

Child-Friendly Innovation: A New Era in Pediatric Drug Delivery Systems

Pranali S. Patil^{1,*}, Sameer R. Shaikh², Akash S. Jain², Divakar R. Patil², Azam Z. Shaikh², Sunil P. Pawar³

Abstract

Pediatric formulations are becoming more popular because of advancements in pharmaceutical delivery technology. For young patients, there is not a safe and effective drug delivery system in place. Since children's pharmacokinetics and pathophysiologic profiles differ from those of adults, it is imperative to design and develop an innovative and appropriate delivery system to provide accurate and dependable medicine administration to pediatric patients. Discussions will be held under this category to improve stability; new technologies and methods of drug delivery are being developed to improve the toxicity, flexibility, stability, and security of pediatric oral formulations. This section specifically discusses patient acceptability and manufacturing challenges, and it looks at novel drug delivery techniques to deal with contemporary problems.

Keywords: Pediatric formulations, innovative devices, novel pediatric dosage form, pediatric diseases, infants, novel approaches

INTRODUCTION

The field of medicine called pediatrics deals with the health and treatment of newborns, children, and teenagers up to 18 years old. The English word “pediatrics” comes from the Greek words “Pais,” meaning child, and “iatric,” meaning doctor or healer. This medical specialty began to take shape in the mid-19th century. Abraham Jacobi (1830–1919) is often regarded as the father of pediatrics [1].

Juvenile patients have different pharmacokinetics and pathophysiology compared to adults, which makes preparing safe and effective medications challenging. Children absorb, distribute, eliminate, and retain drugs in ways that often make adult prescriptions unsuitable. Differences in gastric pH and emptying time significantly influence absorption. At birth, stomach pH is neutral but drops within 2–3 days, reaching adult acidic levels after weeks or even years. Infants aged 6–8 months experience delayed gastric emptying times due to immature neuroregulation (Table 1) [2].

*Author for Correspondence

Pranali S. Patil
E-mail: pranalipatil2100@gmail.com

¹Student, Department of Pharmacy, P.S.G.V.P. Mandal's College of Pharmacy, Shahada, Maharashtra, India

²Assistant Professor, Department of Pharmacy, P.S.G.V.P. Mandal's College of Pharmacy, Shahada, Maharashtra, India

³Principal, P.G.V.P. Mandal's College of Pharmacy, Shahada, Maharashtra, India

Received Date: April 15, 2026

Accepted Date: June 21, 2026

Published Date: June 22, 2026

Citation: Pranali S. Patil, Sameer R. Shaikh, Akash S. Jain, Divakar R. Patil, Azam Z. Shaikh, Sunil P. Pawar. Child-Friendly Innovation: A New Era in Pediatric Drug Delivery Systems. Trends in Drug Delivery: 2026; 13(2): 26–34p.

There is overlap between pediatric age groups in physical, cognitive, and psychosocial development, and there is no consensus on the upper age limit. The American Academy of Pediatrics (AAP) sets the limit at 21 years, dividing adolescence into:

- Early (11–14),
- Middle (15–17), and
- Late (18–21) (Table 1) [3].

PEDIATRICS PHARMACOKINETICS

Absorption

Low pancreatic enzyme activity can affect how drugs function in the body. Children absorb drugs differently when taken non-oral. They have more skin surface relative to their weight. Their skin is

also thinner and more hydrated, which increases absorption from topical applications but may also raise toxicity levels. Absorption through muscles is unclear due to the low levels of muscle and fat. Newborns (under 1 month) and infants (under 1 year) have difficulties digesting fats since their bile and pancreatic secretions are not fully developed. Infants younger than 1 month struggle to absorb fat-soluble vitamins, like D and E, because they lack bile salts. However, absorption improves after several months as the bile salts mature [4].

Table 1. Classification of pediatric age groups.

Term	Age
Pediatric	0–18 years.
Premature	<37 weeks (gestational week).
Neonate	1 day to 1 month.
Infant	1 month to 1 year.
Child	1 to 12 years.
Adolescent	12 to 18 years.

Distribution

Some sustained-release drugs, like theophylline, often have incomplete absorption. In children under 1-year, intestinal transit time shortens because of quicker gut movement. But in infants under 1 month, transit time is longer due to slower gut activity. A more permeable blood–brain barrier increases drug absorption. Distribution relies on tissue permeability, blood flow, binding, illnesses, and other drug interactions. The smaller size and lower blood flow of the liver limit the body’s ability to process drugs through hydrolysis, oxidation, and reduction. Infants distribute hydrophilic drugs more widely, but they have lower distribution for lipophilic drugs because of a higher body water-to-fat ratio [5].

Metabolism and Elimination

The cytochrome P-450 (CYP450) enzyme in the liver plays an important role in breaking down active pharmaceutical ingredients (APIs). This enzyme deactivates APIs by hydrolyzing, oxidizing, reducing, hydroxylating, and conjugating them. Some enzymes, like glucuronidation enzymes, take time to mature and are essential for drug metabolism in babies but are not present in fetuses (Tables 2 and 3) [2].

THE MOST POPULAR PEDIATRICS FORMULATION & THE BEST WAYS TO ADMINISTER THEM

Table 2. Highlights the different categories of orally delivered pharmaceutical dosage forms.

Oral dosages	Transdermal patches	Rectal formulation
• Solid (tablets, pills)	• Microneedles	• Creams–ointments.
• Liquid (syrup, suspensions)	• Iontophoretic	• Suppositories.
• Chewable tablets	• Drug in adhesive	• Foams.

Table 3. Orally delivered pharmaceutical dosage forms.

Dosage form	Distinguishing characteristics	Limitations
<i>A. Oral dosage forms</i>		
Solid tablets (mini, soft, scored)	Tablets can be coated or uncoated for immediate or modified release (gastro-resistant delayed, extended, or prolonged release kinetics).	Young children cannot fully swallow medicines. Many minitables are needed at higher doses, although tolerance has been satisfactory. Insufficient dosage flexibility.
Chewable tablets	Chewing, crumbling, or breaking immediate-release tablets has no	Taste can change significantly. Based on the capacity to chew, bioavailability may change.

	appreciable impact on the stability and bioavailability of the active ingredient.	
Capsules	The medication has little interaction with the excipients, and the flavor of the contents is lessened by the capsules. They work well with hydrophobic medications and oily active ingredients that are dissolved or suspended in oil.	Although some may also be opened, bioavailability is more likely to be impacted by this procedure. The dosage cannot be swallowed full by young children.
Sprinkles	Neonates and critically unwell newborns can utilize it. can be consumed with meals and beverages to enhance flavor.	It is necessary to be able to swallow food or liquids that include medication formulations. compatibility with beverages and meals.
Gummy formulations	issues with dose formulations, lack of stability, safety, and ease of administration. flexible, springy, elastic, and soft. The improvement in texture, flavor, and smell may increase salivation, which facilitates swallowing.	It could be challenging to incorporate drugs with strong or unpleasant tastes, like bitterness, into gummy formulations without using a lot of sweets and flavorings. Because they are hygroscopic, they also need to be stored in an airtight manner in a dry atmosphere.
<i>B. Formulations manufactured as solids but consumed as liquids</i>		
Powders for reconstitution	Reconstitution formulation reduces the weight of the finished product because there is no aqueous carrier, which could result in lower transportation costs. avoiding the problems with physical stability that are often present in traditional suspensions.	Several physical variables of the dosage form, such as storage temperature, formulation, sedimentation rate, and liquid flow properties like viscosity, pourability, dispersion, flocculation, and content homogeneity, affect a drug's integrity.
Effervescent tablets	outstanding dosage adaptability. ensures the active component. stable up until administration and dissolution.	Managing brittle and friable materials.
Oro dispersible tablets, strips, and film	Designed to dissolve in the mouth in a matter of seconds. Oro dispersible tablets (ODTs) eliminate the need to swallow the tablet whole. They provide a great deal of flexibility in terms of administration. Films and strips have greater dosage flexibility because varied strengths can be achieved by simply cutting films/strips to the appropriate size.	They make medications easier to administer and swallow, but they do not offer the same degree of dosing flexibility as traditional tablets, necessitating the use of a range of dosage strengths to meet the needs of all populations.
Granules	Grain and powder are easily swallowed by infants and young children. stability, mobility, and consistent dosing. Options for altered release and varying dosages.	Youngsters might not like how their mouths feel.
<i>C. Oral liquid formulations</i>		
Oral drops and solutions	Easy to swallow	The efficiency of the dose-measuring apparatus is essential for this dosage type.
Suspensions and syrups	Using an API in a suspended form can sometimes help cover up bad flavors and tastes, making swallowing simpler.	Since caking or sedimentation of the solution during storage can occasionally present a significant risk for dosing errors, resuspendability need to be a stability condition.

CONVENTIONAL DOSAGE FORMS

Conventional liquid drug formulations, such as solutions, emulsions, and suspensions, along with solid forms like tablets and capsules, pose challenges for giving medications to young patients. This section discusses the issues with patient acceptance and the difficulties in manufacturing. It also investigates new drug delivery methods aimed at solving these problems [2].

Oral Dosage Forms

Solid Dosage Forms

Solid dosage forms are preferred because they are stable, cost-effective, and easy to manage in supply chains. However, they can be difficult for children to swallow and offer limited flexibility in dosing. Using tools – like pill-swallowing cups and training – can help improve adherence [7].

Mini-Tablets

Mini-tablets (1–4 mm) are solid dosage forms that are easy for patients of all ages to use. They allow for targeted delivery, avoid stability problems, and can mix incompatible drugs. They are made through compression, coating, and encapsulation, making them effective alternatives to pellets and granules [8].

Oro-Dispersible Tablets

ODTs dissolve quickly in the mouth, often without needing water, which helps improve compliance. They bypass first-pass metabolism, work faster, increase bioavailability, and taste better. However, there is less flexibility in dosing [8].

Oral Dissolving Films (ODT'S)

Thin mucoadhesive films (20–500 μm) dissolve quickly in the mouth, bypassing first-pass metabolism and improving bioavailability. They are convenient, accurate, water-free, and child-friendly (e.g., asthma, schizophrenia, dysphasia). Palatability and compliance are key advantages [8, 9].

Chewable Tablets

Chewable tablets are made for patients who have trouble swallowing. They dissolve easily and taste good. The core contains gum base (30–60%), sweeteners, and flavors. Advantages include:

- Faster absorption and better bioavailability.
- Improved patient acceptance, especially among children and the elderly.
- No water needed, quick action, and unique marketing potential. A drawback is that their large size can make them hard to swallow if not chewed [9].

Innovative Dosage Forms

Limitations of conventional dosage forms have created a need for new pediatric drug delivery systems.

Classification of Innovative Pediatric Drug Delivery Systems

- Oral Mucosal Drug Delivery Systems.
- Innovative Drug Delivery Systems.
- Rectal Drug Delivery Systems.
- Transdermal Drug Delivery Systems.
- Pulmonary Drug Delivery Systems.

Oral Mucosal Drug Delivery Systems

- *Physiological Factors:* Children's salivary flow (0.22–0.82 ml/min) is slightly lower than that of adults (0.33–1.42 ml/min). The flow increases until around ages 5 to 6, then decreases. The saliva pH (about 6.6 in children) affects how drugs ionize and are absorbed. Other influencing factors include mucosa, nutrition, and salivary flow.

Innovative Drug Delivery Systems

- *Medi Bottle:* This is a modified feeding bottle with a built-in dispenser. It releases the drug mixed with milk or another beverage while the child sucks. It is suitable for infants and young children.
- *Pulp-Spoon:* This spoon has a dry drug under a microperforated foil. When dipped in water, it forms a paste for easy dosing. It is a simple, unit-dose, spill-free option that is ideal for children.

Rectal Drug Delivery Systems

The rectal route has benefits over oral delivery. It avoids taste issues and is helpful for patients dealing with nausea, vomiting, swallowing problems, or nasogastric suction. It offers both systemic effects (like antipyretic, analgesic, anti-nauseant, anticonvulsant, and sedative) and local effects (such as laxative and anti-inflammatory).

Rectal Dosage Forms

- Common pediatric form: suppositories (≈ 1 g for infants, half adult size). Other forms: creams, ointments, gels, foams, gelatin capsules, and solution/suspension enemas (small <20 ml, large >67.5 ml).
- Rectal mucosa (pH 7–8) has a rich blood and lymphatic supply, bypassing first-pass metabolism and enhancing absorption.
- Enema volume should match age and purpose (local/systemic). Small enemas are preferred for systemic use to improve absorption and reduce discomfort. The rectal tube must be age-appropriate and safe.
- Scaled devices allow personalized dosing, avoiding multiple strengths [11].

Transdermal Drug Delivery Systems (TDDS)

Transdermal drug delivery systems (TDDS) serve as an alternative to oral and injectable methods, addressing challenges, such as taste, palatability, gastrointestinal degradation, first-pass metabolism, liver toxicity, pain from injections, risk of needle-stick injuries, and related emotional distress, while providing prolonged release, improved bioavailability, and better adherence. Transdermal microporation employs technologies such as jet injectors, microneedles, and needle-free devices [12].

Microneedles

- Micron-sized needles, measuring ≤ 1 mm, are painless and non-invasive and do not target blood vessels or pain receptors.
- They create microchannels that facilitate the delivery of both hydrophilic and lipophilic drugs, as well as macromolecules.
- Compared to traditional injections, they result in less tissue damage and discomfort.
- Developed in the 1970s, they saw significant advancements in the 1990s.
- Dissolving Microneedles (DMNs) are constructed from biodegradable polymers and release medications after dissolving in interstitial fluid [12].

Types of Microneedles

- *Solid:* These needles penetrate the skin to improve permeability.
- *Biodegradable/Water-Soluble Polymer-Based:* These are used for controlled depot release.

Microneedle Design Comes in Four Varieties, Which Include

- *Solid Microneedles:* These are utilized to penetrate the skin before the administration of medication.
- *Drug-Coated Solid Microneedles:* Designed for rapid dissolution within the skin.
- *Drug-Free or Drug-Encapsulated Dissolving Polymeric Microneedles:* Intended for fast or controlled drug release.
- *Hollow Microneedles:* Used for the injection of drug solutions.
- *Needle-Free Devices:* These systems employ both subcutaneous and intramuscular delivery techniques to administer drugs and large molecules such as growth hormones, insulin, vaccines,

and local anesthetics. They can administer liquid or powdered formulations under high pressure through a minuscule skin-piercing aperture. Examples of these systems include Pharma Jet, JTip, and Bioject. Generally, the management and disposal of needles are straightforward. Patients can overcome their fear of needles with the implementation of needle-free delivery methods [13].

Pulmonary Drug Delivery Systems

Conventional pressurized metered dose inhalers (pMDIs) are being replaced by breath-actuated pMDIs, which release aerosol once the patient inhales above a set airflow rate. The in-check dial device helps limit children's peak inspiratory flow to ensure the required minimum airflow. Inhalation devices with adjustable resistance and imprinted scales allow selection of the best device for each patient. Since peak inspiratory flow supplies energy for particle dispersion, dry powder inhalers (DPIs) are used instead of pMDIs in airway disease treatment. However, children under 4 usually cannot generate enough inspiratory pressure, while low-resistance DPIs are suitable for ages 4–6. Breath-actuated devices ensure drug delivery only at appropriate flow rates, but DPIs should be avoided during severe asthma attacks [14, 15].

Recent Developments in Pulmonary Delivery

To improve compliance, several spacer/valve-holding chambers have been introduced:

- *Babyhaler* – A chamber with a valve for infants.
- *Vortex* – Non-electrostatic chamber with universal connector and fun facemasks.
- *Watchhaler* – Restricts inhalation flow to 15 L/min.
- *Funhaler* – A chamber with a whistle and a rotating disk that engages children during use (Tables 4 and 5) [14].

Table 4. List of patents in pediatric drug delivery systems.

Year and patent no.	Title and author
2014 CN103505791 (A)	Transdermal-Absorption Local-Anesthesia Painless Injection Puncture Alcohol Pad: Yang Depu.
2013 Mx2011011237 (A)	Compositions In Soft Chewable Gelatine Capsules with Flavor Masker. Osornio Alejandro Ortiz; García Juan Carlos Villeda; Quijano Elena María Brito.
2013 CN202844339 (U)	Disposable Pediatric Rectal Administration Device: Zhang Lina, Ma Mao Lei.
2011 US2011117193 (A1)	Antiretroviral Drug Formulations for Treatment of Children Exposed to Hiv/Aids: Adeyeye Moji C; Esseku Fredrick; Joshi Anajali.
2011 WO2011020610 A1	Drug Delivery System (Wafer) for pediatric use: Sascha General, Ildiko Terebesi, Adrian Funke.
2010 CN201572240 (U)	Apparatus For Dripping Children's Soup: Sufang Liu.
2009 US2009010992 (A1)	Drug Formulations for Oral Transmucosal Delivery to Pediatric Patients: Pamela Palmer, Thomas Schreck, Stelios Tzannis, Larry Hamel, Andrew I. Poutiatine.
2008 US2008319079 (A1)	Method For Administering Formoterol Using a Nebulizer Stephen J. Feanny.
1993 US5223264 A	Pediatric Effervescent Dosage Form: Fred Wehling, Steve Schuehle, Navayanarao Madamala.

EXCIPIENTS IN PEDIATRIC FORMULATIONS

Excipients (>90% of drug weight) act as diluents, binders, sweeteners, preservatives, solvents, absorption enhancers, etc. Selection in pediatrics is challenging due to age, weight, enzyme activity, organ development, and safety concerns. Harmful excipients include propylene glycol, ethanol, parabens; safer ones are starch, erythritol, mannitol, sucrose, etc. The STEP database collects pediatric excipient safety data [16].

- *Diluents*: Used to increase bulk and improve flow, cohesion, and disintegration. Common ones: lactose (may cause hypersensitivity), starch, cellulose, erythritol, mannitol. Must be non-toxic, inert, stable, and safe [17].

- *Coating Agent*: Improve stability, swallowing, release, and palatability. Phthalates (DBP, DEHP) are linked to birth defects; hence not recommended [18].
- *Sweeteners*: Enhance taste in oral pediatric formulations. Common ones: sucrose, sorbitol, mannitol, aspartame, sucralose. Risks include diarrhea, allergies, nutrient malabsorption, or phenylketonuria concerns. Artificial sweeteners are often safer substitutes [19, 20].
- *Coloring and Dyes*: Used for appeal, identification, and light protection. Types: triphenylmethane, azo, xanthene dyes. Risks: hypersensitivity, asthma, urticaria, and anaphylaxis. Azo dyes are often avoided in pediatrics. Must be stable, safe, and API-compatible under FDA/EU regulations [21].

Table 5. List of marketed preparations for pediatrics.

Dosage form	Active ingredient	Trade name	Company
Dispersible Tablets	Artemether-Lumefantrine	Coartem®	Novartis.
	Cowslip (Primula veris /elatior), Yellow gentian (Gentiana lutea). Black elder (Sambucus nigra), Common sorrel (Rumex species), Vervain (Verbena officinalis).	Sinupret®	Bionorica.
Multiparticulates	Artesunate/mefloquine	Artequin™ Paediatric	Mepha.
	Methylphenidate hydrochloride	Medikinet®	Medice.
Mini-tablets	Terbinafine hydrochloride	Lamisil® Oral Granules	Novartis.
	Valproic Acid (Valproate Sodium)	Orfiril long® 150 mg	Desitin.
Orally disintegrating tablets and lyophilisates	Ondansetron	Ondansetron ratios pharm® ODT	Ratiopharm.
	Ondansetron	Zofran® 4mg Zydis lingual ODT	GlaxoSmithKline
Chewable tablets and chewing gums	Montelukast sodium	Singulair 4 mg® Chewable tablets	Merck Sharp & Dohme
	Cetirizine HCl	Zyrtec®	Pfizer
	Dimenhydrinate	Superpep® Travel gum	Hermes
Oral wafers	Diphenhydramine HCl	Triaminic® Thin Strips™	Novartis Consumer Health
	Ondansetron	Setofilm®	Applied Pharma Research & Labtec & MonoSol Rx
Special Oral formulations	Gummy bears (e.g., Pedia Lax®, Fleet) and lollipops (e.g., Get Better Bear®, Helms candy)		

CONCLUSION

In terms of formulation and dosage form, significant advancements have been made in the delivery of medications to infants. Giving a newborn a liquid dose form can be challenging for both parents and medical personnel, and it is rarely possible to administer the full dosage without difficulties. Because of mini-tablet and sprinkle formulations, older infants can mix the dosage form with food without running the danger of choking. Age-appropriate devices have been created to meet neonates' oral dosage requirements rather than trying to alter adult formulations.

The rapid advancement of 3D printed technologies and their use in hospital and pharmacy settings will greatly increase our ability to alter dosage forms for infants. Thin-films, chewable, or covers to actually change patient-centered dosage forms.

It is essential to plan and develop a unique and appropriate delivery method to ensure that pediatric patients receive their medications precisely and consistently. Improvements in drug delivery technology are leading to the development of novel alternative medication administration methods, but to improve

care, the pediatric drug delivery system must keep expanding. Despite the significant advancements in modern antiretroviral therapy, numerous challenges still exist.

Several eye-catching technologies may be used to improve patient acceptability and compliance. These innovative techniques can be applied to pediatric oral formulations to enhance their stability, toxicity, flexibility, and safety. For a given product, selecting an appropriate formulation for a certain target market requires careful consideration.

REFERENCES

1. Ananya Mandal. What is Pediatrics? News-Medical. 2025 Aug 6.
2. Dey P, Bairagi S, Mondal SK. Novel approaches in pediatric drug delivery systems. *Int J Pharm Sci Drug Res.* 2024;16(5):878–887.
3. Domingues C, Jarak I, Veiga F, Dourado M, Figueiras A. Pediatric drug development: Reviewing challenges and opportunities by tracking innovative therapies. *Pharmaceutics.* 2023;15(10):2431.
4. Bereda G. Pediatrics: Pharmacokinetics and dose calculation. *J Pediatr Neonatal Care.* 2022;12(2):96–102.
5. Mistry A, Kapse-Mistry S. Innovative pediatrics drug delivery systems. *J Harmonized Res Pharm.* 2015;4(2):117–130.
6. Ampedi PN, Ogunrombi MO, Adeleke OA. Leading pediatrics infectious diseases—Current trends, gaps, and future prospects in oral pharmacotherapeutic interventions. *Pharmaceutics.* 2024;16(6):712.
7. Lopez FL, Ernest TB, Tuleu C, Gul MO. Formulation approaches to pediatric oral drug delivery: Benefits and limitations of current platforms. *Expert Opin Drug Deliv.* 2015;12(11):1727–1740.
8. Sri Bhavya Reddy, Srinivasa Reddy KS, Kusuma Kumari, Vinay Kumar D. Mini tablets: A child friendly dosage form. *Int J Res Anal Rev.* 2023;10(4):353–373.
9. Renu, Dahiya J, Jalwal P, Singh B. Chewable tablets: A comprehensive review. *Pharma Innov J.* 2015;4(5):100–105.
10. Walsh J, Bickmann D, Breitzkreutz J, Chariot-Goulet M. Delivery devices for the administration of paediatric formulations: Overview of current practice, challenges and recent developments. *Int J Pharm.* 2011;415:221–231.
11. Cram A, Breitzkreutz J, Desset-Brèthes S, Nunn T, Tuleu C, European Paediatric Formulation Initiative. Challenges of developing palatable oral pediatrics formulations. *Int J Pharm.* 2009;365(1–2):1–3.
12. Khomane P, Mirajkar R, Madgulkar A, Velapure M. Microneedle technology: Advancements, applications, and future different directions. *Int J Pharm Sci.* 2025;3(5):3412–3422.
13. Arora A, Prausnitz MR, Mitragotri S. Micro-scale devices for transdermal drug delivery. *Int J Pharm.* 2008;364:227–236.
14. Walsh J, Bickmann D, Breitzkreutz J, Chariot-Goulet M, European Paediatric Formulation Initiative. Delivery devices for the administration of pediatric formulations: Overview of current practice, challenges, and recent developments. *Int J Pharm.* 2011;415(1–2):221–231.
15. Bramson J, Dayball K, Eveleigh C, Wan YH, Page D, Smith A. Enabling topical immunization via microporation: A novel method for pain-free and needle-free delivery of adenovirus-based vaccines. *Gene Ther.* 2003;10(3):251–260.
16. Mascarenhas-Melo F, Diaz M, Gonçalves MBS, Vieira P, Bell V, Viana S, et al. An overview of biosimilars—Development, quality, regulatory issues, and management in healthcare. *Pharmaceutics.* 2024;17:235.
17. Pandolfini C, Bonati M. A literature review on off-label drug use in children. *Eur J Pediatr.* 2005;164(9):552–558.
18. Turner MA, Catapano M, Hirschfeld S, Giaquinto C. Paediatric drug development: The impact of evolving regulations. *Adv Drug Deliv Rev.* 2014;73:2–13.
19. Lu H, Rosenbaum S. Developmental pharmacokinetics in pediatric populations. *J Pediatr Pharmacol Ther.* 2014;19(4):262–276.

20. Buckley LA, Salunke S, Thompson K, Baer G, Fegley D, Turner MA. Challenges and strategies to facilitate formulation development of pediatric drug products: Safety qualification of excipients. *Int J Pharm.* 2018;536(2):563–569.
21. Maheshwari S, Singh A, Varshney AP, Sharma A. Advancing oral drug delivery: The science of fast dissolving (FDTs). *Intell Pharm.* 2024;2(4):580–587.