# Role of Pediatric Nurses in the Long-Term Management of Osteogenesis Imperfecta

**Ibtesam Sattar Mubarak Alruwaili [1], Tahani Saber Alenezi [2], Alruwaili, Intithar Sarhan S [3], Alanzi, Mohammed Ibrhim Jihad [4], Munayfah Ayidh Mohammed Alruwaili [5], Amani Saber Ayed Al Anzi [6], Alazmi, Noaf Abdullah M [7], Nuwayyir Olaywi Ganitan Alruwaili [8], Jamal Mhaly Alenezi [9], Saad Farhan Aladham Alanazi [10]**

1- Nursing specialist, Northern borders health cluster, Saudi Arabia
2- Nursing technician, Regional Laboratory and Blood Bank, Arar, Saudi Arabia
3- Nursing technician, Eastern Turaif Health Center, Turaif, Saudi Arabia
4- Nursing technician, Ministry of Health Branch, Tabuk, Saudi Arabia
5- Nursing technician, Prince Mutaib bin Abdulaziz Hospital, Sakaka, Saudi Arabia
6- Nursing technician, North Medical Tower, Arar, Saudi Arabia
7- Nursing technician, Eradah Complex for Mental Health- Al-Qurayyat, Saudi Arabia
8- Nursing , Al-Rafiah Health Center, Sakaka, Al-Jouf, Saudi Arabia
9- General nursing, Al-Salhiyah North Health Center, Arar, Saudi Arabia
10- Nursing, Purchasing Department of Medical Supply, Arar, Saudi Arabia

**Abstract:**
Pediatric nurses play a crucial role in the long-term management of Osteogenesis Imperfecta (OI), a genetic disorder characterized by brittle bones that fracture easily. These nursing professionals are responsible for the comprehensive care of children with OI, encompassing education, care coordination, and emotional support for both patients and their families. They assess the child's physical condition, monitor for potential complications, and implement individualized care plans that address specific needs. This includes facilitating regular check-ups, promoting safe mobility practices, and educating families about fracture prevention strategies, nutrition, and medication management. Pediatric nurses also serve as advocates for their patients, collaborating with multidisciplinary teams to ensure that children receive holistic care tailored to their physical and psychosocial needs. In addition to clinical responsibilities, pediatric nurses play a pivotal role in providing emotional support and psychological counseling to children living with OI and their families. They help foster a positive environment by encouraging children to participate in age-appropriate activities and social interactions while managing their condition. By offering guidance on coping strategies and resources, pediatric nurses empower families to navigate the unique challenges posed by OI. Furthermore, they stay updated on the latest research and advancements in OI management, allowing them to offer evidence-based care and support that can enhance the quality of life for children affected by this condition.

**Keywords:** Pediatric nurses, Osteogenesis Imperfecta, long-term management, brittle bones, care coordination, education, fracture prevention, emotional support, multidisciplinary teams, evidence-based care

**Introduction:**

Osteogenesis imperfecta (OI), often referred to as "brittle bone disease," is a genetic disorder characterized by fragile bones that are prone to fractures. This condition results from a defect in the body's ability to produce collagen—a critical protein for the strength and integrity of bones and connective tissues. While the severity of OI can vary significantly, from mild forms with few fractures to more severe types that can lead to multiple fractures over a short timeframe, the lifelong management of this condition is universally essential. Given the chronic nature of OI and its profound impact on the daily lives of affected children and their families, pediatric nurses play a pivotal role in the comprehensive management of this disorder [1].

Pediatric nurses serve as the frontline caregivers in various healthcare settings, working collaboratively with families and a multidisciplinary team to provide holistic care to children living with OI. Their involvement across different aspects of patient care extends beyond mere medical treatment; it encompasses education, emotional support,

coordination of care, and advocacy for patients' needs. The role of pediatric nurses in the long-term management of osteogenesis imperfecta merits significant attention, as they bridge clinical expertise and compassion, ensuring that children with OI can lead fulfilling lives amidst their challenges [2].

In the past two decades, advancements in medical knowledge and techniques have greatly enhanced the understanding and treatment of OI. Historically, treatment options were limited, often focusing on managing symptoms and preventing fractures through physical therapy and lifestyle modifications. However, modern therapies, including bisphosphonates and surgical interventions such as intramedullary rods, have revolutionized the management of OI, promoting a more comprehensive strategy that aims to improve the quality of life for affected children. The widening scope of treatment options necessitates a more profound engagement from pediatric nurses, who must remain updated on current therapies, potential side effects, and the ongoing evaluation of patients' progress [3].

Education emerges as a cornerstone of nursing practice in the context of OI. Pediatric nurses play a crucial role in providing education to families about the condition, its management, and preventive measures to minimize fractures. Nurses serve as valuable resources for guidance on safe activities, nutritional considerations, and appropriate physical therapy regimens. Moreover, they empower families to advocate for their children's needs within the healthcare system, including navigating insurance obstacles for necessary treatments and equipment. This educational role is especially vital in the long-term management of OI, where repeated collaborations with healthcare providers become essential as the child grows and their needs evolve [4].

Emotional and psychological support is another critical aspect of pediatric nursing that is integral to managing osteogenesis imperfecta. Families facing the challenges associated with OI often experience emotional distress, anxiety, and uncertainty regarding their child's future. Pediatric nurses are uniquely positioned to provide empathetic support, creating a safe environment in which families can express their concerns and fears. They facilitate communication among family members, healthcare providers, and support networks, reinforcing the understanding that the care of a child with OI is a collective effort that requires coordinated teamwork [5].

In addition to education and emotional support, pediatric nurses play a vital role in care coordination. The management of a complex condition like OI necessitates collaboration among various specialists, including orthopedic surgeons, geneticists, physical therapists, and social workers. Pediatric nurses serve as the keystone that unites these professionals, ensuring that care plans are implemented consistently while monitoring the child's progress and adapting interventions as necessary. This multidisciplinary approach is essential not only for addressing the physical aspects of OI but also for addressing the social, emotional, and developmental challenges that these children may face [6].

The importance of advocacy cannot be overstated in the context of the long-term management of osteogenesis imperfecta. Pediatric nurses often act as advocates for their patients, working to ensure they receive appropriate care and resources. This advocacy might include alerting schools to the needs of children with OI, helping families secure necessary assistive devices, or promoting awareness about OI within the community. Such efforts are critical in facilitating an inclusive environment that acknowledges and accommodates the unique challenges faced by children with brittle bone disease [7].

Research on the long-term management of osteogenesis imperfecta highlights the transformative role that pediatric nurses play. Their contributions to patient education, emotional support, care coordination, and advocacy are indispensable in providing comprehensive care that meets the multifaceted needs of children with OI and their families. As healthcare evolves, the integration of pediatric nursing into the management of chronic conditions like osteogenesis imperfecta must be emphasized, ensuring that the voices of these vital healthcare professionals are heard and valued within the multidisciplinary team [8].

**Nursing Assessment Process for Osteogenesis Imperfecta**

The nursing assessment for children with OI comprises systematic observations, evaluations, and patient history taking, focusing on several key areas.

**1. History and Physical Examination**

The initial stage involves collecting pertinent medical history. Key components include:

- **Family History**: Since OI can be inherited, family background should be assessed for similar conditions or other genetic disorders [9].
- **Birth History**: Inquiry about the child's pregnancy and delivery, including any preterm birth or maternal illnesses, helps contextualize the child's overall health.
- **Fracture History**: Understanding the frequency and circumstances surrounding previous fractures can reveal patterns and may indicate the severity of OI.
- **Growth and Development**: Monitoring growth patterns and developmental milestones assists in evaluating the child's overall health status [10].

Additionally, a thorough physical examination should include:

- **Skeletal Assessment**: Inspecting the bones through palpation and observation, paying special attention to any deformities or signs of past fractures.
- **Muscle Tone and Strength**: Assessing overall muscle strength, including limbs and trunk, helps identify mobility issues or potential impairments [11].
- **Neurological Assessment**: Basic neurological evaluations help discern any potential complications stemming from fractures or neurological issues [11].

**2. Pain Assessment**

Children with OI frequently experience pain due to fractures or bone deformities. Pediatric nurses should employ age-appropriate pain assessment tools, such as the Wong-Baker FACES Pain Rating Scale for younger children or numerical rating scales for older children. Assessing pain severity, location, and frequency is essential for devising an effective pain management plan [12].

**3. Mobility and Functional Assessment**

Understanding the child's mobility and functional capacity is critical. Nurses should perform:

- **Gait Analysis**: Observe the child's walking patterns. Abnormal gait may indicate underlying bone issues or muscle weakness.
- **Range of Motion (ROM) Evaluation**: Assessing both active and passive ROM helps identify limitations that may be exacerbated by fractures.
- **Assistive Device Use**: Evaluating the need for assistive devices (such as walkers or wheelchairs) can foster independence and enhance the quality of life [13].

**4. Nutritional Assessment**

Proper nutrition is vital for children with OI to promote bone health. Nurses should assess dietary habits, focusing on calcium and vitamin D intake, which are critical for bone density. In some cases, children with OI may require nutritional supplements, such as calcium or bisphosphonates, to improve bone health. Collaborating with a pediatric dietitian may be necessary for tailored dietary management [14].

**5. Psychosocial Assessment**

The emotional and psychological wellbeing of children with OI cannot be overstated. Fractures and chronic pain can lead to feelings of anxiety, frustration, or social isolation. Pediatric nurses should observe and inquire about [15]:

- **Emotional State**: Identifying signs of anxiety or depression through conversation and observation.
- **Social Interactions**: Assessing peer relationships and social interactions is vital, as children with OI may feel isolated or different from their peers.
- **Family Dynamics**: Understanding the family structure and support mechanisms in place can provide insight into how the child copes with their condition [16].

**Ongoing Assessments**

The assessment process for children with OI is not a one-time task but rather an ongoing process that requires regular reevaluation as the child grows and develops. Continuous assessments should focus on:

- **Bone Health Monitoring**: Regular check-ups to evaluate bone density through procedures like Dual-Energy X-ray Absorptiometry (DEXA) scans.

- **Fracture Rates**: Keeping track of any new fractures and determining if they are becoming more frequent.
- **Individualized Care Plans**: Regularly updating care plans based on the child's changing health status, developmental progress, and family input [17].

**Creating Individualized Care Plans:**

Given the heterogeneous nature of OI, where symptoms can range significantly between individuals, a one-size-fits-all approach to treatment is inadequate. The complexity of managing OI involves various medical, physical, and psychological factors, which necessitate the development of comprehensive, personalized care plans tailored to the specific manifestations and needs of each patient [18].

Individualized care plans serve as roadmaps guiding patients and healthcare providers towards effectively managing the multifaceted challenges posed by OI. These plans are crucial for several reasons:

1. **Addressing Physical Health Considerations**: Each patient with OI has a unique skeletal structure, pain tolerance, and history of fractures. The primary focus of a care plan is to prioritize the prevention of fractures, management of pain, and safety in activities. For instance, children diagnosed with OI Type III, who often experience more significant mobility challenges, could benefit from physical therapy tailored to strengthen muscle support around fragile bones, while older adults may require specialized exercise regimens aimed at maintaining balance, flexibility, and overall bone health [19].
2. **Psychosocial Support**: Beyond physical health, OI profoundly impacts emotional and psychological well-being. Tailored care plans can incorporate mental health screenings and referrals to counseling services. Children with OI may experience anxiety related to their condition, while adults might face challenges associated with social stigmatization and independence. Support groups can be vital, allowing patients to share experiences and coping strategies, thereby reducing feelings of isolation [20].
3. **Nutritional Considerations**: Nutrition plays a pivotal role in bone health. A personalized care plan could include dietary recommendations, such as increasing calcium and vitamin D intake, which are essential for bone density. Understanding the unique dietary needs of each OI patient assists in optimizing their health outcomes and potentially mitigating the risks associated with low bone mass [21].
4. **Personal Emergency Plans**: Creating a plan specific to emergency situations, including detailed instructions for caregivers on how to respond to fractures or other related emergencies, is particularly important for patients with severe forms of OI. The plan could include contact information for specialists and instructions on safe transportation to medical facilities [22].
5. **Pharmacological Interventions**: Medications such as bisphosphonates can significantly impact the management of OI by increasing bone density and reducing fracture rates. Individualized care plans allow healthcare providers to adjust pharmacological therapies based on the patient's specific type and severity of OI, their age, medical history, and response to previous treatments [23].

Creating individualized care plans is not the sole responsibility of a single healthcare provider; it requires a collaborative effort from an interdisciplinary team. This team may include orthopedic surgeons, physical and occupational therapists, nutritionists, genetic counselors, and psychologists. Each member brings a unique expertise that is essential for a holistic management strategy [24].

Regular multidisciplinary meetings should be part of the care planning process, where team members discuss the latest developments in research, therapies, and individualized treatment approaches. This collaboration ensures that every aspect of a patient's care—physical, emotional, and nutritional—is addressed cohesively and efficiently, ultimately improving overall patient outcomes [25].

Furthermore, the development of individualized care plans extends beyond medical interventions. Empowering patients through education is

paramount. Patients and their families must understand their condition, the rationale behind specific treatments, and the importance of adhering to the care plan. Educational resources, workshops, and informational sessions can greatly enhance the understanding of OI, equipping patients with practical knowledge regarding their condition [26]. In addition, support from advocacy groups focusing on OI can play a crucial role in providing resources, connecting patients and families to specialists, and promoting awareness. Having a trusted network can make a significant difference in navigating the challenges of living with a chronic condition [27].

**Education and Family**

Family involvement plays a critical role in the management of OI. A supportive family environment can greatly enhance the quality of life for individuals with OI. Families that are well-informed, engaged, and empowered tend to better advocate for their loved ones' needs, navigate the healthcare system, and implement effective management strategies at home. [28] Moreover, familial support may mitigate the emotional distress and social stigma often associated with living with a chronic condition like OI. Therefore, educating families about OI is not merely an aspect of medical care; it is a fundamental component in fostering resilience and promoting overall well-being [29].

**Strategies for Educating Families**

1. **Structured Educational Programs**: Healthcare providers can establish structured educational interventions designed specifically for families. These programs can include workshops, seminars, and support groups aimed at teaching families about OI, its implications, and effective management strategies. By creating a structured environment, families can gain access to expert knowledge, discuss their concerns, and connect with others facing similar challenges [30].
2. **Multimedia Resources**: Developing a repertoire of multimedia educational materials can enhance learning experiences for families. These materials can include videos, pamphlets, infographics, and interactive online modules that provide clear, accessible information about OI. Visual aids can help families grasp complex medical concepts and care techniques, making the information more relatable and easier to understand. Moreover, these resources can be available in multiple languages to cater to diverse populations [31].
3. **One-on-One Counseling**: Individual counseling sessions with healthcare professionals can provide families with personalized education on OI management. Such sessions can focus on specific care techniques, such as safe mobility practices, strategies for preventing fractures, and managing pain. One-on-one interactions allow families to ask questions and express their concerns directly, facilitating a more tailored and supportive education experience [32].
4. **Collaboration with Educational Institutions**: Collaborating with schools and educational institutions can promote understanding of OI among teachers, school nurses, and classmates. Educators can be trained to recognize the needs of students with OI and develop inclusive practices that accommodate their unique challenges. Simultaneously, families can also educate peers and educators about the condition to reduce stigma and promote empathy within school environments [33].
5. **Use of Technology**: Embracing technology can enhance education and communication between families and healthcare providers. Telemedicine services can facilitate remote consultations, enabling families to receive ongoing support and guidance regardless of geographic barriers. Additionally, apps and online forums can help families access credible information, track health progress, and connect with support networks [34].
6. **Peer Support Programs**: Prioritizing peer support programs can foster shared learning among families. By connecting families of individuals with OI, experiential knowledge is exchanged, and best practices for management, daily care, and emotional support are discussed. Peers often provide a unique insight that academic education may not cover, helping families to feel less isolated and more empowered [35].

7. **Focus on Holistic Management**: Education should emphasize a holistic approach to managing OI, incorporating not only medical care but also physical therapy, nutritional considerations, and mental health support. Families can be educated on the importance of maintaining a balanced diet rich in calcium and vitamin D, engaging in physical activities suited to individual capabilities, and recognizing the psychological impacts of OI. By addressing multiple aspects of the individual's life, families can support comprehensive care [36].
8. **Feedback Mechanism**: Finally, establishing a feedback mechanism can help healthcare providers assess the effectiveness of educational interventions and make necessary adjustments. Surveys, focus groups, and direct feedback from families can provide insights on the clarity, relevance, and application of the information provided. This iterative process ensures that education remains targeted and responsive to the evolving needs of families dealing with OI [37].

**Emotional and Psychological Support for Patients and Families:**

**1. Emotional Challenges:** Children with OI often struggle with emotional issues stemming from their medical condition. Frequent fractures and hospital visits can lead to feelings of helplessness and anxiety. The unpredictability of the condition itself can foster a sense of insecurity, making many children constantly aware of their fragile state. These emotional challenges can escalate to conditions like depression, especially if the child feels unsupported or misunderstood [38].

**2. Social Challenges:** Social interactions can pose significant hurdles for children with OI. With a heightened likelihood of needing accommodations in school or extracurricular activities, many children may feel excluded or stigmatized. Peer relationships can be complicated by the emotional turmoil they experience, leading to social withdrawal. Moreover, children might refrain from participating in activities they fear could result in injury, further isolating them from their peers [39].

**3. Family Dynamics:** In families with a child diagnosed with OI, emotional challenges extend beyond the affected individual. Parents often grapple with feelings of fear, guilt, and helplessness regarding their child's well-being. Siblings may also experience feelings of neglect, jealousy, or confusion about their sibling's condition, creating tension within the family unit. The stress of managing medical appointments and caregiving responsibilities can further strain familial relationships, necessitating effective coping strategies [40].

**4. Academic Issues:** Educational environments can exacerbate the emotional struggles faced by children with OI. Frequent absences due to medical appointments or hospitalizations can hinder academic progress while also impacting social relationships. Teachers and school staff may lack awareness or understanding of OI, potentially leading to unintentional exclusion or inadequate support for the child [41].

**Implementing Emotional and Psychological Support Systems**

In light of these multifaceted challenges, a well-rounded approach to emotional and psychological support for children with OI and their families is imperative. Effective interventions should involve the following multifaceted strategies [7].

**1. Multidisciplinary Care Teams:** Healthcare providers must prioritize a multidisciplinary approach when treating OI. This team may include pediatricians, surgeons, physical therapists, occupational therapists, social workers, and psychologists. Regular mental health assessments can ensure that emotional struggles are identified and addressed in a timely manner. Coordinated care can also facilitate the sharing of information among specialists, ultimately leading to a more cohesive treatment experience [42].

**2. Psychological Counseling and Support:** Access to mental health professionals is essential for both patients and families. Psychologists specializing in chronic illness can provide therapy tailored to address the unique needs associated with living with OI. Individual therapy for the child can focus on coping mechanisms, resiliency building, and self-esteem enhancement. Family therapy can also play a crucial role in promoting open communication, addressing family dynamics, and fostering supportive relationships [43].

**3. Peer Support and Education:** Creating a network of peer support groups can provide an invaluable outlet for children and families dealing

with OI. Sharing experiences with others who understand the unique challenges of the condition fosters connection and community. Additionally, for children, peer support can alleviate feelings of isolation. Workshops and educational resources can sift through misconceptions regarding OI, promoting an understanding that can help to combat stigma and facilitate inclusivity in social environments [44].

**4. School and Community Interventions:** Educational institutions should be equipped with knowledge and resources to create accessible and supportive learning environments for children with OI. Training for teachers on the psychosocial aspects of the condition can help them accommodate the needs of affected students better. Moreover, schools can employ measures like flexible attendance policies, special accommodations, and awareness programs focused on peeling back the layers of stigma often experienced by children with OI [45].

**5. Parental Support Programs:** Parents should be encouraged to engage in support programs focused on parenting children with chronic conditions. Such programs can provide them with tools to better understand their child's emotional needs, improve their coping strategies, and build resilience within the family [46].

**Conclusion:**

In conclusion, pediatric nurses play a vital and multifaceted role in the long-term management of Osteogenesis Imperfecta (OI). Their involvement extends beyond the basic clinical care of monitoring symptoms and preventing fractures; they are integral in providing education, emotional support, and advocacy for children and their families. Through individualized care plans, pediatric nurses can address the unique challenges faced by each patient, promoting a holistic approach that encompasses both physical and psychological well-being.

Furthermore, the collaboration with multidisciplinary healthcare teams enhances the quality of care provided to children with OI, ensuring that all aspects of their health and development are considered. As advancements in the understanding and treatment of OI continue to emerge, ongoing education for pediatric nurses is essential to implement the latest evidence-based practices effectively. Ultimately, the commitment of pediatric nurses to the long-term management of OI significantly impacts the lives of affected children, fostering resilience, independence, and a better quality of life.

**References:**

1. Munns CF, Rauch F, Mier RJ, Glorieux FH. Respiratory distress with pamidronate treatment in infants with severe osteogenesis imperfecta. Bone. 2004;35(1):231–234. doi: 10.1016/j.bone.2004.03.008.
2. Kidszun A, Linebarger J, Walter JK, Paul NW, Fruth A, Mildenberger E, et al. What if the prenatal diagnosis of a lethal anomaly turns out to be wrong? Pediatrics. 2016;137(5):e20154514. doi: 10.1542/peds.2015-4514.
3. Alcausin MB, Briody J, Pacey V, Ault J, McQuade M, Bridge C, Engelbert RH, Sillence DO, Munns CF. Intravenous pamidronate treatment in children with moderate-to-severe osteogenesis imperfecta started under three years of age. Horm Res Paediatr. 2013;79(6):333–340. doi: 10.1159/000351374.
4. Devin CL, Sagalow E, Penikis A, McGreal CM, Bober MB, Berman L. Long-term vascular access for infants with moderate to severe osteogenesis imperfecta. Pediatr Surg Int. 2021;37(11):1621–1625. doi: 10.1007/s00383-021-04975-2.
5. Ludwig K, Seiltgens C, Ibba A, Saran N, Ouellet JA, Glorieux F, et al. Craniocervical abnormalities in osteogenesis imperfecta type V. Osteoporos Int. 2022;33(1):177–183. doi: 10.1007/s00198-021-06088-x.
6. British and Irish Paediatric and Adolescent Bone Group. Intravenous bisphosphonates: frequently asked questions. 2020.
7. Chinoy A, Mughal MZ, Padidela R. Current status in therapeutic interventions of neonatal bone mineral metabolic disorders. Semin Fetal Neonatal Med. 2020;25(1):101075. doi: 10.1016/j.siny.2019.101075.
8. Carroll RS, Donenfeld P, McGreal C, Franzone JM, Kruse RW, Preedy C, et al. Comprehensive pain management strategy for infants with moderate to severe osteogenesis imperfecta in the perinatal

period. Paediatr Neonatal Pain. 2021;3(4):156–162. doi: 10.1002/pne2.12066.

9. Nijhuis W, Franken A, Ayers K, Damas C, Folkestad L, Forlino A, et al. A standard set of outcome measures for the comprehensive assessment of osteogenesis imperfecta. Orphanet J Rare Dis. 2021;16(1):140. doi: 10.1186/s13023-021-01682-y.
10. Robinson ME, Rauch D, Glorieux FH, Rauch F. Standardized growth charts for children with osteogenesis imperfecta. Pediatr Res. 2023 doi: 10.1038/s41390-023-02550-0.
11. Arundel P, Offiah A, Bishop NJ. Evolution of the radiographic appearance of the metaphyses over the first year of life in type V osteogenesis imperfecta: clues to pathogenesis. J Bone Miner Res. 2011;26(4):894–898. doi: 10.1002/jbmr.258.
12. Hirata K, Aoki R, Nagano N, Kato R, Aoki M, Miyazaki O, Morioka I. Successful helmet therapy in an infant with positional brachycephaly associated with perinatal severe osteogenesis imperfecta. Pediatr Int. 2023;65(1):e15512. doi: 10.1111/ped.15512.
13. Barber LA, Abbott C, Nakhate V, Do AND, Blissett AR, Marini JC. Longitudinal growth curves for children with classical osteogenesis imperfecta (types III and IV) caused by structural pathogenic variants in type I collagen. Genet Med. 2019;21(5):1233–1239. doi: 10.1038/s41436-018-0307-y.
14. Kusumi K, Ayoob R, Bowden SA, Ingraham S, Mahan JD. Beneficial effects of intravenous pamidronate treatment in children with osteogenesis imperfecta under 24 months of age. J Bone Miner Metab. 2015;33(5):560–568. doi: 10.1007/s00774-014-0618-2.
15. Senthilnathan S, Walker E, Bishop NJ. Two doses of pamidronate in infants with osteogenesis imperfecta. Arch Dis Child. 2008;93(5):398–400. doi: 10.1136/adc.2007.125468.
16. Marini JC, Forlino A, Bächinger HP, Bishop NJ, Byers PH, Paepe A, et al. Osteogenesis imperfecta. Nat Rev Dis Primers. 2017;3:17052. doi: 10.1038/nrdp.2017.52.
17. Matarazzo CG, Schreen G, Lago-Rizzardi CDD, Peccin MS, Pinto FC. Orthotic treatment of positional brachycephaly associated with osteogenesis imperfecta. Prosthet Orthot Int. 2017;41(6):595–600. doi: 10.1177/0309364616685596.
18. Dwan K, Phillipi CA, Steiner RD, Basel D. Bisphosphonate therapy for osteogenesis imperfecta. Cochrane Database Syst Rev. (2016) 10:CD005088.
19. Fratzl-Zelman N, Schmidt I, Roschger P, Roschger A, Glorieux FH, Klaushofer K, et al. Unique micro- and nano-scale mineralization pattern of human osteogenesis imperfecta type VI bone. Bone. (2015) 73:233–41.
20. Binder H, Conway A, Hason S, Gerber LH, Marini J, Berry R, et al. Comprehensive rehabilitation of the child with osteogenesis imperfecta. Am J Med Genet. (1993) 45:265–9.
21. Gallacher SJ, Ralston SH, Patel U, Boyle IT. Side effects of pamidronate. Lancet. (1989) 334:42–3.
22. Marr C, Seasman A, Bishop N. Managing the patient with osteogenesis imperfecta: a multidisciplinary approach. J Multidiscip Healthc. (2017) 10:145–55.
23. Land C, Rauch F, Munns CF, Sahebjam S, Glorieux FH. Vertebral morphometry in children and adolescents with osteogenesis imperfecta: effect of intravenous pamidronate treatment. Bone. (2006) 39:901–6.
24. Chevrel G, Schott AM, Fontanges E, Charrin JE, Lina-Granade G, Duboeuf F, et al. Effects of oral alendronate on BMD in adult patients with osteogenesis imperfecta: a 3-year randomized placebo-controlled trial. J Bone Miner Res. (2006) 21:300–6.
25. Fratzl-Zelman N, Barnes AM, Weis M, Carter E, Hefferan TE, Perino G, et al. Non-lethal type VIII osteogenesis imperfecta has elevated bone matrix mineralization. J Clin Endocrinol Metab. (2016) 101:3516–25.
26. DiMeglio LA, Peacock M. Two-year clinical trial of oral alendronate versus intravenous pamidronate in children with osteogenesis imperfecta. J Bone Miner Res. (2006) 21:132–40.
27. Binder H, Conway A, Gerber LH. Rehabilitation approaches to children with osteogenesis imperfecta: a ten-year experience. Arch Phys Med Rehabil. (1993) 74:386–90.

28. Glorieux FH, Bishop NJ, Plotkin H, Chabot G, Lanoue G, Travers R. Cyclic administration of pamidronate in children with severe osteogenesis imperfecta. N Engl J Med. (1998) 339:947–52.
29. Rauch F, Plotkin H, Zeitlin L, Glorieux FH. Bone mass, size, and density in children and adolescents with osteogenesis imperfecta: effect of intravenous pamidronate therapy. J Bone Miner Res. (2003) 18:610–4.
30. Fratzl-Zelman N, Schmidt I, Roschger P, Glorieux FH, Klaushofer K, Fratzl P, et al. Mineral particle size in children with osteogenesis imperfecta type I is not increased independently of specific collagen mutations. Bone. (2014) 60:122–8.
31. Ward LM, Rauch F, Whyte MP, D'Astous J, Gates PE, Grogan D, et al. Alendronate for the treatment of pediatric osteogenesis imperfecta: a randomized placebo-controlled study. J Clin Endocrinol Metab. (2011) 96:355–64.
32. Roschger P, Fratzl-Zelman N, Misof BM, Glorieux FH, Klaushofer K, Rauch F. Evidence that abnormal high bone mineralization in growing children with osteogenesis imperfecta is not associated with specific collagen mutations. Calcif Tissue Int. (2008) 82:263–70.
33. Mueller B, Engelbert R, Baratta-Ziska F, Bartels B, Blanc N, Brizola E, et al. Consensus statement on physical rehabilitation in children and adolescents with osteogenesis imperfecta. Orphanet J Rare Dis. 2018;13(1):158. doi: 10.1186/s13023-018-0905-4.
34. Menezes AH, Traynelis VC. Pediatric cervical kyphosis in the MRI era (1984–2008) with long-term follow up: literature review. Childs Nerv Syst. 2022;38(2):361–377. doi: 10.1007/s00381-021-05409-z.
35. Boyde A, Travers R, Glorieux FH, Jones SJ. The mineralization density of iliac crest bone from children with osteogenesis imperfecta. Calcif Tissue Int. (1999) 64:185–90.
36. Lindahl K, Astrom E, Rubin CJ, Grigelioniene G, Malmgren B, Ljunggren O, et al. Genetic epidemiology, prevalence, and genotype-phenotype correlations in the Swedish population with osteogenesis imperfecta. Eur J Hum Genet. (2015) 23:1042–50.
37. Forlino A, Marini JC. Osteogenesis imperfecta. Lancet. (2016) 387:1657–71.
38. Rauch F, Fahiminiya S, Majewski J, Carrot-Zhang J, Boudko S, Glorieux F, et al. Cole-Carpenter syndrome is caused by a heterozygous missense mutation in P4HB. Am J Hum Genet. (2015) 96:425–31.
39. Braga V, Gatti D, Rossini M, Colapietro F, Battaglia E, Viapiana O, et al. Bone turnover markers in patients with osteogenesis imperfecta. Bone. (2004) 34:1013–6.
40. Marom R, Lee YC, Grafe I, Lee B. Pharmacological and biological therapeutic strategies for osteogenesis imperfecta. Am J Med Genet C Semin Med Genet. (2016) 172:367–83.
41. Tauer JT, Abdullah S, Rauch F. Effect of anti-TGF-β treatment in a mouse model of severe osteogenesis imperfecta. J Bone Miner Res. (2019) 34:207–14.
42. Li L, Zhao D, Zheng W, Wang O, Jiang Y, Xia W, et al. A novel missense mutation in P4HB causes mild osteogenesis imperfecta. Biosci Rep. (2019) 39:BSR20182118.
43. Sillence DO, Senn A, Danks DM. Genetic heterogeneity in osteogenesis imperfecta. J Med Genet. (1979) 16:101–16.
44. Grafe I, Yang T, Alexander S, Homan EP, Lietman C, Jiang MM, et al. Excessive transforming growth factor-β signaling is a common mechanism in osteogenesis imperfecta. Nat Med. (2014) 20:670–5.
45. Wekre LL, Eriksen EF, Falch JA. Bone mass, bone markers and prevalence of fractures in adults with osteogenesis imperfecta. Arch Osteoporos. (2011) 6:31–8.
46. Hoyer-Kuhn H, Franklin J, Allo G, Kron M, Netzer C, Eysel P, et al. Safety and efficacy of denosumab in children with osteogenesis imperfect–a first prospective trial. J Musculoskelet Neuronal Interact. (2016) 16:24–32.