Symposium

POSI
IJPO

Management of Limb Deformities in Skeletal Dysplasia

Binu T Kurian MS Ortho[1], Aditi Pinto MS Ortho[1], James A Fernandes FRCS Tr & Ortho[2]

Abstract

Skeletal Dysplasia encompasses a diverse group of genetic conditions that predominantly affect bone and cartilage formation. The clinical assessment of these conditions requires a detailed family history to assess the genetic inheritance patterns and physical examination of the limb length discrepancies, joint laxity, spinal alignment, and gait abnormalities to identify deviations from normal skeletal development. Pharmacological therapy consists of Bisphosphonates to improve the bone density in conditions like osteogenesis imperfecta. Surgical procedures include Growth modulation techniques, limb lengthening procedures, corrective osteotomies and joint reconstructions. A Detailed genetic counselling is key to parents with a history of skeletal dysplasia in the family to assess recurrence risks, explore reproductive options, and guide personalized treatment strategies. With advancements in gene therapy, 3D navigation and patient specific implants and prosthesis there is a promising future in the management of limb deformities in skeletal dysplasia.

Keywords: Skeletal Dysplasia, Lower limb deformity, Guided Growth, Limb Lengthening

Dr. Binu T Kurian

Dr. Aditi Pinto

Dr. James A Fernandes

Address of Correspondence
Dr. Binu T Kurian,
Department of Orthopaedics St. John's Medical College, Hospital, Bangalore, Karnataka, India.
E-mail: binu.k@stjohns.in

[1]Department of Orthopaedics, St. John's Medical College, Hospital, Bangalore, Karnataka, India.
[2]Department of Orthopaedics, Sheffield Children's Hospital NHS Trust Sheffield S10 4 NH United Kingdom

DOI- https://doi.org/10.13107/ijpo.2025.v11.i01.222
www.ijpoonline.com

Introduction

Skeletal Dysplasia encompasses a diverse group of genetic conditions that predominantly affect bone and cartilage formation. The 2023 revision of the comprehensive Nosology and classification of genetic disorders lists 771 disorders in 41 phenotypically related groups associated with 552 genes, grouped into categories such as spondyloepiphyseal dysplasia, metaphyseal dysplasia, and osteochondrodysplasias [1]. Skeletal dysplasia affects approximately 2.3-7.6 per 10000 in various epidemiologic studies, with achondroplasia being the most common form, occurring in about 1 in 25,000 births [2, 3, 4]. These conditions exhibit significant variability in prevalence based on genetic mutations and regional differences. Advances in genetic screening and prenatal diagnostics have improved early detection rates, allowing for better management and intervention. These disorders often involve defects in endochondral ossification, resulting in disproportionate short stature, joint instability, and early-onset osteoarthritis. Clinically, patients may present with limb deformities, spinal abnormalities, and respiratory complications due to thoracic insufficiency [5]. Mutations in genes such as FGFR3, COMP, COL2A1, and PTH1R disrupt endochondral and membranous ossification, leading to abnormal skeletal growth. Advances in genetic research have enabled targeted therapies, including gene editing and pharmacological interventions, to modify disease progression and improve patient outcomes [6,7].

Clinical Assessment

A detailed history which includes the onset of the short stature or limb deformities can narrow down the differential diagnosis Family history and inheritance patterns, including autosomal dominant, autosomal recessive, and X-linked inheritance

Submitted: 29/01/2025; Reviewed: 22/02/2025; Accepted: 17/03/2025; Published: 10/04/2025

mechanisms, which are vital to determining disease risk and progression [8]. Advances in genetic testing, such as whole-exome sequencing and targeted gene panels, allow for precise identification of mutations associated with skeletal dysplasia. General physical examination to identify facial dysmorphisms, measurement of the upper segment/lower segment ratio are ancillary signs to a diagnosis [9]. Orthopaedic examination for joint abnormalities, assessments of limb length discrepancies, joint laxity, spinal alignment, and gait abnormalities helps to identify deviations from normal skeletal development.

Radiographic and Imaging in Skeletal Dysplasia

Radiographic findings provide an initial assessment of bone morphology and structural deformities. Comprehensive skeletal surveys, including full-body radiographic assessments, are essential for early diagnosis and monitoring of skeletal dysplasia [10]. These surveys help identify characteristic bone abnormalities, assess growth patterns, detect complications such as spinal deformities or joint malalignments, and guide treatment decisions. Serial imaging can track disease progression and assess the effectiveness of interventions over time. CT scans offer detailed cross-sectional imaging for complex skeletal abnormalities, anatomical alignment, and fracture risk assessment, and MRI is key to evaluating soft tissue, cartilage, spinal cord involvement, and early detection of joint complications in skeletal dysplasia [11]. Additionally, ultrasonography can be useful in prenatal screening for early identification of skeletal anomalies, and bone scintigraphy may assist in detecting metabolic activity in bone disorders [12].

Molecular and Genetic Testing

Gene mutations in FGFR3, COMP, COL2A1, PTH1R, and other related genes disrupt key pathways in bone and cartilage development, leading to various forms of skeletal dysplasia. These mutations impact endochondral ossification, chondrocyte proliferation, differentiation, and extracellular matrix composition, leading to abnormal skeletal growth patterns and deformities [6, 7, 13]. Advances in molecular diagnostics have enabled early identification of these genetic variations, enabling personalized treatment.

Non-Surgical Management

A. Pharmacological Treatments

Bisphosphonates, such as pamidronate and zoledronic acid, are used to improve bone density and reduce fracture risk in conditions like osteogenesis imperfecta and other metabolic bone disorders associated with skeletal dysplasia. These medications work by inhibiting osteoclast-mediated bone resorption, thereby enhancing bone strength and reducing deformities [14, 15]. According to the latest guidelines on the use of bisphosphonate therapy in children and adolescents have ben revised. Children who have experienced two or more long-bone fractures in a year, have severe OI (eg. type III), or have spinal compression fractures should be considered for intravenous bisphosphonates admisistration [7]. Vosoritide, a C-type natriuretic peptide (CNP) analog, promotes endochondral bone growth by inhibiting the FGFR3 signalling pathway, thereby increasing linear bone growth in individuals with achondroplasia [16]. Enzyme replacement therapies, such as recombinant human lysosomal enzymes, target metabolic deficiencies in conditions like mucopolysaccharidoses, reducing skeletal abnormalities and enhancing overall function [17]. Additionally, gene-targeted therapies and small-molecule inhibitors are being developed to further modulate bone growth pathways, offering promising future treatment options.

B. Physiotherapy and Rehabilitation

Strength training, including resistance exercises to improve muscle function and endurance, and flexibility exercises such as stretching, yoga, and range-of-motion activities to maintain joint mobility, enhance coordination, and reduce stiffness.) Handling of infants and toddlers need to be emphasised to the carers. Use of mobility aids, including walkers, crutches, canes, and wheelchairs, to enhance independence and accommodate varying levels of mobility impairment in individuals with skeletal dysplasia [18].

C. Bracing and Orthotics

For those with skeletal dysplasia, custom orthoses such as foot orthotics, knee-ankle-foot orthoses (KAFOs), and spinal braces are used to control deformities and provide functional support [4].

Surgical Interventions

A. Growth Modulation Techniques

Hemi epiphysiodesis using Plates is a guided growth technique that utilizes small two holed, tension-band plates to correct

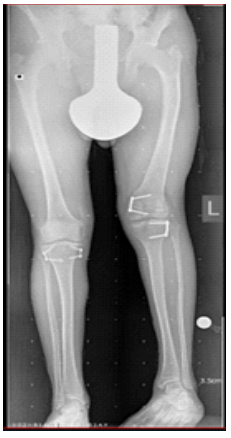

Figure 1: Guided Growth

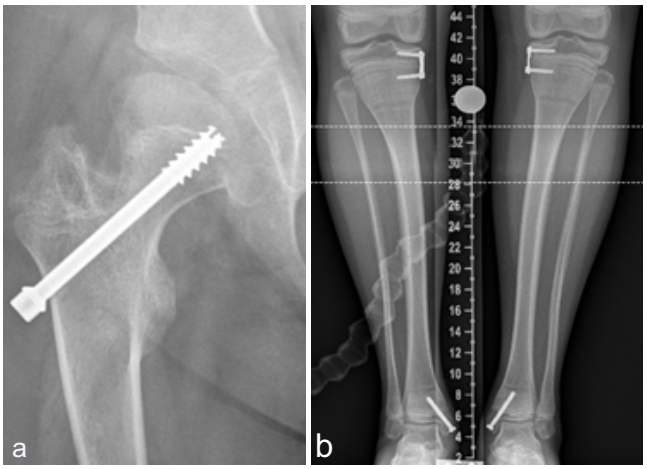

Figure 2: Screw Epiphysiodesis

angular deformities in growing children with skeletal (Fig. 1) dysplasia by modulating growth across the physis [19]. By applying controlled pressure on one side of the growth plate, this technique gradually redirects bone growth, reducing the need for more invasive corrective osteotomies and offering a less disruptive alternative for paediatric patients. It is particularly effective in cases of genu varum and genu valgum [20].

Screw epiphysiodesis (Fig. 2a & 2b) is another method used to modulate growth at the hip, knee, and ankle. This technique involves the insertion of transphyseal screws to restrict growth in specific areas, allowing for correction of limb length discrepancies angular deformities and also length [21].

B. Limb Lengthening Procedures

Internal devices and external fixators are essential tools in orthopaedic surgery for managing skeletal dysplasia.

Internal fixators, such as intramedullary growing rods, provide stable internal support for bone realignment and growth while external complications. These devices are particularly

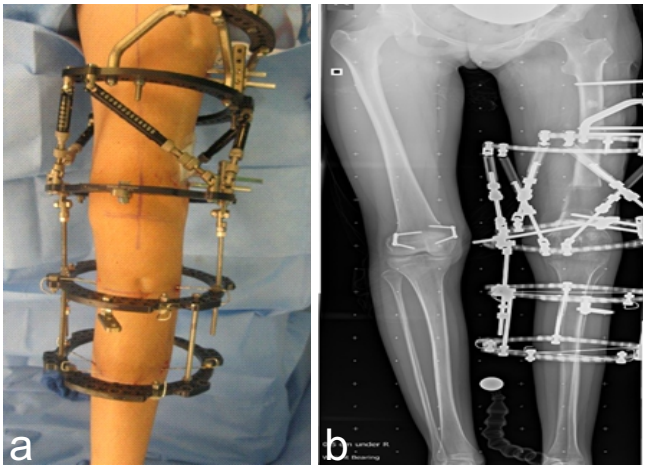

Figure 4: Hexapod- Taylor Spatial Frame (TSF)

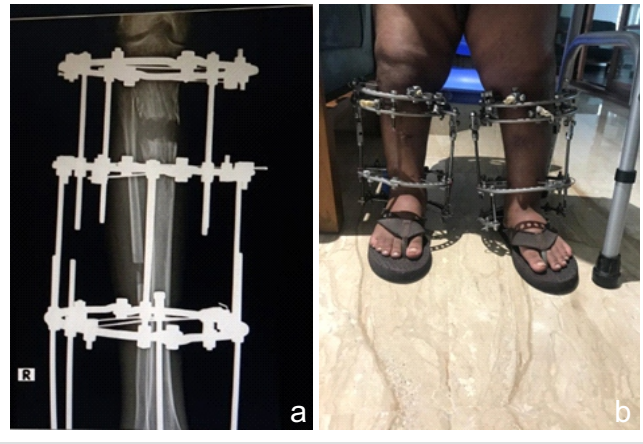

Figure 3: External Fixator- Illizarov

beneficial for patients with open growth plates, as they allow controlled expansion while maintaining bone stability [22].

External fixators, including circular and monolateral frames, allow gradual bone distraction and correction of deformities through external adjustments, offering versatility in complex reconstructions including joint deformity corrections.

External Fixator Techniques

The Ilizarov technique, a method of limb lengthening and deformity correction, utilizes a circular external fixator to apply gradual traction to bones, stimulating new bone growth through distraction osteogenesis whereas a monolateral system has almost similar uses. This technique is widely used for treating skeletal dysplasia, allowing controlled lengthening while maintaining limb alignment and function. It is particularly beneficial for patients with severe limb discrepancies and angular deformities, offering a customizable approach to treatment [23]. (Fig. 3a & 3b)

The TSF is a modern hexapod external fixator that allows simultaneous multi-planar corrections using computer-assisted adjustments, enhancing precision in complex deformity corrections. The LRS, a monolateral fixator, is widely used for gradual limb lengthening and deformity correction with improved patient comfort and easier postoperative management [24]. Recent advancements in external fixation technology, including hybrid fixation systems and motorized distraction devices, have improved precision

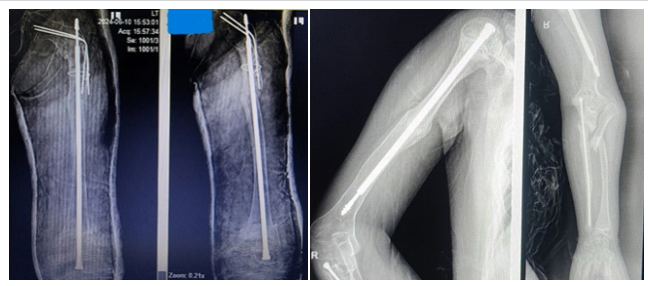

Figure 5: Telescoping Nail

and patient comfort [25]. Despite its effectiveness, the procedure requires prolonged treatment durations and carries risks such as pin-site infections, muscle contractures, and joint stiffness, necessitating careful post-operative management and rehabilitation. (Fig. 4a & 4b)

Types of Internal Fixators:

1. Intramedullary growing (telescoping) Rods:

o Used for bone stabilization and deformity correction (Fig. 5)

o Examples: Fassier-Duval Rods, Bailey-Dubow Rods, Sheffield Rods [26].

2. Lengthening Nails:

o Used for gradual, controlled limb lengthening without external fixators.

o Examples:

PRECICE Nail (NuVasive / Global - Specialized Orthopedics) – Magnetically controlled for precise adjustments [27]. (Fig. 6)

FITBONE (Orthofix) – Electronically controlled lengthening system [28]. (Fig. 7)

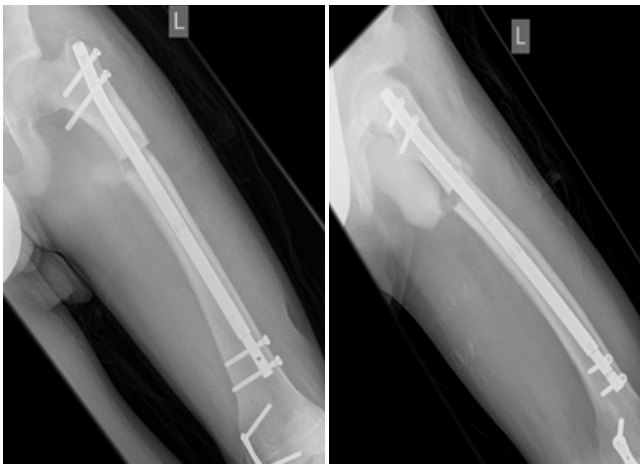

Figure 6: PRECICE Nail

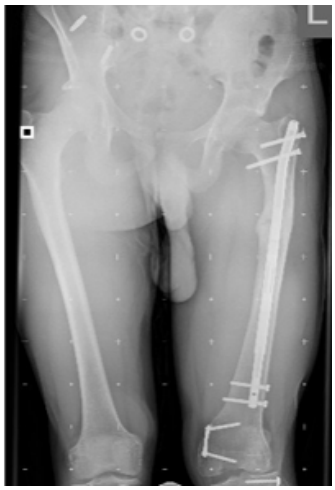

Figure 7: Fit bone

These devices are vital to limb reconstruction, correcting angular deformities, and facilitating post-surgical healing. The choice between internal and external fixation depends on factors such as patient age, severity of deformity, bone quality, and overall treatment goals including improvement in QALY'S [29].

These devices are vital to limb reconstruction, correcting angular deformities, and facilitating post-surgical healing. The choice between internal and external fixation depends on factors such as patient age, severity of deformity, bone quality, and overall treatment goals.

C. Osteotomies and Joint Reconstruction

Surgical corrections for angular deformities involve procedures such as osteotomies and fixation methods to realign bones and improve limb function. Osteotomies, including femoral and tibial wedge resections, correct severe deformities by strategically cutting and repositioning the bone. Valgus and varus osteotomies, commonly performed at the hip, (Fig. 8) correct malalignment and improve load distribution across the joint. Acetabular osteotomies are utilized to address hip dysplasia by reorienting the acetabulum for better femoral head coverage, thereby improving joint stability and reducing the risk of osteoarthritis. Salvage procedures, such as pelvic support osteotomies and arthrodesis, are employed in severe cases where joint preservation is not viable [30]. Percutaneous osteotomies are frequently employed in osteogenesis imperfecta (OI) to minimize surgical invasiveness while correcting bone deformities, limb lengthening and tightening the lateral collateral ligaments at the knee [31]. Joint replacement, including total hip and knee arthroplasty, is considered in patients with advanced degenerative changes to restore function and alleviate pain [32].

D. Spinal Deformity Correction

Spinal deformities cause significant mortality and morbidity in children with Skeletal dysplasia [33]. The range of conditions includes growth disruption in various regions of the spine, which can lead to kyphosis, scoliosis, atlantoaxial instability, spinal stenos

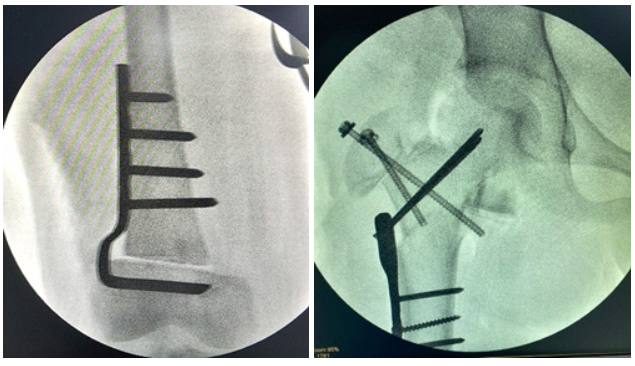

Figure 8: Corrective Osteotomies

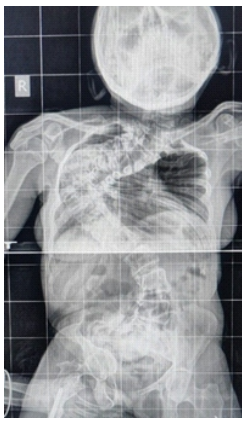

Figure 9: Spinal deformities in OI

is. (Fig. 9) Management of scoliosis and kyphosis involves a combination of non-surgical and surgical approaches, depending on severity and progression. Non-surgical treatments include bracing, physiotherapy, and targeted exercise regimens to maintain spinal alignment and mobility [34]. In severe or progressive cases, surgical interventions such as spinal fusion (Fig. 10), growth-friendly constructs, and vertebral body tethering are employed to stabilize the spine and prevent further deformity. Growing rods, including traditional growing rods and magnetically controlled growing rods (MCGR), are used to correct spinal deformities while allowing continued spinal growth in younger patients [35]. Advances in minimally invasive spine surgery and 3D-printed implants have further improved outcomes for patients with skeletal dysplasia-related spinal deformities.

Post-Surgical Rehabilitation

Physiotherapy and recovery protocols involve a structured rehabilitation plan tailored to the needs of individuals with skeletal dysplasia. Balance and Strength training, flexibility exercises are all part of this protocol to increase range of motion and avoid contractures. Additionally, neuromuscular re-education techniques, proprioceptive training, and aquatic therapy have shown promising results in improving motor function and reducing the risk of secondary musculoskeletal complications.

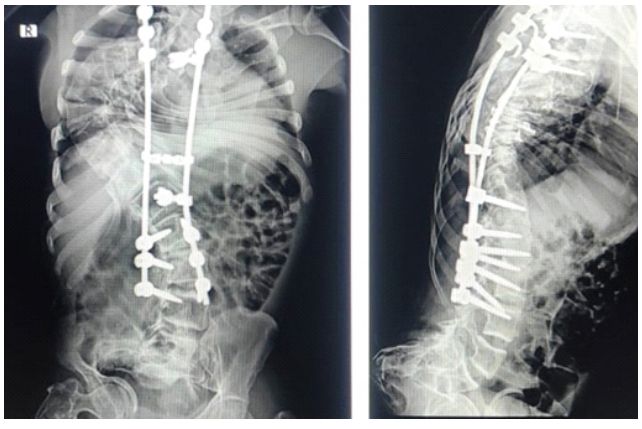

Figure 10: Post correction

Outcomes and Long-Term Follow-Up

Improvements in mobility and independence, including enhanced gait function, increased range of motion, and the ability to perform daily activities with minimal assistance. Advances in assistive devices, orthotic support, and targeted rehabilitation programs have significantly contributed to better functional outcomes and quality of life for individuals with skeletal dysplasia [18]. Additionally, adaptive sports, functional electrical stimulation (FES), and robotic-assisted rehabilitation are emerging as innovative approaches to further enhance mobility and independence.

Complication Rates and Risk Management

Ring fixator lengthening is associated with complications like poor regenerate, transient nerve palsies, delayed union and re-fracture especially in the distal tibia. This can be overcome by reducing the rate of distraction at the distal corticotomy site after the initial lengthening [36]. Infection control involves rigorous perioperative sterilization protocols, prophylactic antibiotic administration, and vigilant post-surgical wound monitoring to prevent complications such as osteomyelitis and deep-tissue infections.

Psychosocial Considerations

There are multiple factors like short stature, disproportionate limb lengths medical complications and decreased level of independence in carrying out activities of daily living that has a psychosocial impact on people living with skeletal dysplasias. Addressing self-esteem and social adaptation through psychological counselling, peer support groups, and community inclusion programs. Encouraging participation in adaptive sports, vocational training, and self-advocacy initiatives can further enhance confidence and social integration [37]. Education about skeletal dysplasia in schools and workplaces fosters a more inclusive and supportive environment for affected individuals.

Future Directions

With the Advent of genomic technology there is a lot of prospective potential in the diagnosis and management of rare genetic disorders like skeletal dysplasia. Advancements in genetic therapy include gene editing techniques such as CRISPR-Cas9, which hold potential for correcting mutations responsible for skeletal dysplasia [38]. Gene therapy approaches targeting fibroblast growth factor receptor 3

(FGFR3) mutations, which are implicated in conditions like achondroplasia, are also being explored [39]. Clinical trials are evaluating the efficacy of RNA-based therapies, including antisense oligonucleotides, to modulate gene expression and improve bone growth [40]. Additionally, stem cell-based regenerative treatments, such as mesenchymal stem cell (MSC) therapy and induced pluripotent stem cells (iPSCs), show promise in enhancing bone repair and correcting skeletal abnormalities [41]. Innovations in minimally invasive surgeries include advancements such as arthroscopic joint preservation techniques, percutaneous osteotomies, and robotic-assisted surgical procedures, which enhance precision and reduce recovery time. The use of 3D navigation systems and patient-specific implants has further improved surgical outcomes by allowing for customized treatment approaches. Additionally, endoscopic spine surgery and minimally invasive growth modulation techniques are being explored to minimize surgical trauma while optimizing skeletal correction [42].

Conclusion

Growth abnormalities in skeletal dysplasia require close monitoring through regular imaging and clinical assessments, with interventions such as guided growth procedures, limb lengthening techniques, and hormonal therapies to optimize skeletal development and functional outcomes. The current medical advancements have the potential to revolutionize the treatment algorithms in children with skeletal Dysplasia.

References

1. Unger S, Ferreira CR, Mortier GR, Ali H, Bertola DR, Calder A, et al. Nosology of genetic skeletal disorders: 2023 revision. Am J Med Genet A. 2023 May 1;191(5):1164–209.

2. Barbosa-Buck CO, Orioli IM, da Graça Dutra M, Lopez-Camelo J, Castilla EE, Cavalcanti DP. Clinical epidemiology of skeletal dysplasias in South America. Am J Med Genet A. 2012 May;158 A (5):1038–45.

3. Stevenson DA, Carey JC, Byrne JLB, Srisukhumbowornchai S, Feldkamp ML. Analysis of skeletal dysplasias in the Utah population. Am J Med Genet A. 2012 May;158 A (5):1046–54.

4. Varghese B, Fernandes J, Skeletal dysplasia. A guide to the orthopaedic surgeon, Orthopaedics and Trauma (2016),

http://dx.doi.org/10.1016/j.mporth.2016.09.003

5. Mindler GT, Stauffer A, Chiari C, Mladenov K, Horn J. Achondroplasia current concept of orthopaedic management. J Child Orthop. 2024 Aug 27;18(5):461-476. doi: 10.1177/18632521241269340. PMID: 39391573; PMCID: PMC11463089

6. Legare JM. Achondroplasia. 1998 Oct 12 [updated 2023 May 11]. In: Adam MP, Feldman J, Mirzaa GM, Pagon RA, Wallace SE, Bean LJH, Gripp KW, Amemiya A (eds.) GeneReviews®[Internet]. Seattle (WA): University of Washington, Seattle, 1993–2024

7. Marzin P, Cormier-Daire V. New perspectives on the treatment of skeletal dysplasia. Ther Adv Endocrinol Metab. 2020 Mar 3; 11:2042018820904016. doi: 10.1177/2042018820904016. PMID: 32166011; PMCID: PMC7054735.

8. Cho SY, Jin DK. Guidelines for genetic skeletal dysplasias for pediatricians. Ann Pediatr Endocrinol Metab. 2015 Dec;20(4):187-91. doi: 10.6065/apem.2015.20.4.187. Epub 2015 Dec 31. PMID: 26817005; PMCID: PMC4722157.

9. Krakow D, Rimoin DL. The skeletal dysplasias. Genet Med 2010; 12:327-41.

10. DL R, RS L. Principles and practice of medical genetics. 3 ed. New York: Churchill Livingstone, 1997

11. Handa A, Grigelioniene G, Nishimura G. Skeletal Dysplasia Families: A Stepwise Approach to Diagnosis. Radiographics. 2023 May;43(5): e220067. doi: 10.1148/rg.220067. PMID: 37053103.

12. Garjian KV, Pretorius DH, Budorick NE, Cantrell CJ, Johnson DD, Nelson TR. Fetal skeletal dysplasia: three dimensional US: initial experience. Radiology 2000; 214:717-23

13. Byers PH, Wallis GA and Willing MC. Osteogenesis imperfecta: translation of mutation to phenotype. J Med Genet 1991; 28: 433–442.

14. Tauer JT, Robinson ME and Rauch F. Osteogenesis imperfecta: new perspectives from clinical and translational research. JBMR Plus 2019; 3: e10174.

15. Simm PJ, Biggin A, Zacharin MR, et al. Consensus guidelines on the use of bisphosphonate therapy in children and adolescents. J Paediatr Child Health 2018; 54: 223–233

16. Wendt DJ, Dvorak-Ewell M, Bullens S, et al. Neutral endopeptidase-resistant C-type natriuretic peptide variant represents a new therapeutic approach for treatment of fibroblast growth factor receptor 3-related dwarfism. J Pharmacol Exp Ther 2015; 353: 132–149.

17. Peracha H, Sawamoto K, Averill L, et al. Molecular genetics and metabolism, special edition: diagnosis, diagnosis and prognosis of mucopolysaccharidosis IVA. Mol Genet Metab 2018; 125: 18–37.

18. The Role of Physical Medicine and Rehabilitation in Managing Skeletal Dysplasia. Int J Phys Med Rehabil. S29:004.

19. Inan M, Chan G, Bowen JR. Correction of angular deformities of the knee by percutaneous hemiepiphysiodesis. Clin Orthop Relat Res. 2007;456:164–169.

20. Stevens PM. Guided growth for angular correction: a preliminary series using a tension band plate. J Pediatr Orthop. 2007;27:253–259.

21. Babu LV, Evans O, Sankar A, Davies AG, Jones S, Fernandes JA. Epiphysiodesis for limb length discrepancy: a comparison of two methods. Strategies Trauma Limb Reconstr. 2014 Apr;9(1):1-3. doi: 10.1007/s11751-013-0180-9. Epub 2013 Nov 23. PMID: 24271553; PMCID: PMC3951623.

22. Lie CW, Chow W. Limb lengthening in short-stature patients using monolateral and circular external fixators. Hong Kong Med J 2009;15:280-4

23. Nicolaou N, Luo Q, Giles SN, Maruthainar K, Kitchen MP, Thomas S, Fernandes JA, Roposch A. Mechanical Analysis of Explanted Telescopic Rods in the Management of Osteogenesis Imperfecta: A Multicenter Study. J Pediatr Orthop. 2021 Jul 1;41(6): e448-e456.

doi: 10.1097/BPO.0000000000001796. PMID: 33734203.

24. Fadel M, Hosny G (2005) The Taylor spatial frame for deformity correction in the lower limbs. Int Orthop 29:125–129

25. Hosny GA. Limb lengthening history, evolution, complications and current concepts. J Othop Traumatol. 2020 Mar 5;21(1):3. doi: 10.1186/s10195-019-0541-3. PMID: 32140790; PMCID: PMC7058770.

26. Goiano EO, Akkari M, Costa PH, Makishi MR, Santili C. TREATMENT OF OSTEOGENESIS IMPERFECTA USING THE FASSIER-DUVAL TELESCOPIC ROD. Acta Ortop Bras. 2023 Sep 8;31(spe3): e266775. doi: 10.1590/1413-785220233103e266775. PMID: 37720808; PMCID: PMC10502982.

27. Kirane YM, Fragomen AT, Rozbruch SR (2014) Precision of the PRECICE internal bone lengthening nail. Clin Orthop Relat Res 472(12):3869–3878

28. Al-Sayyad MJ (2012) Lower limb lengthening and deformity correction using the fitbone motorized nail system in the adolescent patient. J Pediatr Orthop B 21(2):131–136

29.Kenawey M, Krettek C, Liodakis E, Wiebking U, Hankemeier S (2011) Leg lengthening using intramedullary skeletal kinetic distractor: results of 57 consecutive applications. Injury. 42(2):150–155

30. Metikala S, Kurian BT, Madan SS, Fernandes JA. Pelvic Support Hip Reconstruction with Internal Devices: An Alternative to Ilizarov Hip Reconstruction. Strategies Trauma Limb Reconstr. 2020 May-Aug;15(2):91-97. doi: 10.5005/jp-journals-10080-1459. PMID: 33505525; PMCID: PMC7801897.

31. Kurian BT, Belthur MV, Jones S, et al. Correction of Bowleg Deformity in Achondroplasia through Combined Bony Realignment and Lateral Collateral Ligament Tightening. Strategies Trauma Limb Reconstr 2019;14(3):132–138.

32. Ain MC, Andres BM, Somel DS, Fishkin Z, Frassica FJ. Total hip arthroplasty in skeletal dysplasias: patient selection, preoperative planning, and operative techniques. J Arthroplasty. 2004 Jan;19(1):1-7. doi: 10.1016/s0883-5403(03)00455-8. PMID: 14716642.

33. Song D, Maher CO. Spinal disorders associated with skeletal dysplasias and syndromes. Neurosurg Clin N Am. 2007;18(3):499–514.

34. Savarirayan R, Bompadre V, Bober MB, Cho TJ, Goldberg MJ, Hoover Fong J, Irving M, Kamps SE, Mackenzie WG, Raggio C, Spencer SS, White KK. Skeletal Dysplasia Management Consortium. Best practice guidelines regarding diagnosis and management of patients with type II collagen disorders. Genet Med. https://doi.org/10.1038/s41436-019-0446-9

35. White KK, Bompadre V, Shah SA, Redding GJ, Krengel WF, Mackenzie WG. Early-onset spinal deformity in skeletal dysplasias: A multicenter study of growth-friendly systems. Spine Deform. 2018;6(4):478–82.

36. Chilbule SK, Dutt V, Madhuri V. Limb lengthening in achondroplasia. Indian J Orthop. 2016 Jul-Aug;50(4):397-405. doi: 10.4103/0019-5413.185604. PMID: 27512222; PMCID: PMC4964773.

37. Constantinides, C., Landis, S. H., Jarrett, J., Quinn, J., & Ireland, P. J. (2021). Quality of life, physical functioning, and psychosocial function among patients with achondroplasia: a targeted literature review. Disability and Rehabilitation, 44(21), 6166–6178.

https://doi.org/10.1080/09638288.2021.1963853

38. Cetin B, Erendor F, Eksi YE, Sanlioglu AD, Sanlioglu S. Advancing CRISPR genome editing into gene therapy clinical trials: progress and future prospects. Expert Rev Mol Med. 2025 Mar 31;27: e16. doi: 10.1017/erm.2025.10. PMID: 40160040; PMCID: PMC12094669.

39. Carpenter TO, Whyte MP, Imel EA, et al. Burosumab therapy in children with X-linked hypophosphatemia. N Engl J Med 2018; 378: 1987–1998.

40. Dhuri K, Bechtold C, Quijano E, Pham H, Gupta A, Vikram A, Bahal R. Antisense Oligonucleotides: An Emerging Area in Drug Discovery and Development. J Clin Med. 2020 Jun 26;9(6):2004. doi: 10.3390/jcm9062004. PMID: 32604776; PMCID: PMC7355792.

41. Otsuru S, Gordon PL, Shimono K, et al. Transplanted bone marrow mononuclear cells and MSCs impart clinical benefit to children with osteogenesis imperfecta through different mechanisms. Blood 2012; 120: 1933–1941.

42. Wewel JT, Godzik J, Uribe JS. The utilization of minimally invasive surgery techniques for the treatment of spinal deformity. J Spine Surg. 2019 Jun;5(Suppl 1): S84-S90. doi: 10.21037/jss.2019.04.22. PMID: 31380496; PMCID: PMC6626752.

Declaration of patient consent : The authors certify that they have obtained all appropriate patient consent forms. In the form, the patient has given the consent for his/ her images and other clinical information to be reported in the journal. The patient understands that his/ her names and initials will not be published and due efforts will be made to conceal their identity, but anonymity cannot be guaranteed.

Conflict of interest: Nil **Source of support:** None

How to Cite this Article

Kurian BT, Pinto A, Fernandes JA. Management of Limb Deformities in Skeletal Dysplasia. International Journal of Paediatric Orthopaedics. January-April 2025; 11(1): 44-50.