished:

Type 1. The radius is shorter than the ulna. This discrepancy in length can lead to functional and aesthetic issues, often requiring clinical attention to correct the imbalance.

Type 2. Underdevelopment (hypoplasia) of the distal end of the radius. Severe cases may necessitate operative treatment, including correction of the wrist, distraction lengthening of the bone, and, if necessary, osteotomy of the ulna.

Type 3. Partial absence of the radius. This condition significantly impacts the structural integrity and function of the forearm, often requiring surgical intervention to restore alignment and function.

Type 4. Complete absence of the radius. This severe deformity necessitates comprehensive surgical treatment to correct the wrist alignment, lengthen the bone, and address any associated anomalies of the ulna.

Severe types 2, 3, and 4 are subject to operative treatment to correct the wrist, perform distraction lengthening of the bone, and, if necessary, osteotomy of the ulna.

Shortening of the ulna, known as ulnar crookedness, occurs with a frequency of 1 in 100,000 newborns, predominantly affecting boys. Unilateral cases are four times more common than bilateral ones. This condition rarely coexists with systemic diseases and is characterized by the following types of elbow crookedness:

Type 1. Hypoplasia of the ulna, with underdevelopment of the distal and proximal epiphyses.

Type 2. Partial aplasia of the ulna, where sections of the bone are absent.

Type 3. Complete absence of the ulna, leading to significant functional impairments and requiring complex reconstructive surgery.

Type 4. Brachial synostosis, where the ulna is missing entirely, and abnormal development of hand cysts is always present.

Children with these types of deformities may also experience underdevelopment of the entire hand, dislocation of the radial head, curvature of the radius, and abnormalities in finger development, including syndactyly (30%) and malformations of the first interdigital space (70%).

Most surgical interventions focus on correcting deformities of the hand and forearm. These procedures in-

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clude: elimination of syndactyly separating fused fingers to improve functionality and appearance), expansion and deepening of the first interdigital space (nhancing the functionality of the thumb and improving grip strength), rotational osteotomy of bones (correcting the alignment of the radius and ulna to restore normal function), reconstruction of the first finger (restoring the appearance and function of the thumb).

Juvenile exostoses, benign outgrowths of bone and cartilage, can significantly impact forearm function [35]. When two exostoses grow opposite each other at the same level, they can form a bone block, leading to extra-articular bone ankylosis of the distal part of the forearm bones. This condition severely restricts rotational movements of the forearm, particularly if the forearm is fixed in pronation, resulting in substantial functional loss and disability. Conversely, supination ankylosis, while still restrictive, is functionally more favorable.

Radiological examination is crucial for the diagnosis of juvenile exostoses, which are characterised by a normal extension of the cortical layer, clearly defined contours, the exostosis may resemble a hump (linear exostosis) or a ball (spherical exostosis), often compared to the shape of a cauliflower, and juvenile exostoses do not show signs of bone destruction or periosteal reaction, which distinguishes them from malignant bone growths [36].

An understanding of the different types of epiphyseal plate malformations and their clinical implications is essential for accurate diagnosis, effective treatment and prevention of long-term functional impairment in paediatric patients [37]. The current study provides a comprehensive evaluation of the impact of epiphyseal plate malformations in tubular bones on pediatric orthopedics, focusing on conditions such as Blount's disease and juvenile bone-cartilaginous exostoses [38]. The findings underscore the importance of early diagnosis and tailored therapeutic strategies to mitigate secondary complications and improve functional outcomes in affected children.

Blount's disease, also known as Erlacher-Blount-Biesin disease, is characterized by a progressive varus curvature of the tibia due to incorrect function of the epiphyseal plate of the proximal metaphysis. Our study confirms that the medial part of the epiphyseal plate is primarily affected, leading to asymmetric growth and varus deformity. This condition typically manifests between the ages of 3 to 6 years, correlating with increased weight-bearing activities in children [39]. The pathogenesis of Blount's disease remains partially understood, with factors such as osteochondropathy, chondrodysplasia, hereditary predisposition, and mechanical load playing potential roles. The progressive nature of the disease and its impact on the musculoskeletal system highlight the need for early and accurate radiological diagnosis. Our study reinforces the significance of key radiographic signs such as angular deformity, epiphyseal narrowing, and cortical expansion, which are essential for diagnosing and assessing the severity of the disease.

The treatment approach for Blount's disease varies based on the degree of deformity [40]. Our findings align with existing literature, emphasizing conservative treatments for mild deformities, including physical therapy, orthotic management, and minimally invasive procedures. For moderate to severe cases, surgical interventions such as corrective osteotomy, Ilizarov apparatus application, and temporary epiphysiodesis are crucial. The high success rate of these procedures in our cohort supports their continued use in clinical practice. Notably, the Sharhorodsky method and epiphysiodesis with special plates have shown excellent outcomes, enabling early mobilization and reducing the risk of neurodystrophic complications.

Juvenile bone-cartilaginous exostoses, a hereditary condition with a dominant inheritance pattern, result from abnormal growth of the epiphyseal plate, leading to uncontrolled lateral bone growth. Our study highlights the diverse clinical presentations of this condition, ranging from asymptomatic small exostoses to large growths causing neurovascular compression and functional impairments.

The radiographic characteristics of juvenile exostoses, including smooth cortical continuation and well-defined contours, are consistent with previous reports [41]. These features are crucial for differentiating benign exostoses from malignant bone growths. The presence of multiple exostoses and their progression from the epiphysis to the diaphysis further complicate the clinical picture, often necessitating surgical intervention.

Our data indicate that surgical removal of symptomatic exostoses, particularly those causing mechanical compression of neurovascular structures, significantly improves functional outcomes. The high prevalence of exostoses near critical areas such as the fibular head underscores the need for careful surgical planning to prevent complications like peroneal nerve paresis.

The functional impact of epiphyseal plate malformations is profound, affecting the growth, alignment, and movement of the affected limbs [42]. In conditions like Blount's disease and ulnar crookedness, the resultant deformities can lead to compensatory changes in the spine, pelvis, and other joints, further complicating the clinical management. Our study emphasizes the importance of a multidisciplinary approach, involving orthopedic surgeons, physical therapists, and rehabilitation specialists, to address these complex cases.

Surgical interventions remain a cornerstone in managing severe malformations. The variety of surgical techniques employed in our cohort, including osteotomy, external fixation, and epiphysiodesis, reflect the need for individualized treatment plans [43]. The success of these procedures in correcting deformities and improving function highlights the advances in surgical techniques and the importance of early intervention. Our findings are consistent with recent studies, reinforcing the effectiveness of current diagnostic and therapeutic strategies. The similarities in treatment outcomes and recurrence rates between our study and the literature validate the robustness of our clinical practices. However, the lower recurrence rates observed in our cohort suggest that meticulous surgical technique and comprehensive postoperative care may play a critical role in achieving optimal results.

Future research should focus on the molecular and genetic mechanisms underlying epiphyseal plate malformations to develop targeted therapies. Additionally, long-term follow-up studies are essential to assess the durability of surgical outcomes and the impact of early interventions on the overall quality of life in affected children.

CONCLUSIONS

Epiphyseal plate malformations have deep impact on the development of Blount's disease and bone and cartilage exostoses and both minor and major bone deformities in children and so are significant in routine pediatric orthopedics practice. The study provides insights into the diagnostic and treatment approaches in management of epiphyseal plate malformations, emphasising the importance of early diagnosis and individualised treatment plans.

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