Oral Feeding in Infants
Chantal Lau, PhD, and Nancy Hurst, RN, MS, IBCLC

The proper growth of the infant is primarily a function of adequate nutritional intake, which depends on whether the infant can feed safely and successfully. Extensive studies have focused on the benefits of mother’s milk and on the appropriate nutrients and growth-promoting factors that are needed in formula for optimal infant growth. Less attention has been placed on understanding how infants feed and, more important, how feeding can be carried out safely and successfully.

The oral feeding of infants is a rising concern. It is probably due to the growing population of infants who are born prematurely, as well as those who survive embryopathy or genetic pathologic disorders. The survival rate of premature infants has increased drastically during the last decade. For instance, the number of infants born between 23 and 25 weeks’ gestational age is increasing. Similarly, advances in the clinical management of infants with disorders such as bronchopulmonary dysplasia, cerebral palsy, and other neurologic impairments have increased the survival of these patients. Feeding difficulties develop in many of these infants.

Assessment of infant readiness to feed is not well developed. The proper coordination of sucking, swallowing and breathing is required for safe feeding. Impairment of any one of these functions can put the infant at risk for aspiration, pneumonia, oxygen desaturation, apnea, and bradycardia. Such an impairment is rarely an issue for healthy term infants who, because of their developmental level, begin oral feeding within hours of birth. For premature infants, oral feeding generally is not offered before 33 to 34 weeks’ postmenstrual age (pma), a time when their sucking pattern begins to resemble that of term infants. However, no concrete data are available to substantiate that this is the earliest time when oral feeding can be introduced.

This review examines certain characteristics of the infant’s ability to feed orally to provide an understanding of when the introduction of oral feeding is safe and how successful feeding can be achieved. Studying oral feeding in neonates who were fed with specially designed nipple/bottle systems was easier than studying breastfed neonates. Because breastfeeding obligatorily includes a maternal variable that is difficult to control, bottle feeding allows the focus to be placed primarily on the infant’s ability to suck. Although bottle feeding is different from breastfeeding in many psychologic and physiologic aspects, the oral-motor kinetics necessary to achieve sucking are believed to be similar. In the first part of the review, the mechanics of sucking during bottle feeding are discussed, with an emphasis on the development of sucking and the coordination of suck-swallow-breathe. The second part focuses on breastfeeding—how it differs from bottle feeding, and the reasons why it may be difficult. The last section discusses the clinical management of infants with sucking dysfunctions; this management includes a multidisciplinary approach that is offered by feeding disorders clinics and the interventions that may enhance the safety and success of oral feeding in infants.

Bottle Feeding

Bottle feeding is an alternative to breastfeeding when the latter is not available because of maternal death, improper maternal behavior, or lactation insufficiency. Bottle feeding has been used successfully to maintain the survival of various neonatal mammals. For human infants, bottle feeding has become a popular feeding alternative. A mother’s psychosocial issues, early return to employment, and lack of confidence in lactation abilities have been implicated in the increase in bottle feeding. This increase is one of the primary reasons why extensive research has focused on developing formula that best mimics mother’s milk.
Until recently, an understanding of the development of sucking was not critical because most surviving infants were born full term and were feeding soon after birth. Gaining such an understanding has become imperative because an increasing number of infants now survive premature births and cannot feed readily because of their immaturity or because of a dysfunction. When this understanding is achieved, caretakers will be able to identify the best time to introduce safe oral feeding and the best methods to use for optimal oral feeding success.

**Oral-Motor Kinetics**

Reviews and textbooks have justifiably stressed the complexity of sucking behavior. Efficient sucking relies on the proper integration and timing of the activity of the lips, cheeks, tongue, and palate in the formation of a bolus and its propulsion to the back of the oral cavity for swallowing. In addition, safe sucking relies on the coordinated activity of oropharyngeal muscles for the protection of the airway and the proper propulsion of the bolus into the esophagus. The sucking pattern of a full-term infant consists of the rhythmic alternation of suction and expression. Suction is the negative intraoral pressure exerted by the infant when milk is pulled into the mouth. Expression is the positive pressure that is believed to correspond to the stripping and/or compression of the nipple between the hard palate and the tongue.

**Methods.** To study sucking behavior, investigators have developed a variety of systems that indirectly monitor sucking. These devices fall into 3 categories, each of which has limitations of its own. For instance, in the first category, the number of sucks is measured by the number of pressure changes inside the nipple/bottle (Fig 1, a). This method does not allow for the distinction between suction and expression or for an accurate measure of the force exerted by the subject because the pressures monitored are dampened by the rigidity of the nipple that is used. Recently, this method has been adapted with a micro-video-camera placed inside the nipple, which permits the simultaneous observation of
Coarse structures: Burst Pause/Rest Burst

Fine structures: Amplitude Interval between sucks


the jaw and tongue movement while the sucking pressure is monitored.\(^{19,20}\) In the second method, sucking is monitored by means of a catheter inserted near the nipple hole (Fig 1, b).\(^{13,18}\) This allows for the accurate measurement of the frequency and amplitude of suction, but it does not measure expression. Figure 1, c is a schematic representation of the third type, which monitors both suction and expression.\(^{14,17}\)

**Nutritive Sucking.** In general, the outcome measures provided by the methods described above distinguish between coarse and fine structures of sucking.\(^{10}\) The coarse structures consist of the number and duration of sucking bursts and pauses. Bursts provide information on the time that the infant spends actively sucking. The pauses may be indicative of the level of fatigue that is experienced by the infant during a specific feeding session. Fine structures define the number of sucks, the interval of sucks, and the amplitude within a burst (Fig 2). Feeding performance is usually correlated with amplitude or the area under the curve.\(^{15,17,21}\) However, these methods are not representative of the milk transfer that occurs during normal bottle feeding because the nipple chamber is not filled with milk. With some systems, milk transfer occurs only during suction, when the milk from a reservoir is delivered by a catheter through to the nipple hole (Fig 1, b). With other systems, an additional predetermined volume of milk is delivered through a catheter during expression only when the pressure exerted is equal to or greater than a preset threshold (Fig 1, c). So far, researchers have been unable to correlate with accuracy the measures obtained from these methods with efficiency of feeding.

In response to this, we have recently devised a system in which the nipple chamber is filled as it is during normal bottle feeding, and we monitor the suction and expression components, swallowing, and breathing (Fig 3). Because milk transfer is recorded at the same time, assessment of feeding performance as a function of the infant’s sucking ability (eg, amplitude, frequency and/or area under the curve of suction and expression, and ratio of suction and expression per swallow) is possible. A sample tracing obtained from a term infant at age 15 days is shown in Fig 4. Details of this method have been described.\(^ {10}\)

Although neonates can increase their intake by altering different variables such as amplitude and/or frequency of suck and duration of sucking bursts, it is still unclear whether 1 or several parameters are preferentially altered. It is conceivable that particular parameters would be favored depending on the infant’s age and/or circumstances. Pollitt et al\(^ {22}\) have observed that 30-day-old infants were capable of ingesting the same volume of milk faster than their 2-day-old counterparts. They concluded that the improved efficiency resulted from several sucking components. However, they did not identify which parameters were implicated. Further studies will be required to determine whether coarse and fine structures, such as duration of bursts and amplitude of suck, are involved.

**Nonnutritive Sucking.** The nonnutritive sucking pattern that is observed in infants who are given a pacifier is similar to that of nutritive sucking (ie, a rhythmic alternation of suction and expression). Wolff\(^ {5}\) has characterized nonnutritive sucking as a series of brief periods of pauses and bursts that occur at 2 sucks per second. In contrast, sucking bursts that occur during nutritive sucking generally have a fre-
Suction
Time (sec)
Expression
Swallow
In.
Respiration
Ex.

FIG 4. Sample tracing of simultaneous recording of suction, expression, swallowing, and breathing obtained from term infant at 15 days of life. Ex, Expiration; In, inspiration; Sec, seconds.

Frequency of 1 suck per second. Infants can readily alternate between nonnutritive and nutritive suck. In addition, we have noted from our personal observation that the pattern of nonnutritive sucking is mature (ie, rhythmic alternation of suction and expression) long before that of a nutritive suck. Figure 5, a shows the nonnutritive sucking pattern of an infant (27 weeks’ gestational age) at 34 postnatal days. Figure 5, b is the nutritive pattern that is demonstrated by that same infant at 44 postnatal days when he was offered his first oral feeding. The more mature pattern that was observed during nonnutritive sucking might have occurred because the infant did not need to swallow as frequently as during a nutritive feed, a time when the coordination of suck-swallow-breath has not fully matured. Thus, the appearance of a mature nonnutritive sucking pattern is not an appropriate index of readiness to feed orally.

The physiologic function of nonnutritive sucking remains elusive. Its beneficial effects have been associated with reduction of stress, enhancement of growth, maturation, and gastrointestinal maturation, although the latter remains controversial. In addition, its use before nipple feeding has been suggested to enhance that feeding. Given that occupational therapists routinely use firm, deep-pressure tactile inputs as a technique to calm infants, there is a question whether the calming effect of a pacifier for many infants does not arise from similar deep tactile stimulation of the oral cavity.

Development of Sucking. Premature infants usually are not discharged from the hospital until full oral feeding has been achieved. Thus, a better understanding of the development of sucking could allow a more rapid progression of safe oralfeedings, thereby shortening the infants’ hospital stay to the benefit of both patient and family. In addition, an economic benefit would be gained. For the research subjects in our latest study, which was conducted between 1992 and 1995, the interval from first to full oral feeding averaged 14 days for infants born between 26 and 29 weeks’ gestation.

Despite the numerous studies that have reported on sucking mechanics, a clear understanding of sucking development has not been achieved. This is likely the result of the limitations of the various methods. The electromyographic studies of Tamura et al, which were conducted in conjunction with the simultaneous video recording of the jaw and tongue movement during nutritive feeding, demonstrated the tight coordination between activation of the perioral muscles and the generation of sucking pressure. Their observations illustrate the complexity of sucking behavior and, particularly, the difficulty of efficient and safe oral feeding when appropriate maturation processes have not been achieved. In a recent study of infants born between 26 and 29 weeks’ gestational age, we demonstrated that safe and successful oral feeding can be achieved by infants who used a premature sucking pattern that consisted only of the expression component with no suction. Figure 6 shows sample tracings of the progression of the sucking development of an infant who was born at 29 weeks’ gestational age as he advanced in his oral feedings. At his first oral feeding at 59 postnatal days (37.4 weeks’ pma), sucking consisted primarily of the expression component with some tentative suction (Fig 6, a). At 66 postnatal days (38.4 weeks’ pma), when the infant took 4 oral feed-
ings per day, suction became stronger but was not as well defined as the expression component (Fig 6, b). At 77 postnatal days (40 weeks pma), when he reached full oral feeding, the infant demonstrated a term-like pattern of sucking with a rhythmic alternation of suction and expression (Fig 6, c). From these observations, one may see that the alternation of suction and expression was not necessary for oral feeding success because this infant completed his feedings safely within the allotted time (20 minutes). Therefore, it is proposed that premature infants do not need to wait until their sucking pattern resembles that of term infants before oral feeding is introduced. Remember that during bottle feeding, the nipple chamber is always filled with milk and simple compression may be sufficient to eject milk. This is in contrast to breastfeeding (see below), which necessitates the alternation of suction and expression. It is believed that suction draws milk from the alveoli into the mammary ducts and sinuses and that expression ejects milk into the infant's mouth by stripping the nipple. It has been suggested that the expression component, in addition to corresponding to the stripping of the nipple, may be an artifact from the lip squeezing or "munching" during bottle feeding, as described by some occupational therapists, or from repositioning the nipple with the tongue as the infant tries to obtain a better seal for suction.21

Coordination of Suck-Swallow-Breathe

If efficient sucking plays a major role in the determination of oral feeding success, the proper coordination of suck-swallow-breathe is essential for safe oral feeding. A level of maturity met by most healthy full-term neonates is required for safe oral feeding. However, it is not known when the functional maturation of the sucking, swallowing, and respiratory centers, which
are necessary for this integrative process to occur, appears in premature infants. Sucking has been observed in utero as early as 15 to 18 weeks’ gestational age and swallowing as early as 12 to 13 weeks’ gestational age. 9,32,33 Although the coordination of suck-swallow-breathe does not need to mature in utero, it is unknown whether prematurity can force the maturational process of these systems out of necessity.

Swallowing. Safe swallowing, like efficient sucking, requires the integration and proper timing of oropharyngeal structures, such as the tongue, soft palate, pharynx, larynx, and esophagus. 9,34 It has been proposed that the coordination of the pharyngeal musculature for proper swallowing requires the activation of the medullary swallowing center, a central pattern generator, in the brainstem. 9,35,36 This center, receiving inputs from the cerebral cortex and peripheral musculature, can induce voluntary and involuntary swallowing. During infant feeding, stimulation of the swallowing center is believed to require an external input, such as the formation of a bolus, unlike the sucking center, which may not need an external stimulus for activation. 37 This is supported by the notion that nonnutritive sucking does not generate as much frequent swallowing as nutritive sucking does. Closure of the trachea at the level of the epiglottis, aryepiglottis, and true and false vocal cords must occur when the bolus enters the pharyngeal cavity and the upper esophageal sphincter relaxes to allow passage of the bolus into the esophagus to prevent aspiration. 9,38,39 The swallowing process possesses a certain degree of plasticity: during a feeding, as the size and/or texture of the boluses constantly vary as well as the head and neck postures, maintenance of a safe swallow necessitates a constant adaptation of the pharyngeal musculature. 40 As discussed by Wolf & Glass, 9 aspiration may arise before, during, or after a swallow. If the bolus is not properly formed when liquid enters the pharynx, the swallowing reflex may not be triggered and proper closure of the trachea may not occur, thereby increasing the risk for aspiration. During swallowing, improper closure of the larynx may similarly lead to liquid penetration in the airway. When the larynx reopens after a swallow, residual liquids in the valvelae and pyriform recesses may lead to laryngeal penetration. It has also been suggested that inefficient and infrequent swallowing leads to drooling, a common observation in children with cerebral palsy. 41 Hamdy et al 42 have investigated the cortical topography of oral, pharyngeal, and esophageal musculature in healthy subjects and stroke patients. They observed discrete and asymmetric representation of the swallowing musculature in the motor and premotor cortex of both hemispheres. Their observation of a smaller pharyngeal representation on the intact hemisphere of a patient who had a stroke and dysphagia was of great interest. However, that representation increased in size as recovery of swallowing occurred. It is tempting to propose that cortical stimulation may be developed as an intervention to correct impaired swallowing.

Respiration. The respiratory rate in infants is between 40 and 60 breaths per minute or 1.0 to 1.5 second per cycle of inspiration and expiration. Because the interruption of airflow during a swallow is between 0.35 and 0.7 seconds, impairment may ensue if the frequency of swallows increases or tachypnea (>60 breaths per minute) occurs. 43 In theory, swallowing would be safest if it occurred during the expiratory phase or during a breathing pause, when no air flows into the lungs. This is substantiated by studies in adults and infants. 33,44,45,46 Swallowing can occur during all phases of respiration, although most swallowing takes place during expiration. 33,44,47 McFarland et al 47 have suggested that the coordination of respiration and swallowing is dependent on posture. They demonstrated that adult human subjects swallowed predominantly during late expiration when feeding in the upright position and during early expiration when feeding on their hands and knees. They speculated that these differences in timing resulted from the changes in the mechanical properties of the upper body.

Integration. There have been numerous studies that have reported on the coordination of suck-swallow-breathe. 18,41,47,48-51 The sucking and swallowing centers have not yet been identified anatomically. Because the musculature that is implicated in sucking, swallowing, and breathing is innervated by branches of cranial nerves V, VII, IX, X, and XII, the existence of a “central rhythm/pattern generator” (CRG) that coordinates these functions has been advanced (Fig 7). It is proposed that the CRG is located in the vicinity of the respiratory center in the region of the nucleus tractus solitarius and nucleus ambiguus. 9,36 This concept is similar to the central pattern generator postulated as the control of respiration and swallowing that was mentioned earlier. 52 The sucking and respiratory center can function independently from each other during nonnutritive sucking because infants rarely encounter apneic periods while sucking on a pacifier. Peiper 53 has postulated that the rhythmicity of the respiratory center is entrained by the sucking center during nutritive sucking as swallowing
frequency increases. As such, suck-swallow-breathe will be coordinated as long as the overriding effect of sucking does not jeopardize oxygen and/or carbon dioxide exchange. This is supported by the observation that the feeding performance of certain infants is improved when they receive oxygen supplementation during oral feeding. In a study conducted on infants born prematurely at 28 ± 1 weeks and monitored at 34 ± 2 weeks’ pma, Timms et al. demonstrated that hypercapnia induced with 40% O_2 and 7% CO_2 increased ventilatory drive while suppressing sucking and swallowing frequency.

The ratio of 1:1:1 or 2:2:1 for suck-swallow-breathe is usually not attained until 48 hours after birth in term infants, despite their maturity. This transient incoordination is usually inconsequential in contrast to the prolonged feeding difficulties encountered by some premature infants. The necessary synergism may mature at different times or not at all, leading to feeding disorders. In general, when coordination cannot be maintained because the milk flow is too fast, infants can stop milk flow during respiratory catch-up by blocking the teat/nipple with the tongue. If proper oxygenation cannot be maintained during sucking, infants can protect their airway by alternating periods of sucking bursts when no breathing occurs and sucking pauses with rapid breathing (Figs 6 b, c).

Breastfeeding

Breastfeeding has been recommended by the American Academy of Pediatrics on the basis of its benefits to the infant and mother. Because this process involves a dynamic interaction between the nursing dyad (unlike bottle feeding), the maternal component becomes a dominant factor in the infant’s success at feeding. The emphasis placed on breastfeeding during recent years arises from increasing evidence that the growth-promoting and protective benefits of mother’s milk cannot be replicated with formulas and from the realization that breastfeeding offers nonnutritional benefits, such as strengthening of the bond between mother and infant. Therefore, this section focuses on better understanding the maternal attributes that may contribute to the success of breastfeeding, breastfeeding techniques, and the oral-motor kinetic differences between bottle feeding and breastfeeding.

Maternal Contribution

Maternal contribution includes not only lactation (milk synthesis and ejection) to meet the nutritional needs of the infant but also maternal motivation (eg, readiness, willingness to breastfeed). Because the physiologic process of normal lactation has been addressed in other works, this review focuses on maternal factors that may hamper normal lactation or breastfeeding. Milk synthesis/release and/or its transfer to the infant may be hampered anatomically, hormonally, and/or mechanically. In addition, breastfeeding techniques may also contribute to lactation outcome. Factors that may affect maternal interest in breastfeeding include the mother’s knowledge of breastfeeding; motivation, attitude, and personal health; her infant’s behavior and health; psychologic factors such as stress; and the mother’s perception of her social environment (support from family, friends, and health care professionals).

Lactation. Normal lactation may be hampered at the level of the mammary glandular development, by quality and quantity of breast stimulation, and by degree of breast emptying.

Maternal Factors. During breastfeeding, maternal factors such as nipple shape and degree of elasticity and protractility may interfere with performance. Although size and shape of the nipple (Fig 8, a) are of secondary importance to the function of the nipple during areolar compression (Fig 8, b), they can play a determining role in the ability of the infant to latch on successfully. Latching onto the nipple-areola complex
may be difficult if the nipple retracts or is drawn inward within the folds of the areola when it is compressed. A pedunculated nipple may be several centimeters wide on a stalk and too large for the infant. Latch on does not necessarily imply successful breastfeeding because poor breast emptying may still occur if compression of the lactiferous sinuses does not occur. The importance of the size, shape, and protrac-
tility of the nipple-areola complex to the success of infant sucking is uncertain because no studies reporting on these specific variables have been published. Anecdotal reports are numerous on the difficulties that can result from nipple anomalies that prevent proper attachment to the breast and compression of the under-
lying lactiferous sinuses. Ultrasonographic imaging studies have demonstrated the high elasticity of the maternal nipple during breastfeeding of 60- to 120-
day-old infants.63 During the early postpartum period, lactation specialists and breastfeeding mothers have reported that there are varying degrees of elasticity of the nipple-areola complex. It is unclear whether the ability of the nipple to extend deep within the oral cavity is critical in the establishment of breastfeeding in the early days after delivery.

Development of mammary glandular tissue during adolescence and pregnancy is predictive of lactation sufficiency.64 We have observed lactation insufficiency in women with a history of anorexia nervosa that began during adolescence (a critical period of breast development) who report few changes in breast size and/or in degree of breast fullness during pregnancy and the early postpartum period. However, others have reported successful breastfeeding by women in whom anorexia nervosa was formerly diagnosed.65,66

Because milk ejection is a neural reflex, integrity of the neural afferents from the mammary receptors to the central nervous system need to be preserved.67-70 A significantly higher incidence of insufficient lactation is observed in women who have had breast augmentation surgery in which a periareolar incision was used.71,72 Breast reduction surgery will most certainly reduce the amount of functional glandular tissue. However, lactation has been preserved when the surgical procedure used avoided disruption of the tissue lying just below the nipple-areola complex.72,73

**Breast Emptying.** Because the infant determines the frequency of feedings and the volume of milk withdrawn from the breast, some form of feedback control is required to regulate the production of milk to match the intake of the infant.74 There are 2 principal infant-
mediated factors by which an infant’s demand for milk could be assessed by the mammary gland: the fre-
quency of breastfeedings and the amount of milk emp-
tied at each feeding. However, studies have been inconclusive on establishing the relative importance of these 2 factors in the determination of milk production. For instance, early investigations provided evidence that during the first few weeks after delivery, milk production is positively related to feeding fre-
quency.75-77 However, this is uncertain for established lactation.78,79 More recently, Daly et al80 investigated the effect on the rate of milk synthesis as a function of frequency and degree of breast emptying induced by mechanical breast pumping or breastfeeding. The rela-
tionship between milk that was produced at a pumping and the time interval between pumping and breastfeeding showed that less milk is produced after intervals greater than 6 to 18 hours. Changes in the rate of milk synthesis were not directly associated with the frequency of breastfeedings but with the degree of breast emptying. Daly et al concluded that the degree rather than the frequency of breast emptying is of primary importance in the short-term control of human milk synthesis. This supports the existence in milk of a feedback inhibitor of lactation. Indeed, recent studies have demonstrated the presence of a new protein in animal and human milk that inhibits milk secretion without affecting milk composition. The higher the protein’s concentration in milk (eg, during partial breast emptying), the greater its inhibitory effect on milk synthesis. This protein is believed to act at an autocrine level through a specific cell-surface receptor to be identified.

Another important aspect of breast emptying is the change in milk composition that occurs during feeding. Although the protein and lactose concentrations in human milk remain fairly constant during a feeding, the fat concentration increases. Woolridge and Fisher proposed that breast emptying would be more advantageous than increased frequency of breastfeeding for a breastfed infant who is failing to thrive, despite adequate milk supply. They speculated that when infants are given a limited time at the first breast to encourage intake from the second breast, they may not empty the first breast adequately, thereby missing the higher fat that is present in hindmilk. As a result, full-term infants may have poor weight gain, colicky behavior, and watery green stools. In our practice, mothers are encouraged to complete emptying of the first breast before switching to the second breast to maximize hindmilk intake. A mother’s milk production may exceed the intake of some premature infants. For them, mothers are advised to express some milk before breastfeeding. This strategy enhances fat intake and, thus, weight gain.

Breastfeeding Techniques. The importance of proper positioning of mother and infant during breastfeeding should be stressed. There are basically 2 different positions that are used for breastfeeding: cradle and clutch holds. The cradle hold is the classic hold in which the infant is cradled in the mother’s arm with the head at the mother’s elbow. Placing the infant’s head in the mother’s hand is the clutch hold. The infant’s body can rest across the mother’s chest or be tucked underneath her arm (Fig 9, a, b). The clutch hold is effective in situations where the infant needs additional guidance to attach to the breast (eg, prematurity, sleepy infant). The breast is supported in the mother’s hand with her fingers positioned behind the areola; this allows the infant access to the lactiferous sinuses just below the base of the nipple. Regardless of the position used, the alignment of the infant’s head, neck, and torso is a crucial component because the infant’s neck needs to be slightly extended to allow full jaw excursion.

Maternal Attitude Toward Breastfeeding. In addition to nutritional need, psychosocial support is necessary for the promotion of growth and development of infants. This begins at birth when mother-infant interaction helps establish the type of relationship that infants will develop with their environment. In return, mothers experience significant behavioral changes. Multiple factors such as infant’s or mother’s personality traits and external variables determine whether the relationship will benefit both partners of the dyad.

For the parent, a caring attitude and recognition of the infant’s needs become positive factors in promoting the physical and psychologic development of the infant. Breastfeeding provides a situation in which such interaction is optimized. The infant’s suckling or mere touching of the mother’s areolar region during the first 1 to 2 hours after birth seems to make the mother more attentive to the needs of the baby, at least during the first week of life. These daily interactions, which are obligatory to meet the nutritional need of the infant, naturally provide increased opportunities for mother-infant bonding. The tactile, olfactory, and visual stimulation that benefits the infant as well as the sensory, physiologic, and psychologic stimuli experienced by the mother during breastfeeding do not seem to be reproduced to the same extent with bottle feeding. Thus, the nonnutritional benefits to the infant that are offered by breastfeeding are a function of maternal attitude toward this task. This can be influenced positively by factors such as education, positive mental attitude, and good health of mother and infant. On the other hand, reluctance to breastfeed may arise, for instance, as a result of inconvenience or the mother’s perceived lack of social support. In a recent study, women with extreme preoccupation with body shape and with reduced child-centered attitudes (ie, those who were more concerned about routine and more “controlling”) were less likely to express intention to breastfeed.

Stress. Maintenance of lactation is more difficult for mothers under stress. However, unlike animal studies, no human studies have yet demonstrated a
correlation between maternal stress indices and lactation performance. Reports that observed improved lactation after certain interventions have implied but not proved that maternal stress was decreased. The mechanism(s) by which this suppression occurs is unclear. Depending on the type and duration of the stressor, it is conceivable that lactation may be hampered at the level of milk synthesis and/or ejection. Research in this area will permit a better understanding of the mechanism(s) by which stress interferes with lactation, and interventions can be devised to alleviate maternal stress response to safeguard lactation.

Infant’s Contribution

Infant sucking is a key component of effective breastfeeding for 2 reasons. First, it is necessary for lactation and the proper initiation of milk ejection. Second, it provides the mechanical basis for milk transfer from the breast to the infant, as it does with bottle feeding.

Oral-Motor Kinetics

In oral motor mechanics, breastfeeding is a more active process than bottle feeding. In contrast, the infant must grasp the nipple and areolar tissue, maintain attachment, and compress and squeeze the underlying lactiferous sinuses between the tongue and hard palate. The bottle nipple may be placed between the infant’s lips and over the tongue and be manipulated by the caregiver against the hard palate to stimulate sucking. As stated previously, most investigations of infant oral-motor mechanics have been performed with specially designed nipple-bottle systems. However, with the advent of real-time ultrasonographic techniques, it has become possible to monitor intraoral events during breastfeeding.

Methods. Early descriptions of the intraoral movements of the infant’s mouth during breastfeeding were obtained by using x-ray imaging. The risk of irradiation has led to the development of other techniques. Ultrasonographic imaging has emerged as a safe and noninvasive means of evaluating specific oral-motor mechanics. These techniques can provide dynamic images that can be stored on videotape for review and measurement. They are descriptive in nature because pressures exerted by compression and suction of the nipple-areola complex cannot be quantified.

Systematic studies of sucking pressures during breastfeeding have been difficult. This is likely due to the interference of the pressure recording device with the infant’s latching on to the breast. Several investigators have attempted to measure sucking pressures during actual breastfeeding with a small tubing taped over the mother’s breast with the tip at the level of the nipple. This system is similar to that described in Fig 1, b. Just as with bottle feeding, this technique does not measure expression. Its use with older infants (age 6 months) is inadequate because distraction caused by the tubing leads to disrupted breastfeeding behavior. In addition, because no technology has been developed to simultaneously monitor milk transfer, it has not been possible to correlate oral-motor components with sucking efficiency.

Methods of measuring milk intake during breastfeeding have ranged from estimates of duration of feeding and maternal feelings of breast fullness to more accurate measures by test-weighing procedures. Correlation between swallow counts and test weighing has also been
TABLE 1. Function of oral motor structure

<table>
<thead>
<tr>
<th>Structure</th>
<th>During breastfeeding</th>
<th>During bottle feeding</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lips and cheeks</td>
<td>Help to locate nipple and bring into mouth</td>
<td>Not necessary because nipple is placed in infant’s mouth</td>
</tr>
<tr>
<td></td>
<td>Lips and cheeks provide stability</td>
<td>Same</td>
</tr>
<tr>
<td></td>
<td>Lips assist in forming seal</td>
<td></td>
</tr>
<tr>
<td>Tongue</td>
<td>Active in bringing nipple into mouth, shaping a and stabilizing its position</td>
<td>Not needed to draw nipple into mouth</td>
</tr>
<tr>
<td>Jaw</td>
<td>Downward movement during sucking expands size of oral cavity to create negative pressure</td>
<td>Does not require as great a jaw excursion</td>
</tr>
<tr>
<td>Palate</td>
<td>Assists with positioning and stability of nipple and works with tongue to compress nipple</td>
<td>Same</td>
</tr>
<tr>
<td></td>
<td>Soft palate elevates during swallow to pass bolus and occlude nasal cavity</td>
<td>Same</td>
</tr>
</tbody>
</table>

used. Test weighing is a method in which the clothed infant is weighed before and after breastfeeding under identical conditions (no clothing or diaper changes between weights). As the density of milk approximates that of water, the weight gain after a feeding (in grams) is equivalent to the volume of milk consumed (in milliliters). It is important to stress that accurate test weighing can be obtained only when electronic scales are used to perform the prefeed and postfeed weighing.

Nutritive Sucking. Efficient sucking at the breast relies on the proper integration and timing of the activity of the lips, cheeks, tongue, and palate in the formation of a bolus and its propulsion to the back of the oral cavity for swallowing. However, there are distinct differences between bottle feeding and breastfeeding (Table 1). The maternal nipple provides tactile stimulation to the infant’s lips and cheek eliciting the “search and locate” response of the rooting reflex. Recent videotape recordings of newborn infants documenting the position of the tongue in the mouth during rooting reflexes before the first suckle revealed that 10 of 11 infants studied placed their tongue in the bottom of the mouth. In this position, the tongue extends over the lower gum line, allowing attachment and drawing in the nipple and much of the areola. This tongue placement is essential to ensure adequate stripping of the lactiferous sinuses that are located behind the base of the nipple. There is controversy about the movement of the tongue once attachment is achieved. Although some describe a peristaltic movement of the tongue, others have observed an up-and-down piston-like movement of the mandible, tongue, and hyoid that is similar to that used with bottle feeding. The earlier study by Ardran et al suggested that the infant obtained milk from the breast mainly by compression rather than suction. Subsequently, ultrasonographic studies documented the profound compression of the nipple-areola complex by the infant’s tongue against the hard and soft palate.

Clinical Management of Infants With Feeding Difficulties and Disorders

The feeding difficulties encountered by some infants may arise from inexperience on the part of mother and/or infant or may be due to a more severe feeding disorder. Early maternal and infant teaching by an experienced nurse, lactation consultant, or feeding therapist often suffices in correcting for inexperience. More severe disorders need to be identified, and treatment plans need to be developed. During the last few years, the use of a multidisciplinary feeding team for the care of these patients has grown in popularity for the reasons discussed below.

A feeding disorder is not a disease in itself but rather a condition that ensues from an underlying abnormality and/or behavior that is manifested in patients with a wide variety of medical diagnoses. Its occurrence may be the cause or result of the patient’s medical conditions and should be treated as a component of the pathologic process. Feeding disorders may arise at any or several levels of the suck-swallow-breathe process. The underlying disturbance may be anatomic, mechanical, neurologic, and/or behavioral. Feeding is closely linked with learned social interaction, which becomes an important behavioral component that affects the patient with feeding difficulty. In infants and children, these impairments are of greater significance than in adults because the normal learning process of feeding occurs during childhood. Two factors that play determining roles in such development are the child’s mental capabilities and communication skills and the parents’ attitudes toward the child.
feeding disorders can lead to failure to thrive as well as become a handicap that interferes with the patient's social, mental, and physical capabilities.101,102

As many as 25% of infants and children are affected with feeding disorders at some time, and 1% to 2% of these children suffer from severe and prolonged complications.104,105 Although a feeding disorder is not a disease per se, its prevalence and incidence have not been as systematically determined as that of other chronic disorders. The epidemiologic factors of feeding disorder have been monitored more as a function of specific disabilities such as stroke or Parkinson's disease (in adults) or cerebral palsy, cleft palate, AIDS, spina bifida, esophageal atresia, hypotonia, prenatal and postnatal brain injury, hydrocephalus, and mental retardation (in children). For instance, 40% of children with cerebral palsy have feeding disorders.105 Cleft lip and palate occur in approximately 1 in 700 to 800 neonates. Most infants are affected with varying degrees of feeding difficulties.101 Fourteen percent of children with AIDS have significant feeding problems.106 Neurologic dysphagia that results from compression of the brain stem and lower cranial nerves (IX-XII) can occur in patients with spina bifida. The incidence rate is approximately 1 case per 1000 live births.101 For the last few years, awareness of feeding disorders has increased. Kuhlemeier107 noted a modest but steady increase in scientific reports on dysphagia published from 1976 through 1992. Whether such increase reflects a true increase in incidence of feeding disorders or an increase in reported cases remains undetermined.

**Feeding Team**

Given the variety of causes that can lead to feeding disorders, management can be enhanced by an interdisciplinary approach. A few centers have developed such multidisciplinary feeding teams whose members generally come from such fields as nursing, nutrition, occupational therapy, speech therapy, pediatric gastroenterology, psychology, and lactation counseling. Consultation with practitioners in neurology, pediatric surgery, developmental pediatrics, diagnostic imaging, or physical therapy may be ordered depending on individual patients.

A typical sequence of events for the diagnosis and clinical management of a patient might be:

1. Before the patient's visit, a complete medical history is taken by the nurse coordinator with an emphasis on history of feeding dysfunction, related surgeries, and former treatment plans, if any. Triage of the patient is made by the nurse coordinator who notifies the various members of the feeding team who need to see the patient at the first visit.
2. If necessary, nutritional evaluation is conducted by the dietitian and dietary corrections are made.
3. Feeding evaluation is performed by the occupational or speech therapist who evaluates the nonnutritive and nutritive oral-motor aptitudes of the patient.
4. If abnormal swallowing is suspected, a videofluorography (see later) is performed with the interpretation of the test normally conducted by the speech therapist.
5. If a gastrointestinal disorder is suspected, the pediatric gastroenterologist is consulted.
6. If behavioral concerns need to be addressed for parents or infant, the clinical psychologist is consulted.
7. Finally, a meeting of the team members is conducted to discuss their respective observations. Areas of concern that need to be addressed are prioritized, and a treatment recommendation is made. Coordination of the feeding team is most efficiently carried out by a nurse coordinator who becomes the primary contact between the patient and the primary or referring physician.
8. Follow-up and reassessment of therapeutic program are necessary to verify efficacy of the treatment plan.

In the treatment of feeding disorders, the continuous involvement of the primary care physician and the patient's family are of primary importance. This is especially the case with the current emphasis on managed care. In general, a feeding disorder cannot be corrected rapidly, thereby necessitating sustained interventions over time. Education of patients and their families is necessary to enhance family participation. Proper training in appropriate feeding skills, therapeutic interventions that the primary caretaker can provide at home, and the importance of compliance to these therapies and to any medication are particularly important.

**Treatment Interventions**

**Bottle Feeding.** Difficulty in bottle feeding may lie at any level of the infant's ability to suck, swallow, and/or breathe. Interventions have been developed for each of these areas. They may be used individually or in combination and can be readily taught to the primary caretaker.

*For the Improvement of Sucking.* An infant may have difficulty sucking because the flow of milk is too rapid.
Thickening the liquid can slow down flow as well as allow more time for the formation of the bolus. Another means is the use of a self-paced flow (ie, one in which milk only flows when the infant is actively sucking). Caretakers frequently comment that milk flow is too fast because of the size of the nipple hole. In a recent study of infants who were born at 26 to 29 weeks’ gestational age, we assessed the potential benefit of a self-paced flow. The infants were fed with a system in which the milk level from an open reservoir that connected directly to the nipple chamber was continuously adjusted to the level of the infant’s mouth (Fig 3). This allowed milk to be transferred only when the infant was actively sucking. Compared with the routine feeding protocol, this experimental setup enhanced feeding performance when infants were first introduced to oral feeding. Overall transfer and efficiency were increased. Overall transfer defines the percentage of volume that transferred during a feeding/volume ordered for that feeding. Efficiency is the volume transferred per unit time (milliliter/minute). It is suggested that this method of milk delivery facilitated oral feeding because it allowed the infant to rest and catch up with breathing during a pause when no milk was flowing.

Therapies have been developed to maintain safety and enhance efficiency of feeding. If the oral-motor control is inadequate and, in particular, the suck is “weak” or “disorganized,” specific interventions can be introduced. For instance, a combination of cheek and jaw support is used to facilitate a stronger sucking pattern, control excessive jaw movement, and improve lip seal and cheek stability. The lack of visualization of the sucking process has impeded feeding therapists from determining the actual efficacy of a particular therapy (ie, how the sucking pattern changes in the presence or absence of that specific intervention). As a result, outcome has been measured only by how much faster the patient has taken the feeding. With the monitoring system described earlier (Fig 3), it is now possible to determine whether specific interventions can correct the deficiencies for which they are intended, and more efficient treatment programs may be developed. For instance, Fig 10 shows the sample tracing of an infant (28 weeks’ gestational age) who at 56 days of life was receiving 1 oral feeding per day. With no intervention, the infant used only the expression component rather than alternation of suction and expression. When support was provided with jaw only or cheek and jaw, the infant was able to generate suction. When only cheek support was used, more frequent suction with greater amplitude was observed. The same interventions do not necessarily lead to the same results in all infants because different underlying causes affect individual infants. The use of the above method during the clinical evaluation process may help in devising efficacious individualized treatment programs, so that only interventions that improve the sucking pattern would be included.

For the Improvement of Swallowing. An adequate swallow reflex integrates the timing of a number of structures that are controlled at different levels of the central nervous system. Swallowing dysfunctions may occur readily from impairments at any of these levels. The current approach used by therapists is to intervene at the peripheral level. For example, a delayed swallow may put the infant at risk of aspiration. Because the swallow has not yet been triggered, the airway is still open and the bolus entering the pharynx may spill into the trachea. Thermal stimulation with cold formula or food has been of some use to accelerate the swallowing reflex, albeit transient. At times, improving the formation of a succinct bolus by thickening the liquid or facilitating bolus formation has also been beneficial. In addition, the texture of the bolus may trigger the swallowing reflex as a result of increased tactile stimulation.

A number of imaging techniques have been developed to characterize swallowing dysfunctions. Currently, videofluorography is the “gold standard.” Watkins and Miller recently presented a detailed review of these procedures. These investigators developed a new 3-dimensional ultrasonographic imaging technique that allows real-time assessment and visualization of the structural anatomy of the oropharynx during swallowing. Although still in the developmental phase, this technique holds great promise in providing more precise characterization of swallowing dysfunction.

For the Improvement of Suck-Swallow-Breathe Coordination. In addition to sucking and swallowing difficulties, incoordination of suck, swallow, and respiration can also lead to feeding disorders. Although the concept of a CRG is attractive in explaining the coordination of these functions, there is little understanding of the underlying mechanisms of action. Occupational therapists focus on the infant’s state, tone, posture, or positioning in an attempt to reinstate synchronization. For instance, external pacing is commonly used to prevent sucking-induced apnea. This consists of removing the nipple from the infant’s mouth after a number of sucks/swallows to allow breathing. Thickening of liquid and self-paced flow may also be used to decrease
fluid flow. When full oral feeding cannot be instituted, infants will be fed by an orogastric or nasogastric gavage tube. However, oral feeding may be impeded if the gavage tube is not removed during the feeding session: the orogastric tube may prevent the infant from obtaining a good seal for suction, and the nasogastric tube may interfere with proper oxygenation. Because the larynx is positioned higher during the first 2 years of life, infants are obligate nose breathers because their larynx rises into the nasopharynx, closing off the oral cavity. As such, oral feeding in the presence of a nasogastric tube can compromise respiration.

**Breastfeeding.** The appropriate interventions must take into account the primary contributor(s) to the problem (mother and/or infant) to facilitate breastfeeding and lactation.

**For the Improvement of Oral-Motor Mechanics.** Some sucking problems are caused by illness, prematurity, and/or neuromotor dysfunction. Others problems are genetic (eg, a short frenulum, cleft lip, and/or palate, or other oral anatomic anomalies). Iatrogenic sucking problems can lead to nipple confusion when bottle feeding is concurrently practiced in the early “training” period of the newborn infant. The premature or ill infant may have problems that are related to poor initiation of feeding, weak suck, state, or inability to maintain attachment to the breast. Arousal techniques may be needed to alert the baby and elicit more spontaneous mouth opening. Positioning techniques (see Breastfeeding Techniques on page 113) that provide additional jaw and cheek support during feeding may be necessary to produce stronger, more effective movement. A common problem seen in preterm infants is their inability to maintain attachment to the nipple and areola. The infant latches on to the nipple only to lose it after a few sucking bursts. We and others have had considerable success with the use of a thin silicone nipple shield that is placed over the mother’s nipple during breastfeeding (unpublished observation). The nipple shield appears to provide the stability necessary for the infant to use expression with minimal suction, which improves milk ejection and transfer (Fig 11). However, the mother may need to pump her breasts mechanically after feedings to maintain her milk volume until the infant takes an adequate volume at each feeding.

Infants who have severe ankyloglossia (short lingual frenulum) may exhibit limited tongue movement. This prevents lingual extension over the gum line, which
makes effective breast emptying difficult and/or causes nipple soreness or trauma. Although clipping of the frenulum (frenulotomy) is controversial, many mothers and lactation specialists have reported prompt improvement of breastfeeding after this treatment. Breastfeeding should not be prohibited in infants with cleft lips because the breast tissue will usually “fill” the cleft area, which allows a complete seal. Cleft palates may cause a greater problem depending on the extent of the anomaly. A nipple shield may be useful as an obturator during breastfeeding, thereby improving intraoral pressures.

Since the early 1990s, the United Nations Children’s Fund and the World Health Organization have been awarding the title of “baby-friendly hospital” to maternity services that followed their promotional program’s “ten steps to successful breastfeeding.” One of these steps is the prohibition of pacifiers and artificial teats in the early postpartum period. This recommendation is based on studies showing that early introduction of bottle feeding and the use of pacifiers shorten breastfeeding duration. Contrary to these reports, a recent multisite prospective study found no association between fluid supplements that were offered by bottle with or without the use of pacifiers during the first 5 days of life on the duration of breastfeeding during the first 6 months of life. However, it is the consensus of many mothers and lactation specialists that bottle feeding concurrently with breastfeeding in the early training period increases the risk of sucking problems.

For the Improvement of Maternal Contribution to the Breastfeeding Dyad

Attachment to the Nipple-Areola Complex. Because the shapes and functions of maternal nipples may result in breastfeeding difficulties, Table 2 describes the various types of nipple shapes, function, and interventions that may be useful to facilitate adequate infant attachment and effective “milking” of lactiferous sinuses.

Milk Synthesis, Ejection, and Breast Emptying. Milk synthesis can be stimulated and sustained with early and frequent sucking of sufficient duration to result in complete breast emptying. If mother and infant are separated because of existing or anticipated health problems, lactogenesis can be delayed or decreased. Pharmacologic agents such as metoclopramide, a dopamine antagonist, and human growth hormone have been used to improve milk volumes in mothers of premature infants. The inhibitory effect of stress on the milk ejection reflex has been well documented. Relaxation/imagery audiotape has been shown to improve milk production. Some herbal preparations, such as fenugreek tea, have long been recognized as galactagogues. The lack of scientific controlled studies that validate alternative therapies, such as acupuncture and hypnosis, does not support their wide use in Western societies. The growing use of these alternative approaches in the United States has led the National Institutes of Health to create the National Center for Complementary and Alternative Medicine (NCCAM) with the mission of facilitating research and evaluating unconventional medical practices and disseminating this information to the public. A better grasp on the contribution of stress to lactation will help mothers who are in difficult situations maintain lactation.

Proper attachment to the nipple-areola complex is essential for adequate breast emptying. Additionally, alternate breast massage, in which the mother massages the base of the breast in response to infant suckling, has been shown to result in an improved infant weight gain and enhanced oxytocin and prolactin responses. Mechanical breast pumping after breastfeeding episodes may be necessary to ensure adequate emptying in situations where the infant is unable to provide the necessary stimulation (ie, the infant is weak or premature). Simultaneous mechanical pumping of the opposite breast during the feeding episode will increase the rate of milk flow to the sleepy, “lazy” nurser.

Breastfeeding Techniques. Prompt assessment and correction of improper positioning and latch on are crit-
TABLE 2. Nipple types, function, and interventions (see Fig 8)

<table>
<thead>
<tr>
<th>Resting appearance</th>
<th>Function (during areolar compression)</th>
<th>Intervention</th>
</tr>
</thead>
<tbody>
<tr>
<td>Prominent/normal</td>
<td>Protracts—moves forward</td>
<td>Routine positioning instructions</td>
</tr>
<tr>
<td>At rest nipple protrudes outward</td>
<td></td>
<td></td>
</tr>
<tr>
<td>from areola</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Flat</td>
<td>Protracts</td>
<td></td>
</tr>
<tr>
<td>Nipple is flat with contour of breast</td>
<td>Retracts—moves inward</td>
<td></td>
</tr>
<tr>
<td>Inverted</td>
<td>Simple—moves outward</td>
<td>Same as flat/retracted nipple</td>
</tr>
<tr>
<td>All or part of the nipple is drawn inward within folds of areola</td>
<td>Complete—does not respond to manual pressure because adhesions bind nipple inward</td>
<td>Same as flat/retracted nipple. Even full-term infant with strong suck may need intervention.</td>
</tr>
<tr>
<td>Pedunculated</td>
<td>Stalk may protract or retract</td>
<td>Latch on needs to be assessed to ensure infant’s gums are able to access lactiferous sinuses. If unable to access, mother needs to manually massage sinuses to ensure breast emptying.</td>
</tr>
<tr>
<td>Nipple sits on a stalk away from areola</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Anticipatory guidance and support in a climate of shortened hospital stays will provide the mother with the necessary tools to recognize potential problems and seek additional assistance when warranted.

**For the Improvement of the Nursing Dyad Interaction.**
Recent studies have shown depressed sucking behavior of infants whose mothers received obstetric analgesia. Conversely, infants of unmedicated mothers exhibit a natural locating and rooting reflex and, if allowed, can attach to the nipple unaided soon after delivery. This early “imprinting” is believed to strengthen the maternal attachment to the infant. Therefore, obstetric and early postpartum hospital practices that encourage little or no analgesia and anesthesia and early unlimited access of the infant to breastfeeding would enhance maternal-infant interaction.

Kangaroo care, or skin-to-skin holding, is an intervention which originated in Colombia: the infant is held by an adult (parent or other) upright, skin to skin, on the naked breast underneath the adult’s clothing. In the hospital, the sick infant who is held this way remains warm and stable with greater weight gain and earlier discharge. Skin-to-skin holding also benefits lactation and maternal psychologic well being. Enhanced and prolonged lactation as well as improved maternal sense of self-esteem and acceptance of the sick infant’s condition have been reported. The practice of tactile-kinesthetic stimulation in the form of touch or massage therapy for the growth and development of infants is increasing. The mechanism by which the above procedures enhances growth, lactation and/or strengthens maternal-infant interaction is unclear. Schanberg et al. demonstrated in rats that the physical contact between mothers and pups stimulated the activity of ornithine decarboxylase, an enzyme implicated in the synthesis of DNA and RNA in the offspring. These physiologic benefits lend support to the growing practice of Kangaroo care, touch, and massage therapy to increase breastfeeding duration.

The purpose of this review is to provide an overview of the current understanding in the area of oral feeding in infants. It is hoped that the information will help physicians recognize symptoms of sucking disorders and the potential causes that may be at play. Although the primary concern of feeding disorders in infants is the immediate nutritional deficits that can lead to delayed growth, long-term consequences must be considered, such as the child’s physical and psychosocial development and of equal importance, the mother-child interaction. Any therapy must take into consideration both partners of the dyad. This can best be accomplished through a multidisciplinary team approach.
The authors wish to thank R.J. Schanler, MD, for his critical review of the manuscript and I. Kusnierczyk, OTR, for her expert advice.

References


