Oral–Motor Function and Feeding Intervention

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ABSTRACT. This article presents the elements of the Oral Motor Intervention section of the Infant Care Path for Physical Therapy in the Neonatal Intensive Care Unit (NICU). The types of physical therapy interventions presented in this path are evidence based as well as infant driven and family focused. In the context of anticipated maturation of suck–swallow–breathe coordination, the timing and methods for initiation of oral feedings and transition from gavage to full breast or bottle-feedings are presented with supporting evidence.

KEYWORDS. preterm infant, evidence-based practice, neonatal oral feeding, oral motor interventions

INTRODUCTION—IMPORTANCE OF FEEDING SKILLS

Nipple feeding represents one of the greatest challenges for both maturing preterm infants and their parents (Thoyre, 2007). In addition to the oral–motor skills and endurance needed, maturing postural control and early interactive responses are components of this primary functional skill that need to be anticipated by caregivers. Slow or suboptimal progression to enjoyable nipple feeding by bottle, breast, or a combination can complicate parent–infant interaction and prolong hospitalization (Reyna, Pickler, & Thompson, 2006; Thoyre, 2007). Among infants born preterm, the challenge is usually greater for those with complications such as chronic lung disease and gastroesophageal reflux (GER) problems as well as necrotizing enterocolitis (NEC), intraventricular hemorrhage (IVH), periventricular leukomalacia (PVL), and episodes of neonatal sepsis (Gewolb & Vice, 2006b; Jadcherla, Wang, Vijayapal, & Leuthner, 2010; Thoyre, 2007).

This article guides the reader through the elements of the Oral Motor Intervention section of the Infant Care Path for Physical Therapy in the Neonatal Intensive Care Unit (NICU Care Path, Campbell, in press, figure 2.1). This section corresponds to the elements of intervention in the Guide to Physical Therapist Practice (American Physical Therapy Association, 2001). It addresses knowledge areas and evidence-based practice guidelines delineated among clinical competencies for
According to the American Academy of Pediatrics (AAP) guidelines, competent oral feeding by bottle or breast with no cardiorespiratory compromise is a criterion for preterm infant discharge to home (AAP, 2008). There is, however, no consensus regarding the timing and methods for initiation of oral feedings or for transition from gavage to full breast- or bottle-feedings.

Based on clinical experience in NICU settings, occupational, physical, and speech therapists typically serve as consultants to skilled neonatal nurses and physicians, providing guidance on techniques and patterns of feeding progression for infants with atypical or persistently immature, disorganized oral sensorimotor responses. This can include infants with slow development of effective nutritive sucking (NS); those lacking sufficient endurance or persistence for efficient feeding; those with recurrent apnea, bradycardia, and/or desaturation episodes during feeding; and those with persistently immature swallowing and excessive loss of formula. Among infants at high risk for developmental delay with limited endurance and low tolerance of handling, periods of time immediately before, during, or after feeding typically seem to be the best times for brief practice of interactive and/or postural responses included in other sections of the NICU Care Path (Campbell, in press, figure 2.1). With specialized training, therapists may also become lactation consultants and, more specifically, facilitate preterm infants' adaptation to breast-feeding. They also typically serve as parent educators in situations involving more problematic feeders and parents in need of increased experience as well as confidence caring for their infants. They collaborate with parents and staff members to plan a breast or bottle-feeding schedule that incorporates time for increasing parental feeding experience and decision making.

**MATURATION OF SUCK–SWALLOW–BREATHE COORDINATION**

The oral experience of a prematurely born infant obviously differs from the experience of an infant born at term who gains more swallowing experience with larger volumes during a longer period of time prior to birth. In order for a therapist to accurately assess the age-related appropriateness of an infant's oral–motor abilities and plan interventions to enhance their oral experience as they mature, knowledge of typical oral–motor maturation is needed. Throughout this article the age of a preterm infant at birth is indicated by gestational age (GA) in weeks and the age after preterm birth up to term age is indicated by postmenstrual age (PMA) in weeks (AAP, 2004).

The ability to swallow may be observed in utero during ultrasound studies at 12–14 weeks gestation, early sucking movements may be observed at 15–18 weeks but sucking with a licking or anterior-to-posterior tongue movement does not become evident until 18 and 24 weeks gestation (da Costa, van den Engel-Hoek, & Bos, 2008). Although these primary patterns are sufficient for oral experience in utero, coordination of sucking and swallowing with adequate ventilation needed for a preterm infant’s oral experience is much more complex. Among preterm infants, the ability to link sucking with swallowing is present by 28 weeks PMA.
and ability to coordinate sucking and swallowing of more than oral secretions typically develops between 32–34 weeks PMA (Bu’lock, Woolridge, & Braum, 1990). The characteristics of a maturing infant’s sucking pattern should change significantly during the progression from initial oral stimulation and non-nutritive sucking (NNS) to functional bottle and/or breast-feeding. As preterm infants mature, their sucking patterns develop both a suction and expression component between which they rhythmically alternate (Lau, Alagugurusamy, Shulman, Smith, & Schanler, 2000). The expression phase is more specifically described as stripping or compression of the nipple by the tongue against the hard palate as it moves from anterior to posterior in order to draw milk from the nipple (Lau Shenna, Shulman, & Schanler, 1997). The suction phase is the cycle of negative pressure produced by simultaneous lowering of the tongue and jaw while the nasopharynx is closed by approximation of the soft palate and the posterior pharyngeal wall. Lau and colleagues (2000) describe the initial nipple feeding of preterm infants as consisting of only the expression or licking component. They also describe the changes associated with maturation of sucking as a progression through five stages based on increased control of expression prior to suction and, finally, improved rhythmicity and consistency between expression and suction phases (Lau et al., 2000).

Other authors have described similarly predictable patterns of increased sucking pressure and frequency as infants matured from 34 to 36 weeks PMA (Mizuno & Ueda, 2003). These changes in the complexity of sucking occur during the same period as an infant’s coordination of swallowing and breathing is refined. There is evidence that although a preterm infant may manage small amounts of oral intake at 32 weeks PMA, coordination among sucking, swallowing, and respiratory cycles typically matures between 34 and 36 weeks PMA (Mathew, 1991). With the assistance of a skilled caregiver, however, functional nipple feeding can be accomplished by preterm infants without the presence of all of the components of mature, rhythmic NS, swallowing, and breathing (Lau et al., 1997).

Coordination of breathing with swallowing presents the greatest nipple feeding challenge for maturing preterm infants as they progress toward functional breast or bottle-feeding. The idea that infants can somehow breathe while swallowing has been communicated to therapists over the past decades, but there is no evidence to suggest that this is accurate. Oral feeding, regardless of the volume, interferes with ventilation because respiration cycles are inhibited during swallowing (Doty & Bosma, 1956; Durand et al., 1981; Mizuno, Inoue, & Takeuchi, 2000). The least mature protective strategy used by preterm infants is suppression of respiration during numerous suck–swallow sequences. This is referred to as feeding, swallow, or deglutition apnea. Oral feeding guidelines in many NICU settings preclude nipple feeding among tachypneic infants with sustained resting respiratory rates >60 breaths per minute (bpm). When tachypneic, there is insufficient time for completion of swallowing cycles between airway closure and opening (Mizuno et al., 2000). Infants with respiratory rates between 30 and 50 bpm can comfortably adapt to periods of airway closure during a swallow while tachypneic infants with resting respiratory rates >60 bpm are often unable to maintain adequate oxygen saturation. The significant changes in coordination identified between 34 and 42 weeks
PMA include increased minute ventilation during feeding cycles with decreased number and duration of deglutition or swallow-related apnea episodes (Hanlon et al., 1991). Differences in minute ventilation during oral feeding compared with resting state ventilation are reported to be greater at 34 weeks than at 36 PMA weeks and beyond (Shivpuri, Martin, Carlo, & Fanaroff, 1983). Lower minute ventilation among immature infants reflects periods of breath holding or shallow inhalation between the suck–swallow cycles characteristic of immature feeding patterns. Mizuno and Ueda (2003) documented a transition in coordination after 35 weeks PMA when swallowing more consistently followed the end of an inspiration cycle rather than expiration or a period without respiratory effort common among infants <34 weeks PMA. Collecting data from a pharyngeal pressure transducer and a thoraco-abdominal strain gauge, Gewolb and his collaborators have also documented multiple characteristics of breathing and swallowing cycles during feeding among 20 preterm infants from 32 to 40 weeks PMA in contrast with 16 term infants from 1 to 4 days as well as at 1 month. Increasing PMA of low-risk preterm infants positively correlated with a faster sucking rate, more rhythmic sucking pattern, longer series of sequential sucks and more consistently rhythmic suck–swallow patterns (Gewolb, Bosma, & Vice, 2003; Gewolb & Vice, 2006a). They defined “apneic runs” as sequences of at least three swallows not associated with breathing movements. At or less than 35 weeks PMA, preterms had a mean of 16.6% [4.7] (brackets indicate standard deviation) “apneic runs,” while preterms older than 35 weeks PMA had a mean of 6.7% [1.8] while feeding. Term infants shortly after birth and at one month had a mean of only 1.5% [0.4]. These authors found the relationship of swallow to phase of respiration to be quite variable among preterm infants at or less than 35 weeks PMA. Among infants with chronic pulmonary insufficiency of the preterm up to 36 weeks PMA and bronchopulmonary dysplasia (BPD) beyond 36 weeks PMA, coordination of respiratory cycles with suck–swallow sequences is a greater challenge. Increased apnea, less regular respiratory patterns, decreased length of suck–swallow sequences, and need for more frequent rest periods were all evident among these infants (Gewolb & Vice 2006b). Many of the infants with severe respiratory problems may not conform to the NICU Care Path age-related recommendations in general and specifically in regard to nipple feeding.

In summary, preterm infants typically develop a functional though immature NS pattern before they are able to consistently coordinate suck–swallow–breathe sequences without caregiver assistance (Lau et al., 1997). The less mature an infant is at birth, the longer their transition time to autonomous nipple feeding and their dependence upon caregiver assistance usually are (Lau et al., 2000; Medoff-Cooper, McGrath, & Shults, 2002). One retrospective chart review found that degree of prematurity combined with a measure of morbidity accounted for 61% of the variability between infant’s transition time and age of successfully completing all feedings by nipple. Among extremely prematurely born infants (<28 weeks GA), the mean age of initiation of nipple feedings (34.6–35.0 weeks PMA) and duration of transition to nipple feeding (3.6–4.6 weeks) as well as the age at attainment of entirely nipple feedings (38.4–39.6 weeks PMA) are increased in comparison with infants born at 28–32 weeks GA (Dodrill, Donovan, Cleghorn, McMahon, & Davies, 2008).
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Oral Stimulation and Non-nutritive Sucking During Gavage Feedings (Figure 1)

As indicated in the NICU Care Path, early oral stimulation and/or NNS experience during gavage feeding are the initial interventions for facilitation of oral–motor organization and functional feeding.

Between 30 and 34 weeks PMA, these measures can provide several benefits for preterm infants and their parents. Decisions regarding the initiation and progression of this intervention need to include parental input. To minimize energy demands, initial oral stimulation or NNS experiences are typically offered with the infant swaddled inside their isolette or in the context of skin-to-skin care (SSC). The benefits of this stimulation can eventually include increased nipple feeding intake, increased rate of weight gain, earlier discharge from the hospital, and earlier nipple feeding competence (Fucile, Gisel, & Lau, 2005; Hill, 2005). Clinicians should be aware, however, that these positive findings also reflect maturation and are not consistently reported to be enhanced by additional oral stimulation. Benefits that are associated with oral stimulation and NNS experience may reflect benefits from other modes of stimulation or functional activity practice occurring simultaneously. For example, following consistent daily stimulation with a broader focus than oral stimulation, similar improvements are also reported by White-Traut and colleagues (2002). Additional findings of multiple studies of early oral stimulation and NNS are discussed in the following pages.

Even though positive effects of early NNS and oral stimulation are supported by research findings (Fucile et al., 2005; Hill, 2005), the current literature provides limited guidance for PMA or other criteria for the initiation of interventions. Of the 21 studies included in the Cochrane Database of Systematic Reviews, five document inclusion of preterm infants at 30–32 weeks PMA as the age for initiation of intervention specified in this NICU Care Path (Bernbaum, Pereira, Watkins, & Perkham, 1983; Boiron, Da Nobrega, Roux, Henrot, & Saliba, 2007; De Curtis, McIntosh, Ventura, & Brooke, 1986; Ernst et al., 1989; Field et al., 1982; Woodson & Hamilton, 1988). At less than 32 weeks PMA, some clinical settings consider medical stability of infants while receiving 10 cc or more of milk or formula by gavage as a criterion for offering NNS. Dougherty and Luther (2008) describe a “lick & sniff” phase at 31–32 weeks PMA in their care map for extremely low birth weight (ELBW) infant’s early oral stimulation at their mother’s breasts. They
advise mothers to “prepump” their breasts in order to safely encourage NNS and milk droplet stimulation without eliciting the mother’s full milk ejection reflex (MER) until their infant is more mature. Prior to initiation of oral stimulation and NNS, an infant should demonstrate physiological stability and behavioral tolerance of caregiving. This is assessed in an ongoing manner by monitoring vital signs and behavioral cues in the context of routine care. Therapists should understand and in turn teach parents to recognize the degree of environmental protection needed by an individual infant as well as the assistance they need for recovery when planning for or progressing with intervention. As presented by Byrne and Campbell (in press), the Newborn Individualized Developmental Care and Assessment Program (NIDCAP), the Premature Infant Pain Profile (PIPP), and the Behavioral Indicators of Infant Pain (BIIP) provide formalized methods for these observations.

**Description of Oral Stimulation and Non-Nutritive Sucking**

**Oral Stimulation**

Oral stimulation typically includes both perioral and intraoral sensory input. Perioral stimulation consisting of pressure input alone or in conjunction with slow stroking of cheeks and lips typically precedes intraoral input. Intraoral stimulation generally includes pressure with or without slow movement along the upper gum, center of the tongue, and/or palate in various combinations and sequences. Both perioral and intraoral stimulation are provided for various periods of time within the infant’s level of tolerance. The sequence used for oral stimulation by Boiron and colleagues (2007) is more clearly described than within other referenced studies. They describe provision of perioral stimulation in the sequence of cheeks, upper lip, and then lower lip for three repetitions with sustained pressure from the caregiver’s index finger. The intraoral stimulation used in this randomized controlled trial was administered in the sequence of tongue, palate, and then gums for three repetitions with sustained pressure from the caregiver’s fifth finger (Boiron et al., 2007). Most protocols for oral stimulation stipulate a period of 10–15 min within 30 min of scheduled gavage feeding offered once or more daily on a consistent basis. For the youngest, most fragile infants, oral stimulation is often initiated with the infant tucked into flexion while prone inside an isolette with progression to sidelying and then supine or semiupright while swaddled. Within the infant’s tolerance of handling and temperature stability, oral stimulation may occur while the infant is out of the isolette engaged in SSC with a parent. The stated goal of such perioral stimulation is to improve the strength and control of oral musculature as well as to improve the infant’s oral orientation responses. The goals of intraoral stimulation are lower sensitivity to routine oral care methods and improved threshold for a gag response as well as enhanced responsiveness of sucking and swallowing reflexes (Boiron et al., 2007).

**Non-Nutritive Sucking (NNS)**

NNS includes placement of a caregiver’s gloved finger or a pacifier within the infant’s mouth to elicit at least some degree of sucking effort, with minimal fluid other than oral secretions to control. Various facilitation measures may be used as well as drops of warmed breast milk or appropriate formula to initiate a sucking response.
NNS is characterized by bursts of rapid sucking interspersed with rest periods. The sucking pattern initially consists of primarily anterior-to-posterior tongue movement accompanied by up and down jaw movement with only intermittent or no suction pressure. This initial response is generally considered to be a reflexive response, but with ongoing sensory input both the degree of suction and duration of the response are sustained by the infant. As an intervention method, NNS is usually elicited while an infant remains in an isolette with extremities supported in flexion toward the trunk while prone or sidelying prior to or during gavage feeding. Within the infant’s tolerance of handling and temperature stability, NNS can be facilitated while the infant is held by a caregiver for 10–15 min during a gavage feeding or at the mother’s emptied breast during SSC (Kirk, Alder, & King, 2007).

The goals of NNS are essentially the same as oral stimulation. Rather than schedule oral stimulation or NNS measures for a specific time during the day, published protocols usually proceed with daily stimulation at times when the infant is able to sustain a semialert state as well as some degree of positive oral response (Fucile et al., 2005). In order to elicit an infant’s most mature responses, the timing of this initial oral experience during their brief periods of hunger-associated activity and alertness is important. Nurses therefore can often provide more spontaneous and consistent practice for infants than therapists with more restrictive time schedules. Therapists as part of their consultative role often facilitate initiation of early oral experience and practice among infants with persistently immature oral responses and/or at highest risk of developmental delays. Their role includes not only teaching parents the methods for oral stimulation and NNS, but also how to recognize optimal moments to provide their infants with stimulation opportunities as well as recognize the appropriate time to stop.

**Evidence Supporting Benefits of Oral Stimulation and Non-Nutritive Sucking**

Although the positive effects of early oral stimulation and/or NNS are reported to be wide ranging, decreased hospital stay was the single significant result of NNS confirmed by a Cochrane Database Systematic Review (Pinelli & Symington, 2005). Even though reported among the 21 studies of NNS effects, this systematic review did not find consistent evidence of benefits such as increased weight gain, vital sign changes, altered intestinal transit time, younger age for achievement of full nipple feedings, or maturity of behavioral state control. On the other hand, no evidence of detrimental effects from NNS was identified within any age group. Another evidenced-based systematic review of the effects of oral–motor interventions on feeding and swallowing was conducted by Arvedson, Clark, Lazarus, Schooling, and Frymark (2010). They identified 12 relevant studies that met their methodological criteria. Seven of the 12 studies examined the effects of NNS alone either during or prior to gavage feeding. These seven studies showed a significant improvement in measures of swallowing and decrease in the number of days to achieve total oral feeding but inconsistent changes in other measures such as weight gain and volume of intake. Two of the 12 studies examined the effects of just preceding oral and perioral stimulation on feeding parameters. The results of these studies were inconsistent and the authors concluded that there was not enough evidence to support or to negate the effect of oral stimulation.
without NNS. Three of the 12 studies investigated the effects of oral and perioral stimulation with NNS. As with NNS alone, these studies showed a significant decrease in the time infants required to achieve total nipple feeding status but not a consistent improvement in weight gain. The authors concluded that the benefits of oral stimulation with or without NNS remain unclear.

The effect of NNS with pacifiers on preterm infants whose mothers plan to exclusively breast-feed is a subject of debate among NICU staff members and parents. Parents should be involved in planning their infant’s NNS experience and should be knowledgeable about the evidence that distinguishes the preterm from the full-term infant’s responses to pacifier use. For populations of full-term infants, delayed introduction of pacifier use until breast-feeding is well established is supported by studies of large groups of infants (Howard et al., 2003; Jenik, Vain, Gorestein, & Jacobi, 2009). Among infants born <34 weeks GA, there is less evidence for clinical guidance. In one randomized controlled trial that included >300 preterm infants, however, the investigators determined that the use of pacifiers or “dummies” did not negatively effect breast-feeding (Collins et al., 2004).

**Initiate Nutritive Sucking with Small Amounts of Breast Milk or Formula (Figure 1)**

During the 30–34 week PMA period, addition of taste sensation to oral stimulation can improve both the duration and strength of immature NNS (Pickler & Reyna, 2003; Simpson, Schanler, & Lau, 2002). After infants gain tolerance of oral stimulation and NNS, drops can be introduced by the caregiver’s gloved finger dipped in milk or formula. A greater challenge is presented by using a small syringe in a soft nipple from which the infant can express the milk or formula with minimal effort (see Figure 2). With either method, pleasant taste sensation should not be overwhelmed by more liquid volume than an immature infant can swallow easily.

**FIGURE 2.** This infant is syringe feeding in supported upright while swaddled and held on his mother’s lap. She is providing chin support to assist his sucking as well as monitor his swallowing pattern. He can control his own suck–swallow–breathe cycles as he empties the soft, slow flow nipple and is able to rest when the nipple is removed from his mouth to be refilled by his mother.
To minimize energy demands, initial NS experience is offered with the infant swaddled inside their isolette or in the context of SSC. Swaddling is needed not only to contain and limit extremity movement, but to also support the trunk in neutral alignment. The time for this type of stimulation, as stated with oral stimulation and NNS, is during the infant’s brief periods of alertness and hunger-associated activity. Decisions regarding the initiation and progression of initial NS experience need to include parental input. Prior to initiation of NS experiences, an infant should demonstrate physiological stability and behavioral tolerance of oral stimulation during caregiving. This continues to be assessed in an ongoing manner by monitoring vital signs and behavioral cues in the context of routine care. An infant may require more protection from environmental stimulation as well as more assistance for recovery during and following this intervention. Immature infants typically tire rapidly from initial NS experiences and need to sleep without disturbance afterward. The NIDCAP, the PIPP, and the BIIP provide formalized methods for observation and/or documentation of these behavioral observations during and following initial NS experience (Byrne and Campbell, in press).

The therapist’s decisions regarding the initiation of NS as an intervention should be based upon an understanding of the typical maturation of suck–swallow–breathe coordination, the differences between NNS and NS, and other behaviors identified as “feeding readiness behaviors” (FRBs) in the literature such as rooting and hunger-related irritability. Intermittent respiratory cycles between suck–swallow sequences may be evident among 32-week PMA infants, but 34–36 weeks PMA is the typical period during which coordination becomes consistent and functional for nipple feeding (Pickler, Best, Reyna, Wetzel, & Gutcher, 2005; Simpson et al., 2002). Episodes of feeding-related oxygen desaturation (decreased SaO₂) and bradycardia are also associated more closely with inexperience than with PMA among some healthy preterm infants (Simpson et al., 2002). Coordination of these feeding components is generally thought to be more related to maturation than experience, but some infants introduced to nipple feeding as early as 31 weeks achieve competent nipple feeding before those infants introduced at 33 weeks. With early oral feeding experience and parents well trained in assistive feeding measures, some healthy preterm infants can achieve functional, full-volume bottle-feeding status by 34.5 to 35 weeks PMA (Pickler & Reyna, 2003).

**Characteristics of Nutritive Sucking in Contrast with Non-Nutritive Sucking**

NNS or sucking with minimal fluid other than oral secretion to control typically occurs at a faster rate than mature NS or sucking that draws additional fluid into the oropharynx. Wolff (1968) was one of the first authors to describe this difference. He observed a typical NNS frequency of two sucks per second while NS frequency was usually one suck per second. As vigorous, hungry infants initiate nipple feeding, the rapid NNS pattern may be observed briefly even as the infant attempts to swallow the additional liquid between sucking cycles. This initial “guzzling” is then followed by a reduction in sucking rate as the infant begins an NS pattern as described above. The same transition is evident in the two primary feeding patterns identified by Mathew (1991). He documented two distinct patterns in mature NS: continuous and intermittent. Continuous sucking, more common at the
beginning of a feeding, is a series of suck–swallow sequences without respiratory effort lasting 30–60 s and similar to NNS. The intermittent pattern consists of a repeated series of three to five rhythmic sucking bursts followed by self-imposed rest periods for breathing cycles. This functional NS or intermittent phase sucking is also characterized by slower rates of swallowing and fluid intake, a more stable SaO\textsubscript{2} range, and less feeding-related fatigue than is evident in NNS or continuous sucking phase (Mathew, 1991). The intermittent pattern of slowed intake rate and recovery breaths between bursts of sucking provides the basis for the feeding intervention known as “pacing.” Imposed pauses and measures to slow intake rate assist immature infants in their transition from NNS to NS. Studying the sucking patterns of 31-week GA infants reaching 39 weeks PMA, Miller and Kang (2007) documented significant differences between NNS and NS patterns using noninvasive ultrasound imaging. NS required greater range of movement in both the anterior and posterior areas of the tongue. The angle of hyoid movement during NS was also significantly greater than during NNS (Miller & Kang, 2007). The transition from NNS to NS as well as from continuous to intermittent sucking patterns presents a challenge for preterm infants during their initial oral feeding experiences. When preterm infants begin oral feeding, they have a more mature, complex NNS than NS pattern (Lau & Kusnierczyk, 2001). Without the need to control and swallow milk, the preterm’s NNS pattern is usually characterized by more effective expression and suction components as well as more rhythmic coordination between these components. The typical adaptation of an inexperienced preterm infant to the demands of nipple feeding is to limit their sucking pattern to expression or licking without suction cycles. This impressive adaptation allows the infant to maintain a slow but relatively consistent rate of milk intake within the limits of their swallow–breathe control, even though their total intake is a small volume (Amaizu, Shulman, Schanler, & Lau, 2008). As a general rule, the greater the differences between NS and NNS patterns, the less mature the infant’s swallow–respiratory coordination is (Lau et al., 2000).

Although periods of NNS during gavage tube feedings are advantageous, the use of oral stimulation or NNS immediately before an attempted nipple feeding is not clearly supported by evidence (Arvedson et al., 2010). A period of prefeeding NNS can facilitate quiet alertness, but there is no evidence of a direct relationship between oral feeding success and either the ability to sustain NNS or an interactive alert state (Pickler & Reyna, 2003). Pickler and Reyna (2004) found that prefeeding NNS did not result in improved NS coordination, volume of intake, or quality of alertness during the oral feeding that followed. Considering these findings and the differences between NNS and NS identified by Miller and Kang (2007), the influence of prefeeding alertness and oral stimulation on individual infants prior to NS experience needs to be reassessed by therapists frequently as each infant’s feeding capacity improves.

**Nutritive Sucking and Small-Volume Nipple Feeding 1–2 x/day (Figure 1)**

Between 32 and 37 weeks PMA, as indicated within the NICU Care Path, medically stable preterm infants can progress beyond the drops of milk or formula and benefit from small but increased volume nipple feedings, even though they require assistance with pacing for functional suck–swallow–breathe cycles and facilitation
measures for sustained sucking efficiency (Fucile et al., 2005; Pickler, Best, Reyna, Gutcher, & Wetzel, 2006; Pickler & Reyna, 2003). In order for infants less than 34 weeks PMA to benefit from practice of NS with small volumes of milk or formula, their caregivers need to closely monitor and respond appropriately to signs of stress and fatigue. The quality of an infant’s oral feeding practice is more important than the quantity consumed. Although the amount of liquid consumed can be a concrete measure of progress, it can also reflect the effort of a well-intentioned but persistent caregiver to pump liquid into the mouth of an infant too tired to participate in the process. This is not a helpful pattern for the infant and it models an inappropriate pattern for parents to use after discharge. Above all, this practice of feeding tired infants can lead to aspiration, laryngospasm, and/or bronchospasm. Clinicians implementing early nipple feeding with preterm infants need to consider the benefits as well as the limitations of this experience. The knowledge of the typical maturation pattern for suck–swallow–breathe control and infants’ FRBs discussed in other sections of this article need to be considered in this decision-making process.

Evidence Supporting Benefits of Early Introduction of Nutritive Sucking

Among preterm infants born >28 weeks GA who initiate oral feeding experiences at 34 weeks PMA or later, the transition from total bolus gavage or tube feeding to full-volume nipple feeding typically lasts 10–14 days with a range of 3–27 days (Bragelien, Rokke, & Markestad, 2007; Pickler, Mauck, & Geldmaker, 1997; Pickler & Reyna, 2003). Although the transition to nipple feeding begins prior to 34 weeks PMA in many nurseries, this practice has not been confirmed as consistently leading to reduction of the transition time to autonomous nipple feeding (Blackwell et al., 2005; Dodrill et al., 2008). Nevertheless, a retrospective review of 25 preterm infant’s charts revealed that infants offered more bottle-feedings per day took fewer days to achieve full nipple feeding competence (Pickler, & Reyna, 2003). Although this chart review included a relatively small convenience sample, a subsequent study confirmed this conclusion. From a longitudinal, nonexperimental study assessing the maturity and effectiveness of nipple feeding among 88 infants <32 weeks GA cared for in a Level 3 NICU, Pickler and colleagues (2006) again identified feeding experience as the primary factor associated with feeding variables measured by sucks/minute, sucks/burst, and number of sucks during a feeding (Pickler et al., 2006). Simpson et al., (2002) report supportive findings from a randomized controlled trial with a small intervention group of 13 and control group of 16. The preterm infants included in the intervention group initiated oral feeding opportunities after they achieved the benchmark of tolerating full-volume bolus gavage feedings for 48 hr by medical staff assessment. These 13 infants in the experimental group were 33.5 [2.1] (brackets indicate standard deviation) weeks PMA when their first bottle-feeding was given. They were able to complete all feedings by nipple significantly younger than the control group (34.5 [1.6] versus 36.0 [1.5] PMA) and transition to full nipple feeding in fewer days than the control group (26.8 [12.3] versus 38.4 [14] days). In summary, there is limited evidence supporting benefits from early introduction of oral feeding beyond anticipated maturational changes among infants <34 weeks PMA. Factors limiting measures of successful nipple feeding among infants <34 weeks PMA include the infant’s
lack of functional coordination of breathing with suck–swallow sequences and variable levels of assistance from caregivers to compensate for this incoordination. Discussion of FRBs and techniques for introduction of NS among this group of fragile infants are in subsequent sections of this article.

**Feeding Readiness Behaviors**

Reviewing surveys of NICU practices, McGrath and Braescu (2004) found PMA and weight to be the most frequently cited primary criteria for the determination of an infant’s readiness to initiate nipple feeding. They also found there to be little consensus regarding the age and weight criteria as well as limited supportive evidence in the literature. One published protocol uses the marker of 48 hr after achieving full-volume bolus gavage as the time for nipple feeding introduction (Simpson, et al., 2002). Another defines readiness for oral feedings as gaining 10–15 gm/kg of body weight/day on enteral feedings (Fucile et al., 2005). In the published protocols of several NICU facilities, behavioral responses that reflect nervous system maturation have replaced or been combined with PMA and weight criteria. As a group, these responses are called FRBs. These behaviors generally include measures of emerging state control and oral behaviors indicative of hunger. FRBs specifically identified in the literature include rooting responses, crying near scheduled feeding times, squirming or increased general activity level, maintenance of a flexed posture, sustained NNS for 3 min with a respiratory rate <70, and achievement of a quiet alert state for variable periods of time (Kirk et al., 2007; Reyna et al., 2006). The relationship between FRBs and feeding success has been studied by White-Traut, Berbaum, Lessen, McFarlin, and Cardenas (2005). During the first three oral feedings of 21 preterm infants, they identified the following behaviors: mouthing, hand-to-mouth, hand swipes at the mouth, sucking on the hand, and NNS without a pacifier or with a caregiver’s finger in the mouth. They found that the ATVV stimulation program (a multimodal program standing for systematic application of Auditory, Tactile, Visual, and Vestibular inputs) being studied contributed to infant’s alertness and increased the number of observed FRBs. Preterm infant’s limited capacity to respond to multiple simultaneous modes of stimulation was also evident in the finding that quiet alertness at the time of the feeding itself was not related to feeding efficiency. This finding supports the clinical observation that preterm infants with emerging skills are typically able to complete nipple feedings more successfully if they are not simultaneously responding to social or other types of stimulation. This study supports a correlation between observations of the identified FRBs that reflect nervous system maturation and early feeding success.

The Neonatal Oral–Motor Assessment Scale (NOMAS) can offer insight into an infant’s feeding readiness (Byrne & Campbell, in press). This assessment provides an observational protocol and a list of jaw and tongue movement characteristics that can be classified as normal, disorganized, and dysfunctional during NNS. As an infant matures, gains oral–motor coordination and endurance with NNS, the total number of characteristics in the disorganized or dysfunctional categories decreases and those in the normal category increase. While scores on the NOMAS do not serve as a diagnostic assessment, they do communicate progress or lack of progress to other medical caregivers particularly from 32 to 36 weeks PMA (da Costa &
van der Schans, 2008; Howe, Sheu, Hinojosa, Lin, & Holzman, 2007). The initial NS experiences of preterm infants may be too brief and uncoordinated to score according to the NOMAS but progress can also be documented and contrasted with NNS scores once the infant is able to maintain feeding effort for several minutes.

**Techniques for Introduction of Small-Volume Nutritive Sucking**

Based on clinical experience, one of the keys to safe introduction of NS is caregiver limitation of the infant’s intake rate by assisted pacing (Law-Morstatt, Judd, Snyder, Baier, & Dhanireddy, 2003; Premji, McNeil, & Scotland, 2004). With a slow intake rate, young infants seem better able to collect the bolus of liquid for swallowing and actually complete a swallow without respiratory compromise. This can be accomplished by “pacing” and infant positioning as well as other measures to limit flow rate of milk or formula.

**Pacing** consists of limiting the number of sucking cycles permitted between respiratory cycles by emptying the nipple or removal of the nipple from the infant’s mouth. Based on the rhythm of respiratory cycles identified by multiple studies of functional infant feeding patterns, pacing intervention typically interrupts sucking after each series of 3–5 sucks by removal of the nipple from the infant’s mouth for 3–5 s (Bu’lock et al., 1990; Gryboski, 1969; Mathew, 1988; Palmer, 1993). Incorporation of this pacing intervention decreased the number of bradycardic events during feeding as well as improved the oral feeding skill at the time of discharge among 16 preterm infants compared with controls (Law-Morstatt et al., 2003). As infant’s oral–motor control matures, this pacing method is often modified by clinicians to avoid actual removal of the nipple from the mouth. With experience and maturation, infants will interrupt their own sucking when the bottle is simply lowered and the nipple emptied. After analyzing videotapes of 20 preterm infant’s bottle-feeding with concurrent oxygen saturation data, Thoyre and Carlson (2003) found that infant’s behavioral cues were too few and too inconsistent to be relied upon as indicators of decreased ventilation until apnea and bradycardia occurred. They concluded that pacing intervention to minimize feeding apnea and facilitate adequate ventilation was more beneficial than looking for specific behaviors to anticipate inadequate respiratory effort.

Therapists can augment pacing assistance by incorporation of **positioning and swaddling** methods. Feeding in a semiupright but sidelying position (see Figures 3 and 4) helps immature as well as tired infants avoid choking on liquid not cleared from the posterior oropharynx by immature swallowing (Clark, Kennedy, Pring, & Hird, 2007). Swaddling to provide trunk stability and containment of the extremities flexed close to the trunk is needed by infants as they gain tolerance of time out of their isolette as well as endurance and experience with small-volume nipple feedings. Effective swaddling and positioning with attention to neck and trunk stabilization as well as alignment are helpful adaptations taught by therapists to caregivers for initial nipple feeding (McGrath & Braescu, 2004; Updike, Schmidt, Macke, Cahoon, & Miller, 1986). With the trunk stabilized in neutral, immature infants clinically seem to remain awake, sustain adequate ventilation and effective sucking patterns better than when they are allowed to relax into either extension or flexion postures. With the neck stabilized in slight capital flexion and the chin tucked
inward, infants clinically seem better able to control swallowing as well as sustain adequate ventilation (McGrath & Braescu, 2004). While the same guidelines apply for any nipple feeding, therapists often need to help mothers apply them to breast and bottle-feeding individually. As preterm infants tire during nipple feeding, the increased difficulty in maintaining trunk stability and alignment is one of the clinical cues indicating the infant’s need for the nipple feeding effort to stop.

By “prepumping” or a mother’s pumping to express milk prior to any breast-feeding effort by her infant, that infant’s intake rate is limited during initial breast-feeding experiences (Dougherty & Luther, 2008). Rather than delivery of milk or

![Image of baby feeding in side lying with only a slight angle of elevation.](image1)

**FIGURE 3.** This infant is bottle-feeding in side lying with only a slight angle of elevation. With the bottle horizontal and the nipple only half filled with formula, she is able to control her suck–swallow–breathe pattern and coordinate a sustained grasp of her nurse’s thumb with only intermittently imposed pauses for rest.

![Image of baby feeding in side lying with >30° elevation.](image2)

**FIGURE 4.** This infant is bottle-feeding in side lying with >30° elevation. His NG tube has been removed to optimize his feeding experience. With the bottle horizontal and the nipple only half filled with formula, he is able to control his suck–swallow–breathe pattern at the beginning of this feeding with no chin or cheek support and only intermittent pauses for burping and rest.
formula from a standard bottle and nipple, there are other adaptive feeding devices therapists can use to limit fragile infant’s intake rate during their early feeding experiences. One method for limiting intake rate is the use of a syringe (usually 12 cc size) in a nipple to titrate small volumes of liquid into the nipple only after the infant successfully recovers from each suck–swallow–breathe cycle (see Figure 2). Haberman feeders (Medela trademark) are designed for infants with limited oral feeding capacity. They enable a caregiver to control the nipple’s flow rate by rotation of the feeder with or without other assistive measures. Use of a Supplemental Nutrition System (Medela trademark) allows a caregiver to attach a small feeding tube to their gloved finger or one of the mother’s nipples so that the infant can experience NS with a controlled intake rate (Palmer, 1993). The sensory input from a firm finger is different than that of a soft manufactured nipple and more similar to a mother’s nipple. The feeding intake rate can also be controlled by holding a bottle at a 90° angle to the infant’s mouth and allowing only small amounts of liquid in a nipple during active sucking. Multiple combinations of these measures are typically used by therapists and nurses to limit the feeding rate of preterm infants during their early oral feeding experiences (see Figures 3 and 4).

There is controversy regarding whether bottle-feeding during this period of early nipple feeding limits the success of transition to breast-feeding among preterm as well as full-term infants. “Cup drinking” or use of a soft spoon-like feeder is a method used by some nurses and therapists to avoid any bottle-feeding of preterm infants whose mothers wish to exclusively breast-feed. Among skilled caregivers, measures of physiological stability for preterm infants have been equivalent for nipple-bottle feeding compared with cup drinking (Marinelli, Burke, & Dodd, 2001; Mizuno & Kani, 2005). Investigating the effect of avoiding bottle-feeding among preterm infants, Collins, Makrides, Gillis, and McPhee (2008) identified four randomized controlled trials in which cup drinking was used. From the analysis of these studies, they concluded that there were significant compliance issues among parents using the cup drinking method and that no breast-feeding benefit was established following discharge. Infants successfully fed only by breast or the cup feeding method were more likely to be discharged fully breast-feeding, but their hospital stay was increased by an average of more than 1 week in order to accomplish this (Collins et al., 2008). Early, assisted bottle-feeding is still recognized as an appropriate care plan component for preterm infants whose mothers wish to eventually breast-feed exclusively (Dougherty & Luther, 2008). Decisions regarding the initiation, scheduling, and progression of initial breast-feeding experience as well as use of these adaptive feeding methods need to nurture parental input and review as the infant matures and their oral feeding capacity increases.

Prematurely born infants typically have either an orogastric (OG) or nasogastric (NG) gavage tube in place when they are introduced to nipple feeding. Although there are advantages and disadvantages to use of each route for gavage feeding, therapists need to observe individual infant’s responses during oral stimulation and initial nipple feedings to determine whether either OG or NG tubes negatively influence their oral responses or limit their nipple feeding capacity. Hawes, McEwan, and McGuire (2007) concluded that there was currently insufficient published evidence to direct clinical protocols regarding OG versus NG feeding tubes with general NICU application. Therapists need to be aware that NG tubes
can increase an infant’s work of breathing by direct obstruction of the nasal passage as well as facilitate nasal secretion accumulation. OG tubes can limit the seal an infant establishes with their lips around a nipple and therefore decrease sucking effectiveness. The presence of even an NG tube can decrease the duration of sucking bursts (Shioa & DiFiore, 1996). Movement of an OG tube during NNS or NS can result in swallow incoordination or an increase in apnea and bradycardia episodes (Hawes et al., 2007). The presence of an NG tube may not increase the number of desaturation events during oral feeding, but an increase in the duration of these episodes for an average of 8 min has been documented particularly among infants with <95% saturation levels prior to oral feeding efforts (Shioa et al., 1996). The presence of either an OG or an NG tube can increase the number and severity of GER episodes by splinting the lower esophageal sphincter (LES) open (Peter, Wiechers, Bohnhorst, Silny, & Poets, 2002). Some infants persistently presenting with these problems benefit from feeding with the gavage tube removed in combination with other assistive measures (see Figure 4).

**Differences Between Breast-Feeding and Bottle-Feeding**

Initial NS experience can occur at the breast or with a bottle. An understanding of the differences is needed by therapists to assist infants and mothers with either or both of these methods. Breast-feeding requires an infant to sustain a NNS with sufficient suction to initiate their mother’s “let down” response or MER. Once the milk flow begins, the infant needs to decrease their sucking rate by about half and switch to an NS pattern coordinated with swallowing and respiration cycles. The initial sucking pressure is typically higher for NNS than during actual breast-feeding with an NS pattern (Mizuno & Ueda, 2006). After milk flow has been established, the duration of sucking cycles is shorter and the frequency of sucking is typically higher among breast-feeding infants compared with bottle-feeding infants. This may be due to slower flow of breast milk than formula or milk from a standard nipple and bottle (Mizuno & Ueda, 2006). In contrast with breast-feeding, an infant immediately receives milk or formula when bottle-feeding unless the caregiver deliberately limits the flow rate. The duration of sucking cycles is longer and the frequency of sucking is lower among bottle-feeding infants in comparison with breast-feeding infants if caregivers impose no control measures. With high negative pressure during either NNS or NS, a mother’s nipple is elongated and compressed slightly. This usually provides a more consistent flow rate for a breast-feeding infant than is possible from a wide variety of manufactured nipples used for bottle-feeding. Manufactured nipples can collapse with negative pressure resulting in the infant unintentionally limiting or stopping the liquid flow rate. One of the main factors limiting breast-feeding success among preterm infants is their inability to sustain sufficient negative pressure to elicit the MER (Mizuno & Ueda, 2006). Clinically, another limiting factor among immature infants appears to be their inability to smoothly transition from NNS to NS and make adaptive changes in their swallow–breathe pattern as breast milk flow begins. Furman and Minich (2004) compared the total intake, rate of intake, and duration of sucking bursts of 35 breast-feeding infants with 70 bottle-feeding infants at 35 weeks PMA. The milk consumption of breast-feeding infants was determined indirectly by weight change registered on an electronic scale,
although the consumption of bottle-feeding infants was a direct measure of volume. They found no significant difference in the mean duration of feeding between the two groups of preterm infants (13.8 [4.8] min bottle-feeding, 13.3 [5.7] min breast-feeding). The median volume of intake among breast-feeding preterm infants however was 6.5 ml in comparison with 30.5 ml among bottle-feeding infants of the same PMA. The median intake rate among the breast-feeding infants was 0.6 ml/min in contrast with 2.2 ml/min among the bottle-feeding infants. The breast-feeding infants spent an average 33% of the feeding time engaged in sucking bursts, but the bottle-feeding preterm infants spent an average of 55% of their time so engaged (Furman & Minich, 2004). The significant difference in intake reported by these authors may in part reflect the different means of measurement, but it nevertheless supports the need for evidence of sustained weight gain prior to discharge of prematurely born infants fed by breast with or without supplemental bottle or cup feeding. Supplementing breast-feeding with cup feeding may prevent an immature infant from favoring the lower “workload” of bottle-feeding over breast-feeding and facilitate the infant’s practice of similar sucking patterns. Cup feeding, however, does not typically provide practice of either the complex suck–swallow–breathe coordination or strong suction needed for successful breast-feeding.

Before planning an infant’s initial breast-feeding experiences, the infant should demonstrate physiological stability and behavioral tolerance of oral stimulation during skin-to-skin care (SSC). This continues to be assessed in an ongoing manner by monitoring vital signs and behavioral cues in the context of caregiving. As previously stated, the NIDCAP, the PIPP, and/or the BIIP may still provide the best methods for observation and/or documentation for fragile infants. NO-MAS scores for NNS can be helpful in confirming breast-feeding readiness, but NS scores are more difficult to determine than with bottle-feeding. The Preterm Infant Breastfeeding Behavior Scale (PIBBS) however, has been developed to document oral–motor coordination and feeding capacity (Hedberg Nyqvist, Rubertsson, Ewald, & Sjoden, 1996). These scales are discussed in more detail by Byrne and Campbell (in press).

**Gradual Increase in Frequency, Volume, and Duration of Nipple Feeding**

(Figure 1)

During the period from 32 to 37 weeks PMA, preterm infants graduate from slowly taking less than 10 cc once or twice a day to feedings of 20–30 cc two to three times each day. During this period, infants continue to require the adaptations previously described to limit their intake rate, facilitate practice of their own suck–swallow–breathe pattern as well as assist their postural stability and alignment during nipple feedings. Initiation of these 2–3 daily nipple feedings should be timed to match each individual infant’s hunger and activity cycles. This usually means that these nipple feedings are seldom consecutive and that they are both preceded and followed by gavage feedings as well as periods of minimal stimulation to support energy conservation and growth. The infant’s fatigue and stress behaviors should determine the duration of the feeding effort more than the volume taken (Howe et al., 2007), McGrath & Braescu (2004), Ross & Browne (2002). Endurance building is one goal of early bottle-feeding, but opportunity to practice and adapt
maturing oral–motor control patterns is another primary goal that can be undermined by fatigue. Clinicians facilitating the transition from small volume, infrequent nipple feeding to functional nipple feeding for approximately half of the preterm infant’s daily intake need to consider the previously addressed characteristics of OG gavage in contrast with NG gavage feeding as well as the multiple nipples, bottles, and other means designed to assist preterm infant feeding. Consideration of the benefits and limitations of frequently used facilitation and support measures used to assist immature, weak sucking is also important.

**Characteristics of Nipples and Bottles**

As immature infants initiate NS, it is tempting to think that use of soft, rapid flow rate nipples will decrease energy expenditure and enhance the infant’s success. Although some preterm infants are able to increase their sucking and swallowing rate in response to high liquid flow rate, the resulting increase in liquid loss due to drooling limits the nutritional value of the feeding (Schrank, Al-Sayed, Beahm, & Thach, 1998). By decreasing the flow rate of liquid from a nipple, a preterm infant clinically seems to have more time to form a bolus and swallow resulting in better swallowing-respiratory control and less protective spilling or drooling. While multiple studies over the past decades (Chang, Lin, C.-P., Lin, Y.-J., & Lin, C.-H., 2007; Lau & Schanler, 2000; Schrank et al., 1998) have supported the benefit of diminished flow rate for infants with immature oral coordination, published research lacks consensus regarding a specific nipple that consistently delivers an optimal flow rate for infants with immature oral feeding capacity. The nipples currently available in nurseries are manufactured with different materials than those in common use and adapted for studies 15–20 years ago. One recent study (Chang et al., 2007) compares use of a cross-cut nipple designed for a high flow rate with a single-hole nipple designed for a slower flow rate while feeding preterm infants. The results confirmed that less efficient feeding and greater challenge to respiratory stability were associated with the high flow rate cross-cut nipple while more milk was consumed at a more efficient rate with less respiratory rate increase using the single-hole nipple. Commercially available soft nipples with a broad shape present challenges for infants with immature oral–motor coordination. Although recommended by some clinicians for primarily breast-feeding infants, clinical experience has shown that these nipples tend to encourage more licking than tongue cupping and limit negative pressure during sucking. This may be satisfactory for full-term infants, but most of the broad, soft nipples have a high flow rate and appear to present a similar challenge to preterm infants as the cross-cut nipples currently available in nurseries. Acknowledging that immature infants are more likely to need practice with the suction phase of sucking rather than the licking or suckling phase, nipples with a straight shape and single hole are recommended for preterm infants needing bottle-feeding as a supplement to breast-feeding (Dougherty & Luther, 2008). Using 3 different nipple types, Scheel, Schanler, and Lau concluded that more variation in sucking patterns was evident among 10 “healthy very low birth weight” infants taking 1–2 nipple feedings daily than among the same infants when they were more mature and able to take 6–8 nipple feedings daily at a later time (Scheel et al., 2005). This suggests that infants with oral–motor maturity and endurance sufficient for 6–8 nipple
feedings daily also have sufficient oral–motor control to sustain their most efficient feeding pattern regardless of the nipple characteristics. For infants with immature oral–motor control and limited endurance, their response to any nipple is likely to change during the course of a single feeding as well as during a 24-hr period. Within one feeding period, caregivers need to anticipate, identify, and respond to subtle changes in an infant’s suck–swallow–breathe coordination. A nipple from which an infant can efficiently draw milk or formula during the first half of a feeding, may present more challenge during the second half when chin support is needed to sustain efficient intake. Within the same feeding period, variation in sucking pattern can reflect fatigue and require variable levels of pacing assistance with the same nipple.

Another factor that influences infant’s milk intake rate is the hydrostatic pressure created by the volume of liquid present in a bottle. Liquid will flow from any nipple more rapidly if there is 60 cc of milk in the bottle in contrast with 30 cc in the bottle (Lau & Schanler, 2000). Feeding infants with a bottle that contains only small amounts of liquid is an intervention that diminishes the hydrostatic pressure created simply by the weight of the liquid above the level of the infant’s mouth. The use of angled bottles also decreases the role of hydrostatic pressure in liquid flow rate. Elimination of hydrostatic pressure can be accomplished by positioning a bottle and nipple horizontally at an infant’s mouth (see Figures 3 and 4). This intervention has been reported to allow immature infants to competently complete larger volume feedings more frequently during a 24-hr period (Lau & Schanler, 2000). Elimination of vacuum build-up within bottles is another factor that improves feeding. Immature infants lacking rhythmic suction–expression cycles in their sucking pattern can collapse the soft nipples intended to make their oral feeding easier. With the nipple collapsed, milk or formula flow is impeded if not eliminated (Lau & Schanler, 2000). Infants may tire while expressing minimal liquid and revert to NNS patterns. They become vulnerable to choking if the nipple opens suddenly due to altered suction pressure thus delivering milk for which the infant is unprepared. There are commercially available bottle systems that eliminate vacuum build-up as well as nipples molded with angled ridges on the internal surface that significantly decrease the chance of the nipple collapsing. Intermittent removal of the nipple from the infant’s mouth or pacing allows for adjustment of pressure equilibrium within a bottle as well as the other benefits of “pacing” previously described. Infants using these adaptations have also demonstrated need of them for only a brief period while gaining experience with autonomous, self-paced feeding (Lau & Schanler, 2000).

The temperature and viscosity of the breast milk or formula are other factors that affect the flow rate during feeding. As the temperature of a liquid increases, its thickness or viscosity typically decreases which results in a more rapid flow rate through a nipple. Mizuno, Ueda, and Takeuchi (2002) compared the effects of bottle-feeding distilled water, formula, and breast milk on suck–swallow–breathe coordination as well as respiratory rate and oxygen saturation levels. Among a group of 10 term infants recovering in an NICU from varying types of respiratory compromise, they maintained more mature coordination between swallowing and breathing cycles during bottle-feedings with expressed breast milk than with formula. Bottle-feeding formula, however resulted in better coordination than
bottle-feeding distilled water. Although the authors discuss the possible reasons for these differences and draw no conclusions regarding cause, their statement that expressed breast milk is the most appropriate liquid for initial nipple feeding may also apply to preterm infants having less mature swallow–breathe coordination. The findings with regard to formula and water also apply to preterm infants recovering from gastrointestinal problems who are limited to elemental formula diluted with distilled water for intake by mouth. The high flow rate of diluted formula increases the challenge of nipple feeding among these inexperienced, easily fatigued infants. One of the most common methods used to increase the viscosity of formula is addition of rice cereal. The role of formula thickening as treatment for GER problems as well as the capacity of an immature digestive system to tolerate cereal remains a point of debate (Vandenplas et al., 2009).

**Evidence Supporting Benefits of Intervention Measures to Assist Nipple Feeding**

From 32 to 37 weeks PMA, the measures that therapists teach to parents and use to assist infants gradually increase the frequency, volume, and duration of nipple feeding include not only pacing but also chin and cheek support to augment suck–swallow effectiveness and feeding effort persistence (Boiron et al., 2007; Einarsson-Backes, Deitz, Price, Glass, & Hayes, 1993; Hill, Kurkowski, & Garcia, 2000). Although research findings support the use of pacing as an intervention that is likely to result in more mature feeding patterns at discharge, this positive finding is typically not reflected in significantly shortened duration of infant’s nursery stay in comparison with control groups (Lau & Schanler, 2000; Law-Morstatt et al., 2003; Medoff-Cooper, 2005). Regardless of the intervention measures provided by skilled clinicians, the transition times to full-volume nipple feeding with parents and the time to discharge were not altered in a study by Law-Morstatt and colleagues (2003). Among other factors, this finding reflects the challenge of training parents to provide feeding intervention measures at an adequate skill level for earlier hospital discharge than is typical among neurologically immature infants with or without pacing assistance from their caregivers.

Beneficial effects of oral support measures have been reported among preterm infants (Boiron et al., 2007; Einarsson-Backes et al., 1993; Hill et al., 2000). Boiron and colleagues (2007) studied the effects of perioral and intraoral stimulation once daily prior to gavage feeding for 14 consecutive days among one of four groups of preterm infants (n = 11) not yet trying to nipple feed. They also studied the effect of oral support provision during two nonconsecutive nipple feedings daily among preterm infants (n = 12) until autonomous nipple feeding was established. These two groups, in addition to a third group (n = 9) receiving both oral stimulation and support were compared with a control group (n = 11). Sucking assessments documented enhanced coordination and forcefulness of NNS among the infants receiving oral stimulation but without the oral support measures there was no enhancement of NS characteristics or oral intake. The experience of oral support measures with or without oral stimulation for the duration of the study was associated with improved coordination of NNS, improved measures of feeding performance such as number of bottle-feedings attempted and amount of daily milk ingestion as well as decreased transition time to full nipple feeding. Boiron and colleagues
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(2007) included multiple techniques in their oral support intervention. In addition to sustained cheek support with two fingers of one hand and chin support or jaw stabilization with the other hand, the two intervention therapists provided pacing assistance. Because this is a more complex sensorimotor skill than isolated pacing assistance, the task of teaching this intervention to parents can be challenging. Clinically, this degree of support is often not needed by infants for the entire duration of a feeding. Skilled caregivers typically adapt the degree of support and pacing to the infant’s needs rather than follow a strict protocol. Infants with strong effective sucking at the beginning of a feeding can require pacing and oral support measures to finish the feeding once they tire. When confronted with high flow rate from a nipple, preterm infants adapt their sucking to primarily licking or expression phase sucking without suction. This adaptability is more evident as infants mature and gain endurance for feeding (Amaizu et al., 2008). Cheek support or efforts to maintain a tight lip seal, therefore, may increase the suction phase when the infant’s intention was to use only expression or licking phase sucking to better coordinate swallow–respiratory cycles. Caregiver efforts to encourage sucking by jiggling or rapidly rotating a bottle with the nipple in the infant’s mouth are usually not helpful to the infant. This intervention often interferes with an infant’s respiratory recovery periods, may introduce more liquid into the infant’s mouth than can be safely controlled, and may contribute to overstimulation of a tired infant (McGrath & Braescu, 2004; Ross & Browne, 2002). An exploratory study of oral support effects on PMA at time of autonomous nipple feeding or nursery discharge was reported by Bragelien et al. (2007). As part of a randomized controlled trial, they followed a group of 36 infants <36 weeks PMA without complicating medical conditions but judged to be making slower than typical progress with NS coordination until they were discharged from the nursery. All the infants received routine care that included encouragement to nipple feed. In order to prevent staff and family members from knowledge of the infants’ group assignments, all interventions occurred in a room separate from the nursery each day. The 18 infants in the intervention group at a mean PMA of 35.1 weeks received nipple feedings with cervical and thoracic spinal support by the caregiver’s hand as well as jaw stabilization each day. The 18 infants assigned at a mean PMA of 34.4 weeks to the nonintervention group spent a 15-min interval in the same room without any specific measures to assist nipple feeding or to otherwise provide stimulation. With this period of daily intervention, infants receiving the stimulation program failed to improve their rate of nipple feeding progress in comparison with the group receiving no oral stimulation or feeding assistance. The infants in both of the groups required approximately 2 weeks time and probably maturation to transition from NG to full PO feeding and 3 weeks until discharge. Within the authors’ discussion of their findings, they acknowledge the strength of the study’s design but draw attention to the weakness of small sample size in attempting to document benefit from an intervention of four days duration. Although this study paradigm reproduces the typical once per day treatment pattern of therapists working in an NICU setting, it does not reflect other factors they influence while modeling and teaching infant handling and feeding method adjustments to staff and family members. Beyond teaching caregivers the exact techniques for facilitation and pacing measures, these caregivers need to gain skill adapting to not only the infant’s feeding assistance
requirements but also their behavioral cues of stress or fatigue. Parental sensitivity to infant behavioral cues, the clarity of the infant’s cues, the duration and quality of social interaction as well as calming following distress are important factors to be addressed. The Nursing Child Assessment Feeding Scale (NCAFS), is a formal measure of this interaction that is helpful as infants gain competence completing several full-volume nipple feedings each day (Byrne & Campbell, in press; Hodges, Houck, & Kindermann, 2007).

**Progression to Autonomous Breast or Nipple Feeding (Figure 1)**

Competent infant nipple feeding skill and the ability to progress to autonomous nipple feeding emerges, as indicated on the NICU Care Path, between 35 and 40 weeks PMA as a result of maturation, experience, and endurance building. Analysis of 865 medical records from infants born at 32 weeks gestation or less determined that the median age for infants to receive their final gavage feeding was 34.6 [1.7] weeks PMA. Infants born at 26 weeks or less GA achieved this same milestone about two weeks later at an average of 36.2 weeks PMA with a range of 35.3–37.7 weeks. The diagnoses of either BPD or NEC increased the median age for final gavage feeding by 2–3 weeks with 25% unable to achieve the milestone by 38–40 weeks PMA (Bakewell-Sachs, Medoff-Cooper, Escobar, Silber, & Lorch, 2009). This reference information emphasizes the need for therapists treating infants born at extremely preterm GA with or without medical complications to have realistic goals and timelines for achievement of functional nipple feeding. Frequent and timely communication with neonatologists and neonatal nurse practitioners about an infant’s oral–motor maturation, endurance, and parental feeding skill needs to be added by therapists to the daily record of amounts of milk or formula intake by nipple versus gavage.

**Evidence Supporting the Benefits of a Gradual Transition from Gavage to Nipple Feeding**

There are numerous published protocols for progression of nipple feeding frequency. Although consensus with regard to the specifics of the progression is lacking, there is evidence that a relationship exists between the consistency and continuity of feeding management practices and improved feeding performance (Pickler et al., 2005). Infants fed following protocols for progression based upon previous success and adequate recovery time demonstrate that competent nipple feeding is developed more rapidly than among infants with inconsistent feeding progression plans (Simpson et al., 2002; McCain, Gartside, Greenberg, & Lott, 2001). A limited number of medical caregivers ideally need to make decisions regarding oral feeding progression with close communication among themselves and with parents. Decisions regarding how often to offer nipple feeding, when to offer breast- or bottle-feeding, and how long to spend on nipple feedings each require discussion and communication.

Simpson and colleagues (2002) present a protocol for orderly progression to full-volume nipple feedings with supportive evidence from a randomized controlled trial. According to this protocol, one nipple feeding is attempted per day until
the infant is able to complete one full-volume nipple feeding. After one feeding was completed, two were attempted nonconsecutively the following day. An additional nipple feeding was attempted each subsequent day until the full volumes were consumed without need for completion by gavage. No more than one additional feeding by nipple was attempted within a 24-hr period regardless of infants’ hunger-related oral behavior. The experimental group of preterm infants \( (n = 13) \) transitioning to full nipple feedings according to this protocol did so in 26.8[1.5] days at 34.5[1.6] weeks PMA in contrast with the 38.4[14] days at 36.0 [1.5] weeks PMA for the control group \( (n = 16) \) progressing at the discretion of the medical staff.

Following discharge home, many preterm infants are fed variable volumes based upon their hunger cues. Although the feeding volume offered in the nursery seldom exceeds 150 ml/kg/d, Lucas, King, and Bishop (1992) documented intake of up to 230 ml/kg/d among recently discharged infants with no volume limits imposed in their homes. Most preterm infants receive a prescribed volume of either formula or breast milk on a set schedule due to concerns for neurodevelopmental, metabolic, and gastrointestinal immaturity. This scheduled feeding is generally thought to guarantee adequate nutrition for appropriate growth among immature and/or medically compromised infants. A specific volume of milk or formula is typically divided among eight feedings during a 24-hr period and administered by various combinations of nipple and gavage feeding. In many nurseries, an infant’s feeding readiness cues guide neither the feeding time nor the volume offered. There are alternatives to this practice designed to be responsive to the infant’s emerging self-regulation, digestive system maturation, and feeding capacity that can be recommended and facilitated by therapists treating infants with limited progress toward functional nipple feeding. Among growing preterm infants without medical complications at 32–34 weeks PMA, cue-based introduction of gradually increasing frequency of oral feeding has facilitated the progression to autonomous oral feeding (Kirk et al., 2007). Following a “semidemand” feeding protocol, immature infants \( (n = 28) \) were provided an opportunity to initiate breast or bottle-feeding in response to hunger cues a few times each day. Usually at 3-hr intervals, infants were assessed and gavage fed if no hunger cues were evident. When caregivers noted hunger cues, a set volume of intake was offered by bottle and completed by gavage as needed. The number of nipple feedings offered by caregivers each 24 hr increased when the following criteria were met: >75% of feedings attempted were completed in <30 min for two consecutive days with acceptable weight gain. Kirk et al. (2007) report success following this gradually increasing semidemand progression with a 6-day decrease in average PMA when full oral feeding competence was achieved in comparison with PMA of the historic cohort control group \( (n = 23) \). A semidemand nipple feeding progression can be adapted for inclusion of breast-feeding experience. The estimation of intake can include the mother’s assessment of duration of active feeding and/or infant weight change pre- and postnursing. These patterns of feeding transition are appealing from a developmental standpoint, but a systematic review by McCormick, Tosh and McGuire (2010) concluded that the evidence is currently insufficient to support their general use. From their analysis of 7 randomized controlled trials, neither demand nor semidemand feeding protocols improved growth patterns, oral feeding skills, or led to earlier hospital discharge
at a statistically significant level. Although the evidence for these nonscheduled or semischeduled feeding practices is limited due to small sample sizes and other methodological issues, there is also no body of evidence supporting eight rigidly scheduled daily feedings as a superior plan for feeding progression.

**TRANSFER OF EVIDENCE INTO CLINICAL PRACTICE**

The challenge of implementing change in clinical practice is well known. Many creatively written and illustrated feeding progression guidelines have been neglected and forgotten in neonatal care settings in spite of cleverly presented in-service sessions following years of committee work. The process and lessons learned by one such group implementing “comprehensive evidence-based oral feeding guidelines” in a group of Canadian facilities is presented in an article by Lasby and Dressler-Mund (2011). The content of their “bedside reference poster” presented in the article provides a user-friendly summary of evidence-based practices as well as a strategy for promotion of guideline implementation in routine care.

In conclusion, all of the interventions described in this article may be initiated by occupational, physical, or speech and language therapists but are selectively taught to parents who gradually assume all aspects of their infant’s care. Parents benefit from frequent and consistent practice nipple feeding their infant by bottle, breast, or both. Information gathered by interviews following discharge supports both the need for specific feeding-related content in predischarge teaching as well as the need for extended parental caregiving opportunities (Reyna et al., 2006). The more consistent the information and guidance the family receives from nursery staff members, the more secure and competent the parents feel at time of discharge.

**Declaration of interest:** The authors report no conflicts of interest. The authors alone are responsible for the content and writing of this article.

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