Narrative review

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Selection of oral feeding delivery devices and regimens in preterm infants: a narrative review adults

Abstract

The transition from enteral tube feeding to independent oral feeding represents a critical developmental milestone for preterm infants in the neonatal intensive care unit (NICU). Successful oral feeding necessitates complex neuromuscular coordination of sucking, swallowing, and breathing, which typically matures between 32 and 34 weeks' postmenstrual age. This transition is governed by two key clinical variables: the physical characteristics of the oral delivery device (including bottle teat flow dynamics, self-paced systems, and non-bottle alternatives) and the structured feeding regimen (scheduled versus cue-based/infant-driven strategies, continuous versus bolus tube feeds). This review synthesizes current evidence evaluating how oral device selection and feeding patterns influence physiological stability, suck-swallow-breathe coordination, time to achieve full oral feeds, and long-term breastfeeding success. Current data favor low-flow or self-paced teats to mitigate cardiorespiratory compromise, cup feeding when the primary objective is maternal lactation preservation, and infant-driven cue-based feeding to shorten transition duration.

Keywords: preterm infants, oral feeding transition, nipple flow rate / bottle teat mechanics, suck-swallow-breathe coordination, cue-based feeding, neonatal intensive care unit (NICU)

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Abbreviations: NICU, neonatal intensive care unit; PMA, postmenstrual age; BPD, bronchopulmonary dysplasia; NEC, necrotizing enterocolitis; CBF, cue-based feeding; SF, scheduled feeding; MOM, mother's own milk; MEN, minimal enteral nutrition; NG, nasogastric; OG, orogastric; EFS, early feeding skill assessment; FRAPPS, feeding readiness and progression in preterms scale; ELBW, extremely low birth weight (<1000g); VLBW, very low birth weight (<1500g)

Introduction

Preterm birth imposes an acute nutritional crisis, requiring specialized enteral strategies to support growth while protecting an immature gastrointestinal tract and uncoordinated airway protection mechanisms. Among the complex developmental milestones encountered during neonatal intensive care unit (NICU) hospitalization, the transition from gavage (orogastric or nasogastric) to total oral feeding is one of the most challenging.[1,2] Successful oral feeding depends on the precise, rhythmic coordination of sucking, swallowing, and breathing—a sequence that generally matures between 32 and 34 weeks' postmenstrual age (PMA), alongside gastrointestinal motility maturation occurring between 33 weeks and term equivalent age.[1,2]

Two interdependent clinical management decisions dictate the trajectory of this transition:

1) The physical modality selected for oral milk delivery (e.g., bottle teat design and flow characteristics, cup, or direct breastfeeding).
2) The operational structure of the feeding regimen (e.g., scheduled versus responsive/cue-based paradigms, bolus versus continuous gavage feeds, and inter-feed intervals).

This narrative review synthesizes the pathophysiological rationale and clinical evidence evaluating how delivery device design and feeding schedule architectures influence cardiorespiratory stability, feeding efficiency, and clinical outcomes in preterm infants.

Pathophysiological rationale: biomechanics of preterm oral feeding

Owing to reduced gastric capacity, gastroesophageal sphincter incompetence, and impaired airway protective reflexes, infants born at < 35 weeks' gestation initially rely on parenteral nutrition and enteral gavage support.[2,4] Enteral feeds are typically initiated as minimal enteral nutrition (trophic feeding at 12–24 mL/kg/day) to stimulate gut maturation before stepwise volumetric advances occur over 7–14 days.[3]

A primary physiological constraint in premature infants is an impaired capacity to self-regulate intraoral milk flow.[5] When milk volume exceeds the infant's swallow-clearing capacity, the suck-swallow-breathe rhythm is disrupted. The biological consequence is ventilatory depression, manifested as prolonged central apneas, bradycardia, oxygen desaturation, and potential pulmonary aspiration.[5,7] Consequently, the fluidic properties of the delivery device directly mediate physiological stability during the transition to oral feeding.

Oral feeding delivery devices: fluid mechanics and clinical impact

Bottle teat flow rate and hydrodynamic variability

Milk flow rate is the primary physical determinant of infant physiological stability during bottle feeding. Historical benchtop fluidic analyses by Mathew demonstrated marked variability in flow rates across commercially available teats, demonstrating that manufacturing labels (e.g., 'slow,' 'preterm,' 'orthodontic') correlate poorly with actual volumetric delivery.[6] Orthodontic teats generally demonstrated higher flow rates than standard teats, and teats labeled for preterm infants frequently exhibited flow rates overlapping with those engineered for term infants.[6] Modern integrative reviews confirm that this lack of standardization persists across international manufacturers.[7]

High milk flow rates impose significant physiological strain on preterm infants. Exposure to excessive flow forces the infant to drop intraoral sucking pressure while simultaneously decreasing minute ventilation and breathing frequency.[5] When milk delivery is continuous or excessively rapid, immature suck-swallow-breathe coordination fails, producing clinical instability (e.g., choking, stridor, desaturations).[7]

From a mechanical perspective, laser-cut teat orifices demonstrate significantly less flow rate variance than mechanically punched orifices.[5] Selecting a teat with a consistently low and predictable flow rate mitigates feeding-induced respiratory compromise during early oral transition, although high-powered randomized controlled trials evaluating specific commercial brands remain limited.

Self-paced and vacuum-free bottle systems

In rigid bottle systems, fluid extraction creates an internal vacuum that increases the physical work required by the infant to draw subsequent drops of milk, leading to fatigue. Lau and Schanler demonstrated that eliminating this internal hydrostatic vacuum improves feeding mechanics in infants born at < 30 weeks' gestation.[8] Vacuum-free and self-paced systems allow infants to establish internal pause-burst patterns, thereby enhancing overall feeding efficiency, shortening feeding duration, and increasing the proportion of fully completed feeds.[8]

Specialized 'breast-like' teats

Commercial teats engineered to mimic maternal nipple mechanics are marketed to prevent 'nipple confusion' and preserve breastfeeding continuation. However, high-quality evidence supporting their clinical superiority is lacking. In a Cochrane systematic review evaluating bottle-avoidance strategies, a trial utilizing specialized breast-like teats demonstrated no statistically significant improvement in long-term breastfeeding rates compared to standard bottle teats.[1]

Non-bottle modalities: cup and supplemental gavage feeding

Cup feeding represents a well-studied alternative to bottle teats when preservation of maternal lactation is the primary clinical endpoint. A Cochrane review of 7 trials (n = 1,152 infants) demonstrated that avoiding bottle teats via cup feeding significantly increased the rate of exclusive and any breastfeeding at hospital discharge and through 3 to 6 months post-discharge, without increasing length of hospitalization or compromising weight gain trajectory.[1] However, device standardization across these studies was low, utilizing medicine cups, specialized baby cups, or bottle protective caps interchangeably.[1]

Alternatively, supplementing direct breastfeeds using an indwelling nasogastric tube avoids bottle exposure completely, though available clinical trial evidence supporting this isolated approach remains of low certainty (Table 1).[1]

Table 1 Comparative analysis of oral feeding delivery modalities

Modality	Key hydrodynamic / operational considerations	Clinical evidence & impact on outcomes
Standard bottle teat	Highly variable flow rates within/between brands; manufacturing labels lack standardization.	High flow increases ventilatory depression and desaturation; slow/laser-cut teats reduce respiratory compromise.
Self-paced / vacuum-free system	Prevents internal negative pressure build-up within the rigid bottle container.	Enhances suck-swallow-breathe pacing, improves feeding efficiency and success in <30-week infants.
Specialized 'Breast-like' teat	Engineered to mimic natural maternal tissue compliance and extraction mechanics.	No demonstrated superiority over standard teats for preserving direct breastfeeding success.
Cup feeding	Non-sucked delivery system (medicine cup, small container) avoiding teat exposure.	Increases exclusive and total breastfeeding rates through 6 months post-discharge; neutral on length of stay.
Supplemental gavage (NG) feeding	Bypasses oral phase entirely during supplemental feeds to preserve direct breast practice.	Protects direct breastfeeding establishment, but overall evidence certainty remains low.
Direct breastfeeding	Physiological gold standard; optimizes intraoral mechanics and maternal bond.	Superior immunological and developmental outcomes; relies on mother's own milk availability.

Structured feeding regimens in preterm infants

Trophic feeds and enteral advancement

Initiation of early trophic feeding (12–24 mL/kg/day) within the first 72 hours of life primes the mucosal barrier, stimulates gastrointestinal hormone release, and accelerates time to achieve full enteral nutrition without increasing the risk of necrotizing enterocolitis (NEC).[10] Subsequent volumetric advancements are titrated based on clinical tolerance, weight, and gestational age.[2]

Continuous versus intermittent bolus tube feeds

For infants weighing < 1500 g, the clinical decision between continuous nasogastric administration and intermittent bolus feeding (every 2–3 hours) remains equivocal. A Cochrane systematic review concluded that current evidence is insufficient to demonstrate the superiority of either approach regarding time to achieve full enteral nutrition, somatic growth, or NEC incidence.[11] Continuous feeding is occasionally reserved for extremely low birth weight infants with severe gastrointestinal intolerance, whereas bolus feeding more closely simulates physiological hormone release (e.g., ghrelin, insulin) associated with discrete meals.[2,11]

Scheduled versus cue-based (infant-driven) feeding

Historically, NICU protocols enforced scheduled feeding (SF), delivering prescribed volumes at rigid intervals (2–3 hours) dictated by weight and gestational age. Contemporary neonatology has largely

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transitioned toward Cue-Based Feeding (CBF)—also termed infant-driven or responsive feeding—where oral feeds are initiated in response to physiological and behavioral readiness cues (e.g., rooting, alertness, hand-to-mouth movements) and ceased upon satiety signals.[12,13]

A 2025 systematic review and meta-analysis confirmed that CBF significantly reduces the time required to achieve full oral feeding compared to SF, while offering a protective effect against feeding intolerance.[13] However, heterogeneity among primary studies remains high, and CBF does not significantly alter total daily volumetric intake or overall hospital length of stay.[13]

Transition frameworks and readiness assessment instruments

Safe transition from gavage to oral feeds requires objective clinical evaluation. Instruments such as the Early Feeding Skill (EFS) assessment and the Feeding Readiness and Progression in Preterms Scale (FRAPPS) evaluate autonomic stability, motor organization, and oral-motor skills.[14] While systematic reviews indicate a lack of large-scale clinical trials proving that any single standardized instrument independently reduces total hospital stay,[14] structured skills-based transition algorithms (e.g., the Mansoura Early Feeding Skills Assessment) have been shown in case-control studies to significantly reduce the duration of gavage dependence without increasing adverse events.[15]

The role of enteral substrate selection

Decisions regarding delivery hardware and scheduling paradigms must be contextualized alongside the nutritional substrate administered. Mother's own milk (MOM) is the universally recommended primary substrate for preterm infants.[2,4,9]

Compared with bovine-based formula, the administration of human milk markedly reduces the incidence of NEC. Meta-analyses demonstrate that formula administration is associated with a nearly threefold increase in the odds of developing NEC (OR 2.99, 95% CI 1.75–5.11).[16] Because preterm human milk requires target fortification with protein and minerals to meet high metabolic demands, device selection strategies (e.g., cup feeding, bottle avoidance) serve as critical structural interventions to safeguard the establishment of direct maternal lactation.[1,4]

Clinical synthesis and management recommendations

1) Lactation preservation: For infants whose mothers intend to directly breastfeed, minimizing exposure to conventional bottle teats during early oral transition is recommended. Cup feeding is the most evidence-supported alternative for improving long-term breastfeeding success.[1]

2) Teat hydrodynamics: When bottle feeding is indicated, teat selection should prioritize low, consistent flow rates (e.g., laser-cut orifices). Self-paced or vacuum-free systems should be considered for immature infants (< 30–32 weeks' PMA) to mitigate flow-induced apneas and improve feeding efficiency.[5,8]

3) Protocolized oral transition: Transition from tube to oral feeding should follow a responsive, cue-based paradigm paired with a structured developmental assessment framework, which accelerates the attainment of independent oral feeding compared to rigid time-scheduled protocols.[13,15]

4) Substrate primacy: Human milk (fortified appropriately) remains the essential substrate of choice regardless of the delivery mechanism utilized.[2,16]

Conclusion

Current evidence underscores the profound impact of delivery device mechanics and operational feeding patterns on the neurodevelopmental and physiological trajectory of preterm infants. Although early low-flow teat selection and cue-based feeding frameworks demonstrate clear clinical utility, substantial heterogeneity across trial designs, device manufacturing terminology, and readiness scales remains a key limitation in the current literature. Future research should focus on standardized benchmarking of fluidic delivery hardware and large-scale, randomized trials evaluating structured oral-motor transition protocols.

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Conflicts of interest

The author declares no conflicts of interest.

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