Dysphagia 20:46–61 (2005)
DOI: 10.1007/s00455-004-0025-2

Dysphagia

Tube Feeding in Infancy: Implications for the Development of Normal Eating and Drinking Skills

Sarah J. Mason, MSc,[1,2] Gillian Harris, PhD, CPsychol,[1,2] and Jacqueline Blissett, PhD, CPsychol[1]
[1]School of Psychology, University of Birmingham, Edgbaston, Birmingham; and [2]Birmingham Children's Hospital, Birmingham, West Midlands, United Kingdom

Abstract. Tube feeding is commonly used as a method of giving children nutrition while they are being treated for disease. While this is an effective way of ensuring a child thrives and grows, research studies and clinical experience have shown that long-term oral feeding difficulties often arise when the child no longer requires tube feeding. This article gives a critical review of the literature on tube feeding and its effect on normal eating and drinking skills. While few studies have followed a rigorous research design, there is enough literature to identify a number of factors which may be implicated in later feeding difficulties and which therefore need further exploration in research studies. These factors include age at which oral feeding commences, medical complications, exposure to taste and textures during sensitive periods, aversive experiences, and different methods of delivering tube feeds.

Key words: Tube feeding — Oral feeding — Sensitive periods — Oral-motor skills — Aversion — Deglutition — Deglutition disorders.

In children's hospitals it is not unusual to see sick babies and young children being fed artificially, by nasogastric tube or gastrostomy. Studies have shown that tube feeding can be beneficial to children with a variety of conditions such as chronic renal failure, liver disease, or heart disease, where calorie intake might otherwise be inadequate and lead to malnutrition [1–3]. Other children may have structural abnormalities of the digestive tract or absorption problems, which require tube feeding and/or total parenteral nutrition. While tube feeding is essential to ensure that these children grow and thrive while their disease is active, it is usually anticipated that they will feed normally in the long term, unless the tube is placed because of long-term swallowing difficulties. However, these children often present with feeding difficulties when the time comes for them to eat by the normal oral route. Resistance to weaning onto oral feeding has been described in a number of studies [4,5]. Dello Strologo et al. [6] reported difficulties in chewing and swallowing that persisted even after children with chronic renal failure were established on oral feeds. In our clinical experience, tube feeding can lead to feeding difficulties lasting months and sometimes years, with some children refusing to allow food into their mouths at all, while others may accept only a very small range of tastes and textures. Trying to wean a child off the tube may be a traumatic or prolonged process causing considerable stress and anxiety for families [4].

While many studies have investigated the medical and nutritional benefits and complications of tube feeding, there is relatively little literature about the effects of tube feeding on later oral feeding. However, it is important to understand when and how tube feeding impacts on normal eating and drinking. This can then be taken into account in the child's care at the time of tube feeding. The topic is difficult to investigate because of the number of variables that could have an effect on outcome, for example, duration of tube feeding, the age of the child when tube feeding commences, the method and schedule of delivery of tube feeding, and the child's medical condition and treatments.

Correspondence to: Sarah J. Mason, MSc, Speech and Language Therapy Department, Birmingham Children's Hospital, Steelhouse Lane, Birmingham, West Midlands, B4 6NH, UK, E-mail: sarah.mason@bch.nhs.uk

The aims of this literature review are twofold: first, to examine the current state of knowledge regarding tube feeding and the effect it may have on a child's willingness and ability to eat normally; second, to highlight weaknesses and gaps in existing literature and suggest research questions that need further investigation.

Search Strategy

Literature was found by searching using key words *enteral*, *tube*, *gavage*, *gastrostomy*, *nasogastric*, *oral*, *feeding*, *infant*, *paediatric*, and *pediatric*, on a variety of databases such as Web of Science, Science Direct, PubMed, Medline, Ovid, and Cochrane Library as well as the internet. Literature was also found from these sources that informed the discussion on sensitive periods, aversive experiences, appetite regulation, and social interaction. Reference lists given in papers were searched for further relevant titles.

The literature was of variable quality. Only a few of the studies met the gold standard of being randomized controlled trials and these were mainly in the body of literature on non-nutritive sucking in premature infants. As infants grow, it becomes more difficult to control variables and to find matching experimental and control subjects. Studies with less rigorous design methodology have been included in this study when it is considered that they have been influential in current theory and practice and help to raise issues that need further examination. Details of individual studies of tube feeding, including methodology, participants, and outcomes, are included in tables to allow readers to determine their scientific validity.

Tube Feeding and Infant Sucking (Table 1)

Tube feeding is commonly used in neonatal units since premature babies may not have the neurologic and digestive maturation for oral feeding. A number of studies have investigated tube feeding in this population, particularly the effect of allowing babies to suck on pacifiers during tube feedings [7–9]. Premature infants were assigned to the study groups and control groups matched for gestational age and weight. Those in the study groups were given pacifiers to suck on during tube feedings while the other infants were not. Infants given pacifiers to suck on needed tube feeding for a shorter time, started bottle feeds earlier, and were discharged from hospital quicker. Some studies reported greater weight gain despite matched energy intake with controls [8,9].

In the study by Bernbaum et al. [9], the babies who were given pacifiers showed decreased intestinal transit time and more rapid weight gain. Bernbaum et al. [9] suggested that the non-nutritive sucking might reduce energy expenditure in restless activity and/or increase lipid absorption. Other studies have shown that non-nutritive sucking leads to a decrease in restless states [10–12]. DiPietro et al. [10] found that sucking on a pacifier during tube feeding did not alter physiological responses (heart rate, vagal tone, and oxygen saturations) but did significantly change behavioral responses. When provided with a pacifier the infants showed less behavioral distress and spent less time in fussy and active states after feeding. In contrast to the Bernbaum findings, De Curtis et al. [13] did not find that sucking during tube feeding made any difference to energy and nitrogen balance, net nitrogen utilization, fat absorption, or intestinal transit time. However, the small sample size and short duration of their study limit the "generalizability" of these findings.

Bernbaum et al. [9] also studied the sucking patterns of the study and control groups on a weekly basis and found that both sucking pressure and number of sucks per sucking burst increased with age in both groups but significantly more so in the study group. These data supported the idea that sucking is dependent on maturation *and* experience. Mizuno and Ueda [14] studied four term or near-term infants who were not able to suck nutritively in the first two months of life because of gastrointestinal problems. They noted that when their infants were first offered bottle feeds, their sucking behavior approximated that of normal term infants at the first feed. With practice, sucking performance improved. Their findings supported the importance of experience in developing sucking competence, but since their infants had been able to suck on pacifiers from birth, they argued that non-nutritive sucking did not directly affect the development of nutritive sucking. Given the small sample size of this study, firm conclusions cannot be drawn from these findings alone.

Rochat et al. [15] found that premature infants showed increased non-nutritive sucking activity on pacifiers while being given an intermittent (bolus tube) feed, compared to their non-nutritive sucking on a pacifier when they were not being fed. This indicated that the infants must have been responding to stomach cues and/or temperature changes associated with tube feedings. Rochat et al. [15] suggested that the use of the pacifier during bolus tube feeding optimizes the functional link between sucking and

Table 1. Studies of infant sucking behavior

Authors	Research Area	Methodology	Participants	Outcome
Measel and Anderson (1979) [7]	Effect of non-nutritive sucking during tube feeding	Study group given pacifier during and for 5-min after tube feed. Control group did not have a pacifier at these times. Both groups allowed pacifier at other times.	59 infants, 28–34 weeks gestation, allocated to control (30) and study (29) groups by alternate sequential series.	The study group was discharged four days earlier than the control group. Although the study group showed slightly more weight gain each day, this did not reach significance.
Field et al. (1982) [8]	Effect of non-nutritive sucking during tube feeding	Only experimental group given a pacifier during tube feeding. At other times, both groups allowed pacifier as customary ICU practice.	57 infants of birth weight <1800 g and gestational age <35 weeks. Assigned to control (27) and study (30) groups by stratified random sampling techniques.	Experimental group required fewer tube feedings, started bottle feeds earlier, averaged more weight gain, and were discharged 8 days earlier than control group.
Bernbaum et al. (1983) [9]	Effect of non-nutritive sucking during tube feeding	Only study group given pacifier during tube feeds. Pacifiers not given to either group at other times to control for amount of non-nutritive sucking.	30 infants of birth weight <1500 g. Pair-matched for weight and postnatal/gestational age into study and control groups.	Use of pacifier led to accelerated maturation of sucking reflex, quicker transition to oral feeding, increased weight gain, and shortened hospital stay
DiPietro et al. (1994) [10]	Effect of non-nutritive sucking on physiological and behavioral states	Behavioral and physiological states measured on two consecutive days, in two conditions: with pacifier during tube feed and without pacifier at tube feed.	36 infants, ≤34 weeks, 1000–2000 g acted as their own controls.	Significant change in behavioral but not physiological responses when given a pacifier. Infants less distressed and spent less time in fussy states after feeding.
Gill et al. (1988) [11]	Effect of non-nutritive sucking on behavioral state	Infants randomly assigned to group receiving pacifier for 5 min prior to tube feed or to group that did not receive pacifier.	24 preterm infants of <2000 g and gestational age of ≤34 weeks.	Infants receiving the pacifier prior to tube feeding spent less time in restless states and more time in awake states.
Gill et al. (1992) [12]	Effect of non-nutritive sucking on behavioural state	Infants randomly assigned to group receiving pacifier for 5 min prior to tube feed or to group that did not receive pacifier.	42 preterm infants of <2000 g and gestational age of <34 weeks.	Infants given a pacifier prior to tube feeding had more sleep and fewer restless states.
De Curtis et al. (1986) [13]	Effect of non-nutritive sucking on nutrient retention	Random crossover design. Infants studied under two conditions in either order: 3 days of just nasogastric feeding (control period) and 3 days with a pacifier during feeding (sucking period).	Ten infants, mean birth weight 1111 g, gestational age 28.8 ± 2.3 weeks.	Sucking during tube feeding had no immediate effect on the infants' energy and nitrogen balance, net nitrogen utilization, fat absorption, or intestinal transit time.
Mizuno and Ueda (2001) [14]	The need for oral-feed practice to develop sucking behavior	Evaluation of sucking behavior during bottle feeds using standardized teats, with a silicon tube attachment that allowed measurement of sucking pressures. Values of sucking pressure and frequency were taken at the first oral feed, and at one and two months post first bottle feed.	Four term or near-term infants (36–40 weeks gestation) who had not been able to feed orally for approximately two months after birth because of digestive tract problems. Age at time of study between 5 months and one year.	Significant increments in sucking efficiency (ml/min) were obtained with time, i.e., at first feed, after 1 month and after 2 months.

(*Continued*)

Table 1. *Continued.*

Authors	Research Area	Methodology	Participants	Outcome
Rochat et al. (1997) [15]	The effect of bolus tube feeds on sucking behavior	The non-nutritive sucking behavior of 6 infants on intermittent tube feeding was tested for three 5-min periods (before, during, and after) tube feeds. This was compared with the sucking behavior of 5 infants on tube continuous feeds.	11 infants, gestational age of $\leq$32 weeks.	During the intermittent tube feeds, the infants had longer sucking bursts, with more and longer sucks per burst. At other times, their sucking was similar to the group of infants fed by continuous nasogastric feeds.
Pinelli and Symington (2004) [16]	Systemic review of the effect of non-nutritive sucking on clinical variables, including length of transition from tube to bottle feeding, length of stay in hospital, weight gain, and state behaviors	Detailed search of relevant literature and meta-analysis of experimental results.	20 studies included, 14 of which were randomized control trials	Significant benefits in terms of length of stay in hospital, length of transition from tube to bottle, and bottle feeding performance. No benefits found in weight gain and other clinical variables. No negative outcomes reported but suggest the potential for negative outcomes for breast feeding or oral aversion.

feeding and may lead to earlier transition to oral feeding.

The relatively wide literature on non-nutritive sucking has been usefully examined by Pinelli and Symington [16] in their systematic review of the subject. They concluded that non-nutritive sucking has a positive effect on the transition from tube to bottle feeding and on bottle feeding performance and leads to a shortened length of hospital stay (in days). Non-nutritive sucking did not show a benefit in other major clinical variables such as weight gain, energy intake, and heart rate. No negative outcomes were reported in any of the studies they reviewed, but they did note that no account was taken of the effect sucking on a pacifier might have on breast feeding. With this reservation in mind, research evidence supports the use of pacifiers in neonatal units.

Tube Feeding in the First Year of Life (Table 2)

While tube feeding in neonatal units is often required because an infant has immature sucking skills, as the infant matures continued tube feeding is more likely to be related to medical and neurodevelopmental problems. In a retrospective design, Bazyk [17] studied the cases of a 100 infants who had commenced tube feeding in the first 6 months of life but were being reintroduced to oral feeds before the end of the first year. She found that six infants, described as "poor feeders," took a year or more to make the transition from tube to oral feeding, while the remaining 94 infants made the transition within 2–58 days (mean = 17.50). She excluded the six poor feeders from her statistical analysis since they were substantially different from the other 94 infants. Bazyk examined the correlation between medical complications and the time taken to make the transition from the tube to oral feeding. The variables she studied were the total number of medical complications, the number of neurologic conditions, the number of respiratory conditions, the number of digestive conditions, the number of congenital cardiac defects, and the number of diagnoses related to the oral structure. Her results showed that infants with multiple complications, and those with complications to do with digestive, cardiac, or respiratory systems, were most at risk of lengthy transitions. Bazyk noted that prematurity alone did not show a significant and positive correlation with length of transition to oral feeding and 90% of her good feeders were premature. This suggests that weaning off tubes may be relatively easy to do when babies are of an age where feeding is largely reflexive, provided there are

Table 2. Tube feeding and the young infant

Authors	Research area	Methodology	Participants	Outcome
Bazyk (1990) [17]	Variables affecting the transition time from tube to oral feeding	Retrospective review of patient records to establish criterion variable (number of days taken to make transition to full oral feeds) and predictor variables (medical complications thought to influence transition times).	First 100 infants under 1 year of age admitted to children's hospital who met criteria of (a) fed by nasogastric tube within first 6 months, (b) physician's order for oral feeding within first year.	Six infants were identified as extremely poor feeders and had lengthy transitions or never progressed to oral feeding. Total number of medical complications and digestive, cardiac, and respiratory complications were all predictors of lengthy transitions.
Hawdon et al. (2000) [19]	Prematurity and the likelihood of feeding difficulties in infancy	Prospective study. Infant feeding pattern assessed at 36–40 weeks. Parents were sent questionnaires on weaning at 6 and 12 months.	35 neonates (mean gestational age 34 weeks at birth) recruited from NICU.	21 infants had normal feeding patterns, 12 had a disorganized pattern, and 2 were dysfunctional feeders. Those with disorganized/dysfunctional feeding were more likely to be born at <30 weeks gestation, need longer periods of ventilatory support and tube feeding. These infants had significantly greater difficulties with feeding at 6 and 12 months of age.
Cerro et al. (2002) [20]	Parents' perceptions of the eating behavior of young children who were born prematurely	Mailed questionnaire to parents of children born over a two-year period at a neonatal unit. A parallel study using a similar questionnaire was conducted on toddlers born at term.	Qs sent to parents of all infants born over a two-year period and admitted to a neonatal unit, with very low birth weight or <32 weeks gestational age. 95 Qs returned. In the parallel study, children at a gestational age of 3 weeks or more were identified from the birth register. 143 Qs were returned.	Parents reported preterm children to be poorer feeders as compared to children born at term ($p < 0.001$). 78% of parents of preterm children were concerned about quality of food intake and 45% wished to change their child's eating behavior. Parents of children who had received home tube feeding ($n = 5$) or had respiratory or neurological disability ($n = 16$) reported poorer feeding indicators.

no significant complications. At first, sucking will be triggered automatically by any sort of stimulation of the lips and tongue but gradually this reflex response comes under voluntary control. Morris and Klein [18] described how the baby develops separation of movement that enables the jaw, lips, and tongue to move separately and thus perform more complex tasks. The mouth cavity enlarges which also widens the opportunities for tongue movement. However, this means that an older baby exposed to a bottle for the first time, or after an interval, will not necessarily start sucking. A variety of movements are available, for example, biting, munching, or rolling the teat around or pushing it out of the mouth. Mizuno and Ueda [14] noted that in their experience, once a baby reached 6 months or more, it was very difficult to establish bottle feeding for the first time.

Now that medical advances are allowing younger premature infants to survive, there is a greater risk of medical complications that may impact on the infant's feeding. Recent followup studies of premature infants [19,20] have highlighted the fact that feeding difficulties are likely to persist through the first year and beyond, especially if tube feeding has been prolonged. Bazyk [17] found that, while prematurity in itself was not significant in the transition from tube to oral feeding, multiple medical complications or complications associated with respiratory, digestive, or cardiac systems were significantly related to the length of transition. As Bazyk pointed out in her study, although these complications were identified as predictors of length of transition, they did not necessarily imply causation. The way in which these complications impact on feeding is not clear, but Hawdon et al. [19] discussed how primary feeding difficulties related to neurologic and respiratory status may be compounded by aversive oral experiences such as endotracheal and nasogastric (NG) tube placement and delayed establishment of normal feeding patterns. A child may become hypersensitive to any stimuli presented to the mouth because of his/her experiences of unpleasant oral procedures or may miss out on oral feeding experiences because of acute illness.

Aversive Stimuli Associated with Feeding

Pelchat and Rozin [21] described how nausea and vomiting have a particularly strong effect on human dislike of food. If ingestion of food is followed by nausea and vomiting, it will cause a dislike of that food, even if there is no direct link between the food and the nausea. Rozin [22] found that taste aversion was acquired by one trial learning, whereby one exposure to a food followed by nausea and vomiting was enough to cause dislike of a food. Bazyk [17] found that conditions relating to digestive functioning were the most significant predictors of the length of transition from tube to oral feeding. Gastroesophageal reflux disease (GERD) was the most common complication noted in her sample. Reflux can lead to nausea, vomiting, and esophagitis, all of which may link feeding with aversive experiences. Mathisen et al. [23] reported how children of 6 months of age with GERD had significantly more feeding difficulties and food refusal than a matched sample.

Skuse [24] suggested that aversive experiences might also come directly from tube feeding itself since nasogastric tubes are often reported to cause some degree of reflux, vomiting, or inflammation of the esophagus. Meyer Palmer and Heyman [25] hypothesized that long-term use of the nasogastric tube leads to altered sensory perception, with sensory perception of the pharyngeal area becoming suppressed in order to withstand the trauma inflicted on the mucosa of the mouth or pharynx. They described how children with a nasogastric tube will often hold food in their mouths and suggested that this was done purposefully to avoid swallowing and to protect the pharynx from stimulation. Lumpy foods might be sorted so that the lumps were expelled from the mouth and only the liquid consistency swallowed. However, it could be argued that these were hypersensitive responses to taste and texture stimuli that were mediated by the tongue and had nothing to do with the pharynx itself.

Tube Feeding by Gastrostomy (Table 3)

There is a fairly general consensus in the literature that gastrostomy feeding is preferable for children who are likely to be fed by tube for any length of time, in part because this will reduce aversive oral experiences and thereby promote more pleasurable oral feeding [17,18,26]. While some studies show that gastrostomies are generally well accepted by parents and lead to improved quality of life [27], negative consequences are possible because of the risk of the anesthetic and medical complications [28]. In a systematic review of the effects of gastrostomy in children with cerebral palsy, Samson–Fang et al. [29] noted that there was a low level of evidence but a consistency of results in favor of gastrostomy in this population. In a qualitative study, Craig et al. [30] found that parents often felt ambivalent about putting a child through another procedure and regarded gastrostomy placement as an admission of failure with oral feeding.

Table 3. Studies of gastrostomy feeding

Author	Research area	Methodology	Participants	Outcome
Tawfik et al. (1997) [27]	Parent satisfaction with gastrostomy	Qualitative study, using 35 item questionnaires	29/38 families completed questionnaires. All families had a child with neurodevelopmental disability and a gastrostomy.	Only one parent regretted the decision to have a gastrostomy. Coughing, choking, and vomiting improved in most cases.
Khattak et al. (1998) [28]	Complications following gastrostomy	Review of medical notes of all patients who had a percutaneous endoscopic gastrostomy over 5-year period	120 pediatric patients, having 130 gastrostomies. 52 were neurologically impaired. Reasons for gastrostomy included inability to swallow ($n = 74$) and inadequate intake ($n = 30$).	17.5% gastrostomies led to major complications. There were minor complications in 22.5%. Authors considered that PEG should be considered a major surgical undertaking.
Samson-Fang et al. (2003) [29]	Effects of gastrostomy feeding in children with cerebral palsy	Systematic review of studies of gastrostomy feeding in children with cerebral palsy	Ten studies met the criteria for inclusion in the review.	Although the review found a low level of credible evidence, there was a consistency of results in favor of gastrostomy.
Craig et al. (2003) [30]	Parental perceptions of gastrostomy	Semistructured interviews, usually carried out at parental home, were audiotaped. Themes were compared within and across interviews	Parents recruited from a surgical outpatient clinic and dysphagia service. Parents of 22 children with severe neurodevelopmental disability agreed to participate.	Parental accounts of oral feeding and tube feeding were ambivalent and contradictory. Parents identified a need for more information, not just about the procedure, but about how the gastrostomy might affect family life.

Most of the literature concerning gastrostomy is focused on children who have neurodevelopmental disabilities and may need tube feeding long term because of oral-motor and swallowing difficulties. However, the issues are rather different when children have potentially normal eating and drinking skills. One of the criteria for having a gastrostomy may be to improve oral feeding. However, children with gastrostomies have been described to exhibit behavior such as fighting, crying, gagging, coughing, and vomiting when offered oral feeds [4,31]. This would seem to suggest that adverse oropharyngeal experiences associated with the nasogastric tube cannot alone account for reluctance to eat orally. If problematic feeding is the major criterion for performing a gastrostomy, research is needed to demonstrate exactly what the outcomes are for oral feeding in children fed by gastrostomy compared to children fed by nasogastric tube. Even if gastrostomy placement is recommended, professionals and parents need to be aware that oral feeding will not be established by the procedure alone. Morris [32] suggested that some doctors might believe that a gastrostomy will solve any feeding problems and they would therefore not see the need to actively encourage the child to feed orally. The child would then not have the opportunity to experience the sensations of food in the mouth and develop the oral-motor skills to manage different food consistencies and textures. In summary, the effect of gastrostomy on the oral feeding of children with normal oral motor function is not fully understood and needs further research.

Tube Feeding in Older Infants and Children (Table 4)

Studies of older children who are tube fed are useful because they enable us to compare the effects of tube feeding at different stages of feeding development. Senez et al. [5] compared two groups of children who were being weaned off tube feeding. The first group comprised nine infants of 14 months or less; the second group consisted of 10 children ranging in age from 2 to 15 years. The first group had never successfully fed orally before the study commenced, but the second group had been oral feeders until they needed tube feeding following brain injury, disease or, in one case, swallowing a noxious substance. The first group took between 30 and 330 days to wean off the tube (excluding one child who was not successfully weaned off the tube), while the second group took 11–45 days to wean off the tube. Senez et al. explained the difference in the speed of weaning off the tube between the two groups in terms of neurologic maturation. They suggested that lack of oral feeding in infancy leads to deficits in cortical development because motor and sensory pathways between the oropharynx and the cortex are not established. One of the limitations of this study is that the children in the two groups showed considerable variation in both medical condition and age at which weaning off the tube began, both factors that could be significant in determining outcomes. Furthermore, since most of the children had neurologic conditions, it is unclear how much one can generalize from this study to the population of tube-fed children who are neurologically intact. Comparing the infants in the first group to the older, second group, Senez et al. felt that the establishment of oral feeds depended less on the severity of the brain disease than on how long the child had been tube fed.

Dello Strologo et al. [6] carried out a retrospective multi-center study of 12 children with severe chronic renal failure who had been nasogastrically fed for periods of 9 months or more. Eight had commenced tube feeding in the first year of life, the other four between 2 and 4 years of age. The mean duration of tube feeding for the whole group was 18.4 months, plus or minus 8 months. It is not clear how long the transition from tube to oral feeding took, as the data are presented in terms of eating difficulties that persisted after the withdrawal of tube feeding. The age at which tube feeding commenced appeared to be significant in determining whether the children had subsequent difficulty with oral feeding. Three out of four children, who were over 1 year old at the start of tube feeding, did not have problems with oral feeding, while seven out of eight children who had been tube fed in the first year of life had significant problems. Both the Senez and Dello Strologo studies [5,6] support the idea that children will have more difficulty establishing oral feeding if the children are in the first year of life when tube feeding commences, rather than if they are older and have already experienced oral feeding. These younger children will be less willing to accept foods into their mouths and are more likely to have difficulty chewing solid foods. It is possible that within the first year of life there are significant periods when tube feeding has more impact than at other times, but neither of these studies compares the outcomes within a narrower age range.

Senez et al. [5] suggested that the difficulty their young infants had in accepting oral feeds occurred in large part because the infants failed to suppress the strong "gag" reflex which is present from birth but normally decreases in strength over time. By the time the infant is 6–7 months of age, the gag is triggered only on the posterior one quarter of

Table 4. Studies of tube feeding in older children

Authors	Research Area	Methodology	Participants	Outcome
Senez et al. (1996) [5]	Weaning children off tubes	Nursing protocols instituted: Group 1: bolus tube feeds, cradling, tactile, olfactory, and taste bud stimulation Group 2: bolus tube feeds, cryotherapy, tactile, olfactory, and taste bud stimulation Time taken to wean off the tube recorded.	19 children, 12 with neurologic disease. Divided into two groups Group 1 (9 children) had not been fed from birth and were aged 14 months or less. Group 2 (10 children) had fed orally before becoming ill and were aged 2–15 years. No control groups, wide range of medical conditions included.	Normal feeding quickly restored in Group 2, range of 11–45 days. In group 1, only one child did not make the transition to oral feeding due to brain stem problems. The time taken to wean off the tube varied from 30 to 330 days.
Dello Strologo et al. (1997) [6]	Oral feeding difficulties after long-term tube feeding in renal patients	Retrospective multicenter study of clinical data completed by physicians. Analysis of age at start of tube feeding, duration of tube feeding, feeding difficulties reported after removal of tube feeding.	12 children met selection criteria (tube feeding > 9 months and glomenular filtration rate less than 3 ml/min per 1.73 m^2). 8 children were under 1 year of age at start of NG feeding and the remaining 4 were aged 1–4 years.	Eight children showed significant and persistent eating difficulties. These were described as food refusal, chewing difficulties, and "panic" attacks when swallowing. Seven of these children had started NG feeding before the age of 1 year.
Geertsma et al. (1985) [31]	Behavioral intervention to overcome resistance to oral feeding	Single case study of a child with resistance to oral feeding. Intervention program of oral desensitization and association of feeding with positive social experience.	Female infant, born with ileal atresia and an ileal perforation. Required an ileostomy and TPN until 7 months, then had a gastrostomy. Intervention program commenced at 7.5 months.	Gradual acceptance of oral stimulation and weaning onto oral feeding. Gastrostomy removed at 13.5 months.
Scarborough (2002) [33]	The effect of altered neurophysiological development on preswallowing skills	Matched control study of response to touch along a hierarchy of body points. Changes in state behavior and/or abnormal gag recorded.	20 children with mixed failure to thrive matched with 20 controls. Age range 3–18 months (adjusted age). All children in study group had at least 2 weeks tube feeding in first 3 months of life.	Significant difference in the study group's response patterns to firm pressure, with 16/20 showing an abnormal response (gagging). None of the controls showed an abnormal response.

the tongue, as it is in adults. Senez et al. [5] suggested that nutritive sucking inhibits the gag reflex so that it moves from the anterior to the posterior part of the tongue and that between birth and 7 months is a "critical" period in which this process must occur. They observed oversensitive gag reflexes in all except one of their younger group, with the gag being triggered in the anterior third of the tongue whenever foreign objects were introduced into the infants' mouths. Their treatment protocol emphasized the importance of oral stimulation, using tactile, taste, and olfactory stimuli. Geertsma et al. [31] also observed how gagging interfered with early attempts to introduce oral feeding to a child fed intravenously but noted how this was replaced by a volitional tongue thrust as the child became older. A recent study by Scarborough [33] showed how toddlers and full-term infants deprived of oral feedings during the first 3 months (13 weeks) of life showed altered physiological responses to touch. The response of children to touch along a hierarchy of body points was examined, measuring changes in state behavior and/or abnormal gag reflex responses. She found that her study group showed a significantly different response to firm touch than did her normal control group. This intolerance of touch is then likely to interfere with the child's feeding since this involves tolerance of a spoon to the lips or food in the mouth.

Sensitive Periods

Dello Strologo et al. [6] noted that even after children were weaned off the nasogastric tube, several of them had persistent chewing difficulties. If these children had not experienced solid food in the first year, this would support the hypothesis that there is a sensitive period for the acquisition of chewing skills, first proposed by Illingworth and Lister [34]. A sensitive period occurs when the child's maturation and opportunities to learn a new skill coincide. If the opportunities to learn are not there at the sensitive period, then it becomes much more difficult for the child to learn the skill at a later date. Illingworth and Lister [34] identified that readiness for chewing occurred at around 6 months for most normal children. They presented a number of case studies of children who were introduced to solid foods at a late stage, having either had tube feeding or a liquid or pureed diet. These children exhibited refusal behavior, including vomiting, and failure to chew. This is the kind of behavior noted in studies of tube feeding [4–6]. However, such feeding problems have been reported in other circumstances and may be attributable to other causes [35]. The hypothesis of a sensitive period for chewing put forward by Illingworth and Lister has not been tested experimentally.

The difficulty that tube-fed children have with textured foods appears to have two components: first, a refusal to try unfamiliar foods, and, second, an inability to manage the texture because chewing skills have not been acquired through practice. Reilly et al. [36] pointed out that most researchers agree that movement patterns, such as lateral tongue movements, are texture dependent and therefore do not emerge unless the child is given the particular textures requiring these skills. Gisel [37] examined how normal children between 6 months and 2 years of age developed the skills to manage three different textures of food: puree of unsweetened applesauce, viscous orange gelatin, and solid Cheerios. Chewing was measured in the two dimensions of duration (placement of food in the mouth to completion of swallow) and number of cycles (one down and up movement of the mandible). She found that as children get older, their chewing becomes more efficient with less cycles needed to chew a standard-sized bite of food and therefore chewing duration decreases. While efficiency increased over the whole period between 6 months and 2 years, the most marked changes occurred between 6 and 10 months. Gisel's data support the idea that the second half of the first year is a period of rapid maturation for chewing skills. This does not necessarily imply that lack of opportunity to practice with solid foods in the first year means that the child will find it more difficult to develop chewing at a later stage. It may simply be that the child becomes increasingly resistant to trying new foods and that this prevents the child from learning the skill of chewing.

Dello Strologo et al. [6] did not think that the link between lack of previous oral experience and chewing skills was significant because two children in their study who did not have any oral intake while tube fed showed no disturbance in their ability to eat orally. However, it is possible that these children could have had taste or texture experiences that did not make a significant contribution to calorific intake and were therefore not recorded but which would have constituted sufficient oral experience to facilitate chewing skills. While Dello Strologo et al. [6] considered the percentage intake given by the oral route and by tube, they did not record the specific types of food eaten orally. There are no studies that have investigated systematically the relationship between foods experienced by infants during tube feeding and later transition to oral nutrition and subsequent range of foods accepted.

The literature on the development of feeding skills shows that preference for foods is a function of exposure, i.e., we learn to like foods as we become familiar with trying them [38–40]. From the age of 3–4 months, babies seem to be particularly willing to try new tastes of food and, by repeated exposure, develop their food preferences. As they move into the later half of the first year, and into the second year, this willingness to try new foods lessens, as the child becomes increasingly neophobic, i.e., fearful of anything new.

In addition, as children move into the second year of life, they also become more autonomous. Food refusal is often exhibited as the child tries to take control. Gisel [37] collected data on food refusal from questionnaires on the child's feeding history completed by parents. Parents recorded how frequently children refused specified foods. The refusal rate of foods increased from 7% at 6 months of age to 41.4% by 24 months of age. Reilly et al. [36] noted that infants between the age of 12 and 18 months were more likely to refuse food presentations in the Schedule for Oral Motor Assessment. They linked this to the child's growing independence, as well as to the texture being presented and whether the child had a feeding difficulty or not. Thus, if tube-fed children do not get exposed to a wide variety of tastes and textures in the first year of life, it may be harder to achieve oral acceptance at a later age. In a longitudinal study, Harris [40] noted that some infants were consistently difficult to feed and suggested that this was linked to infant temperament. These infants would refuse to try new foods at the age of 1 year. It seems likely that a more pervasive feeding problem will arise in children where delayed oral feeding and a more difficult temperament coexist. If these children were identified early in life, it would be even more important to make sure that they were exposed to tastes and textures at sensitive periods when food will most easily be accepted, allowing food preferences to be established.

Social Interaction at Mealtimes

Geertsma et al. [31] felt that the social interactive dimension of feeding was a significant contributor to the success or failure of oral feeding. With a healthy child, feeding is one of the earliest activities in which the mother and child interact communicatively. If the child is able to signal hunger and satiety, likes and dislikes, and the mother responds appropriately, feeding is likely to be successful. Harris et al. [40] noted that infants as young as 4 months can take control of feeding interactions and demonstrate food preferences and satiety as long as parents do not override the infant's behavioral signals. Wright [41] pointed out that breast-fed babies have more opportunity to regulate their intake, since the mother does not know how much the baby is having at each feed. This may mean that breast-fed babies have an earlier sense of mastery over their environment than bottle-fed babies. Harris [42] found that the age at which infants were introduced to solid foods was determined in part by the mothers' perception of the behavioral signals of the infants. This was a more significant determinant of the introduction of solids than the weight of the child. However, this exchange of signals between child and caregiver may be lost if a child is receiving medical care and/or tube feeding. Boucher [43], in a study of babies with cleft palate, reported how a mother of a child fed by nasogastric tube felt unable to make her own decisions about when to wean her infant because she felt feeding had become part of the medical management and had taken away her autonomy in the context of feeding.

Particular sensitivity is needed when trying to feed tube-fed children orally because they are likely to have little or no appetite for oral intake. Harris [44] pointed out that when dietary supplements or tube feeds are given to children, this will naturally lead to a decrease in the child's consumption of other foods as the child attempts to regulate their energy intake. This means that a child is likely to accept only small amounts of food and only if the context of feeding is positive. If caregivers do not understand appetite regulation, there is a danger that their expectation of oral feeding will be unrealistic and feeding times become difficult as the child starts to refuse food. Harris and Macdonald [45] found that parents of children with cystic fibrosis often had high levels of anxiety because a high calorie intake was necessary for the children to maintain optimal lung function. This anxiety was associated with more refusal behavior by the children and more coercive behavior by the parents at mealtimes. Blissett et al. [46] found that children with growth disorders who were not on growth hormone received more negative prompting and coaxing from their parents to eat than did children who received growth hormone. They suggested that parents try to impose control of their child's intake when they perceive it is too little and this leads to the child's feeding difficulty. Once a decision is made to attempt to wean a child off a tube, parents become highly anxious that the child may not be able to maintain weight gain and growth through oral intake alone.

While some authors recognize the possible significance of child–parent interaction in achieving

successful oral feeding [26,31], this aspect of tube feeding has not been investigated systematically. In some cases this is because retrospective studies do not allow for analysis of parental behavior, and in other cases parents may not have been physically present [48]. Geertsma et al. [31] noted the behavioral signals of the infant they studied, using videotape, and used nurses to carry out a behavioral/social intervention. Blackman and Nelson [4] used trained staff to carry out their intensive in patient weaning program although parents were able to observe treatment sessions. This was in part because they felt parents would not be able to carry out the feeding with the degree of firmness required; in some cases, this included physical restraint and force feeding. Finally, nurses and parents carried out the interventions recommended by Senez at al. [5], but their interactions with the infants were not analyzed. In general, it does not seem that those researching tube-fed children have felt that the role of parents in the establishment of oral feeding is a key area for investigation.

Weaning Off the Tube (Table 5)

Appetite regulation is important when considering weaning off tube feeding. Some authors [5,26] have emphasized the importance of approximating tube feedings to normal mealtimes in size and timings. Food has been offered before a tube feeding when a child was thought to be hungry. Senez et al. [5] suggested that continuous tube feedings do not allow for the development of normal biological rhythms, which have an alternation between sleep and activity, hunger and repletion, empty and full stomach states. They based this proposal on a study by Salzarulo et al. [48] who found that long-term continuously fed infants do not develop heart rate circadian rhythm. This is a decrease in heart rate at night time, thought to occur as a result of mealtime fasting.

Underlying oral feeding regimens that approximate normal mealtimes is the idea that the stomach should experience a normal daytime pattern of distension and emptying. While a newborn baby's sensations of satiety or hunger are determined by the peripheral signals of stomach distension and rate of gastric emptying, Drewett [49] described how, from 6 weeks of age, appetite regulation develops to allow the infant to regulate the calorific intake of food in a different way than the first 6 weeks. Subsequently, appetite regulation is mediated by a central mechanism involving the monitoring of blood sugar. Studies [50,51] have shown that preschool children are able to regulate their appetites and tend to do this over a 24-hour period. Birch et al. [50] noted considerable variability in intake from one meal to another but found that energy intake was relatively constant from one day to another. This suggests that it is the amount of calories given by tube in a 24-hour period that will influence a child's appetite regulation rather than the way the tube feeds are timed during that period of time. If the caloric intake of tube feeding is reduced in a 24-hour period, this should eventually lead to compensatory oral feeding as the brain adjusts to a reduced intake. This will happen only if the child is already accepting some food by the oral route. As children grow older, ''extrinsic'' cues to eat also have some effect on intake. Children may eat to enjoy the taste of favorite foods when they are not hungry, or eat when there are others eating, or eat in response to environmental cues such as smells, presence of food, and a room in which eating usually takes place [52].

In contrast to tube feedings that approximate mealtimes, some authors have advocated overnight feeding as a better way of promoting oral intake and the eventual weaning off the tube [6,53]. Overnight feeding means that the child is not so aware of the process of artificial feeding and the day is left clear for attempts at oral feeding. The child may begin to feel hungry toward the end of the day as blood sugar drops, and then begin to ingest food. As this intake increases, the overnight feeding can be decreased. However, there is no specific research that has compared the relative effectiveness of using an overnight or a daytime bolus schedule to achieve the transition to oral feeding. There is also very little literature to guide clinicians as to how quickly any reduction in tube feeding should take place, irrespective of the schedule used.

Whatever schedule is used to promote oral appetite, a major determinant of successful weaning from tube feeding is the child's existing acceptance of any food into the mouth. If a child does not accept any foods orally, the link between eating orally and satisfying hunger is not made. Thus, stimulating appetite by reducing tube feeds will not in itself lead to oral intake. Benoit et al. [54] used a randomized control design to compare the success of nutritional and behavioral interventions in weaning children off gastrostomy feeds. The children ranged in age from 4 to 36 months, were all gastrostomy fed, and showed resistance to oral feeding. Nutritional counseling alone did not achieve any successes during the study period (4.5 months). This intervention was based on reducing intake from the tube by 25% for a week and promoting normal hunger

Table 5. Weaning off the tube

Authors	Research Area	Methodology	Participants	Outcome
Salzarulo et al. C (1985) [48]	Continuous feeding and modulation of heart rate	Recordings of heart rate were taken during four periods of the 24-hour day (3 am, 9 am, 3 pm, 9 pm).	Eight infants fed continuously from birth by parenteral nutrition (due to severe medical or surgical gastrointestinal disease) were compared with a control group of the same age receiving oral feeds. Both groups had normal births and no neuropathology.	Comparisons between the older and younger groups of infants showed that older controls modulate their heart rate during the nighttime; older continuously fed children do not show this modulation.
Greene et al. (1981) [53]	Use of overnight feeding at home to overcome malnutrition associated with disease	Patients were fed by overnight-' continuous infusion. Weight gain and any complications were recorded.	14 patients, age range 2 months to 68 years, with malnutrition associated with renal, bowel, heart disease or malignancy.	12 of 14 patients showed substantial increases in their weights.
Benoit et al. (2000) [54]	Weaning from gastrostomy feeds to oral feeding	Randomized controlled trial, with children randomly assigned to either a behavioral or a nutritional intervention.	64 children, age 4–36 months, tube fed for at least 1 month. All were resistant to oral feeding at the start of the study. The aim was to wean children off tube feeding.	47% of 32 children in the behavioral group were successfully weaned off tube feeding. No children in the group receiving nutritional advice were successfully weaned off the tube.
Blackman and Nelson (1985) [4]	Weaning from gastrostomy feeds to oral feeding	The 10 children selected underwent a behavioral feeding program. Five children were managed as outpatients, 4 as inpatients, and 1 did not complete the intervention because of aspiration. The intervention consisted of a preparation phase of establishing tube feedings at normal mealtimes with cow's milk or a soya-based formula. The treatment phase consisted of oral feeding where positive behaviors were rewarded at oral feed times, negative behavior was ignored.	17 children under 4 years of age with gastrostomies were evaluated for admission to oral feeding program. The age range for insertion of gastrostomy was from birth to 18 months, with 75% having the tube inserted at less than one year. All but one child had developmental delay, 5 classed as moderate and 11 as severe. Ten children were selected against the criteria of (1) original reason for gastrostomy corrected or stabilized, (2) no functional/anatomical impediment to swallowing, (3) developmental level of 6 months or more.	Nine of the 10 children selected for the program were weaned off gastrostomy feeds. This was achieved rapidly with children in hospital (2 weeks to 2 months) whereas the outpatient program took much longer (4 months to > 31 months). One child died of an airway obstruction 5 months after the gastrostomy was removed.
Gutentag and Hammer 2000) [55]	Use of behavior modification program to wean a child of gastrostomy feeding	Single case study, multiphase design. Intervention comprised positive reinforcement of positive behavior and ignoring of minor inappropriate behaviors.	Three-year-old girl selected because of her refusal to eat orally. She had a history of cardiac, respiratory, and gastrointestinal problems. She had a gastrostomy placed at the age of 6 months.	An overall improvement in intake occurred over time, although it was variable from one day to another. There was a moderate inverse relationship between total food intake and illness.

and satiety cycles through the feeding schedule. If weight was gained or remained stable over the following week, a further reduction was made, but if not, intake by tube was increased by 25%. Not all the children in this group refused food completely. It may be that the lack of success in such cases was because reductions in calorie intake from the tube were made too quickly to allow the brain to adjust to the change in intake, to trigger compensatory oral eating. While reduced energy intake stimulates appetite and feeding in a normal population within a matter of hours [51], this process may not occur in children who have little or no experience of taking in calories from an oral route.

The behavioral therapy used by Benoit et al. [54] was more successful in weaning children off the tube, with 47% ($n = 15$) achieving success after completion of treatment. In the behavioral therapy intervention, parents were shown how to use the technique "extinction," whereby the reinforcer to a response is removed so as to decrease this response. Benoit et al. gave the example of how removal of a spoon when a child refuses to accept it is reinforcing the behavior of refusal. Therefore, extinction requires that the spoon is not removed, however much the child resists. The child has no choice but to conform and the undesired behavior of refusal is extinguished.

A similar behavioral approach to weaning children off the tube was used by Blackman and Nelson [4], the goal of which was to override the resistance to feeding, tasting, and swallowing food that the children showed at the start. Children were assigned to inpatient and outpatient program according to parental choice. Under the inpatient program, transition to oral feeding was achieved within two months, but the outpatient program led to much slower transition times (months to years). Blackman and Nelson attributed this difference in weaning times to the reluctance of parents on the outpatient program to push the child to eat without the support of more experienced professionals. This suggests that such an approach is emotionally difficult for parents to carry out and indeed would not be recommended by all clinicians [24,55]. When force feeding occurs, eating will be associated with negative experiences and is not likely to establish long-term food preferences and enjoyment of food. Furthermore, the child's ability to signal likes and dislikes and satiety and the family's sensitivity to these signals are likely to be impaired by this approach. Benoit et al. [54] pointed out that the followup period in their study was relatively brief and therefore long-term effects could not be examined. It is also not clear from these studies whether these children were successful in progressing to self-feeding. Furthermore, in the Blackman and Nelson study [4], many of the children had neurologic conditions and learning disabilities that may have affected the extent to which forced feedings could be imposed. Children with physical disabilities are not always able to resist unwanted intervention in the same way as able children, while children with learning disabilities may become neophobic at a later stage than other children and may therefore accept new foods over a longer developmental period. It is therefore difficult to generalize from this study to a normal population of tube-fed children.

Other clinicians have used approaches based on positive reinforcement of eating behavior. Gutentag and Hammer [56] reported some success with introducing oral feeds to a 3-year-old girl, "Jenny," using social praise, games, and access to toys as reinforcers of eating behavior. Undesired behaviors were ignored. Her progress to oral feeding was greatly influenced by her health but also by the foods she was given. During a baseline period, it was established that she preferred foods that were sweet and salty with a watery and smooth consistency, for example, strained fruit, canned fruit syrup, soup, juice, and water. It was possible to increase her intake of these foods over time and to increase their thickness to some extent, but it was almost impossible to gain acceptance of solid foods. Gutentag and Hammer suggested that her difficulty with solids was due to oral-motor delay, because she swallowed foods whole and was unable to copy chewing motions. From her early history, it can be deduced that she never made the transition to solid foods during the second half of the first year. This may be consistent with Lister and Illingworth's hypothesized "sensitive" period for learning to chew. It is also possible that Jenny's tendency to swallow foods whole was a sensory-based response—she may not have liked the taste and texture of the food and/or may have been hypersensitive to touch, especially at the sides of her mouth—and therefore tried to remove the food from her mouth as quickly as she could.

Another problem with many of these behavioral approaches is that they are highly labor intensive and thus involve considerable monetary cost. Hospital inpatient stays or numerous visits to clinics are required as the intervention is highly prescriptive. This highlights the importance of trying to establish at least some oral feeding during the time that tube feeding is necessary so that such interventions are less likely to be needed.

Conclusion

What this review highlights is that there are a number of factors that may have the potential to disrupt the normal development of eating and drinking in children who are tube fed, and it may be the subtle interaction of these factors that causes some children to have long-term feeding difficulties that may prevent weaning off the tube when it is no longer medically necessary or may continue after tube feeding is terminated. There is a paucity of literature that goes beyond the descriptive and speculative and tests out specific hypotheses. The relative significance of these factors—age when tube fed, duration and method of tube feeding, medical complications, aversive experiences, experience of oral feeding, parental anxiety, and feeding style—in determining oral feeding outcomes is essential if we are to develop practices to support oral feeding while tube feeding is ongoing, thereby minimizing the likelihood of later feeding difficulties. In addition, further research is needed to compare different methods of weaning children off the tube, including the use of overnight or a daily bolus regimen, gastrostomy or NG feeding, and the effectiveness of intensive versus slower transitions from tube to oral feeding. It is not an easy area in which to set up carefully controlled research designs because of the diverse population of children who are tube fed. However, a prospective study would enable researchers to ensure that all the necessary data are collected to allow for comparison between variables. This might include medical diagnosis, type and schedule of tube feeding, child temperament, exposure to taste and texture, oral-motor skill developmental, parental perceptions of feeding and parental feeding management style.

References

1. Warady BA, Belden B, Kohaut E: Neurodevelopmental outcome of children initiating peritoneal dialysis in early infancy. *Pediatr Nephrol 13:*759–765, 1999
2. Ciotti G, Holzer R, Pozzi M, Dalzell M: Nutritional support via percutaneous endoscopic gastrostomy in children with cardiac disease experiencing difficulties with feeding. *Cardiol Young 12:*537–541, 2002
3. Hofner G, Behrens R, Koch A, Singer H, Hofbeck M: Enteral nutritional support by percutaneous endoscopic gastrostomy in children with congenital heart disease. *Pediatr Cardiol 21:*341–346, 2000
4. Blackman JA, Nelson CLA: Reinstituting oral feedings in children fed by gastrostomy tube. *Clin Pediatr 24:*434–438, 1985
5. Senez C, Guys JM, Mancini J, Paz Paredes A, Lena G, Choux M: Weaning children from tube to oral feeding. *Childs Nerv Syst 12:*590–594, 1996
6. Dello Strologo L, Principato F, Sinibaldi D, Appiani AC, Terzi F, Dartois AM, Rizzoni G: Feeding dysfunction in infants with severe chronic renal failure after long-term nasogastric tube feeding. *Pediatr Nephrol 11:*84–86, 1997
7. Measel CP, Anderson GC: Nonnutritive sucking during tube feeding: Effect on clinical course in premature infants. *JOGN Nurs 8:*265–272, 1979
8. Field T, Ignatoff E, Stringer S, Brennan J, Greenberg R, Widmayer S, Anderson GC: Non-nutritive sucking during tube feedings: Effects on preterm neonates in an intensive care unit. *Pediatrics 70:*381–384, 1982
9. Bernbaum JC, Pereira GR, Watkins JB, Peckham GJ: Nonnutritive sucking during gavage feeding enhances growth and maturation in premature infants. *Pediatrics 71:*41–45, 1983
10. Di Pietro JA, Cusson RM, Caughy MO, Fox NA: Behavioral and physiologic effects of nonnutritive sucking during gavage feeding in preterm infants. *Pediatr Res 36:*207–214, 1994
11. Gill NE, Behnke M, Conlon M, McNeely JB, Anderson GC: Effect of nonnutritive sucking on behavioral state in preterm infants before feeding. *Nurs Res 37:*347–350, 1988
12. Gill NE, Behnke M, Conlon M, Anderson GC: Nonnutritive sucking modulates behavioral state for preterm infants before feeding. *Scand J Caring Sci 6:*3–7, 1992
13. De Curtis M, McIntosh N, Ventura V, Brooke O: Effect of non-nutritive sucking on nutrient retention in preterm infants. *Pediatrics 109:*(5)888–890, 1986
14. Mizuno K, Ueda A: Development of sucking behavior in infants who have not been fed for 2 months after birth. *Pediatr Int 43:*251–255, 2001
15. Rochat P, Goubet N, Shah B: Enhanced sucking engagement by preterm infants during intermittent gavage feedings. *J Dev Behav Pediatr 18:*22–26, 1997
16. Pinelli J, Symington A: Non-nutritive sucking for promoting physiologic stability and nutrition in preterm infants (Cochrane Review). *The Cochrane Library, Issue 2*. Chichester, UK: John Wiley & Sons, Ltd., 2004
17. Bazyk S: Factors associated with the transition to oral feeding in infants fed by nasograstric tubes . *Am J Occup Ther 44:*1070–1078, 1990
18. Morris SE, Klein MD: *Pre-feeding skills*. 2nd ed. San Antonio, TX: Therapy Skill Builders, 2000
19. Hawdon JM, Beaurgard N, Slattery J, Kennedy G: Identification of neonates at risk of developing feeding problems in infancy. *Dev Med Child Neurol 42:*235–239, 2000
20. Cerro N, Zeunert S, Simmer KN, Daniels LA: Eating behavior of children 1.5–3.5 years born preterm: Parents' perceptions. *J Paediatr Child Health 38:*72–78, 2002
21. Pelchat ML, Rozin P: The special role of nausea in the acquisition of food dislikes by humans. *Appetite 3:*341–351, 1982
22. Rozin P: One-trial acquired likes and dislikes in humans: disgust as a US, food predominance, and negative learning predominance. *Learn Motiv 17:*180–189, 1986
23. Mathisen B, Worrall L, Masel J, Wall C, Shepherd RW: Feeding problems in infants with gastro-oesophageal reflux disease: a controlled study. *J Paediatr Child Health 35:*163–169, 1999
24. Skuse D: Identification and management of problem eaters. *Arch Dis Child 69:*604–608, 1993

25. Meyer Palmer M, Heyman MB: Assessment and treatment of sensory-versus motor-based feeding problems in very young children. *Infants Young Child 6:*67–73, 1993
26. Shauster H, Dwyer J: Transition from tube feedings to feedings by mouth in children: Preventing eating dysfunction. *J Am Diet Assoc 96:*277–281, 1996
27. Tawfik R, Dickson A, Clarke M, Thomas AG: Caregivers' perceptions following gastrostomy in severely disabled children with feeding problems. *Dev Med Child Neurol 39:*746–751, 1997
28. Khattak IU, Kimber C, Kiely EM, Spitz L: Percutaneous endoscopic gastrostomy in paediatric practice: complications and outcome. *J Pediatr Surg 33:*67–72, 1998
29. Samson–Fang L, Butler C, O'Donnell M: Effects of gastrostomy feeding in children with cerebral palsy: an AACPDM evidence report. *Dev Med Child Nuerol 45:*(6)415–426, 2003
30. Craig GM, Scrambler G, Spitz L: Why parents of children with neurodevelopmental disabilities requiring gastrostomy feeding need more support. *Dev Med Child Neurol 45:*(3)183–188, 2003
31. Geertsma MA, Hyams JS, Pelletier JM, Reiter S: Feeding resistance after parenteral hyperalimentation. *Am J Dis Child 139:*255–256, 1985
32. Morris SE: Development of oral-motor skills in the neurologically impaired child receiving non-oral feedings. *Dysphagia 3:*135–154, 1989
33. Scarborough DR: Consequences of interrupting normal neurophysiological development: Impact on preswallowing skills. Ph.D. Thesis, University of Cincinnati, 2002
34. Illingworth RS, Lister J: The critical or sensitive period, with special reference to certain feeding problems in infants and children. *J Pediatr 65:*839–848, 1964
35. Committee on Medical Aspects of Food Policy (COMA): Department of Health, Report on Health and Social Subjects 45, *Weaning and The Weaning Diet: Report of Working Group*. London: HMSO, 1994
36. Reilly S, Skuse D, Mathisen B, Wolke D: The objective rating of oral-motor functions during feeding. *Dysphagia 10:*177–191, 1995
37. Gisel EG: Effect of food texture on the development of chewing of children between six months and two years of age. *Dev Med Child Neurol 33:*69–79, 1991
38. Birch LL, Marlin DW: I don't like it; I never tried it: effects of exposure on two-year-old children's food preferences. *Appetite 3:*353–360, 1982
39. Harris G, Booth DA: Sodium preference in food and previous dietary experience in 6-month-old infant. *IRCS Med Sci 13:*1177–1178, 1985
40. Harris G, Thomas A, Booth DA: Development of salt taste in infancy. *Dev Psychol 26:*534–538, 1990
41. Wright P: Mothers' ideas about feeding in early infancy. . In: St. James–Roberts I, Harris G, Messer D (eds.) *Infant crying, feeding, sleeping*. New York: Harvester Wheatsheaf, 1993, pp 99–117
42. Harris G: Determinants of the introduction of solid food. *J Reprod Infant Psychol 6:*241–249, 1988
43. Boucher J: MSc project, Birmingham University, UK, 2002
44. Harris G.: Development of taste perception and appetite regulation. In: Bremner G, Slater A, Butterworth G (eds.) *Infant Development Recent Advances*. East Sussex: Psychology Press, 1990
45. Harris G, Macdonald A: Behavioural Feeding Problems in Cystic Fibrosis. 6th Annual North American Cystic Fibrosis Conference Proceedings. *Pediatr Pulmonol Suppl 8:*324.
46. Blissett J, Harris G, Kirk J: Effect of growth hormone therapy on feeding problems and food intake in children with growth disorders. *Acta Paediatr 89:*644–649, 2000
47. Van Dyke DC, Mackay L, Ziaylek E: Management of severe feeding dysfunction in children with fetal alcohol syndrome. *Clin Pediatr (Phila) 21:*(6)336–339, 1982
48. Salzarulo P, Fagioli I, Ricour C: Long term, continuously fed infants do not develop heart rate circadian rhythm. *Early Hum Dev 12:*285–289, 1985
49. Drewett RF: The infant's regulation of nutritional intake. In: St. James–Roberts I, Harris G, Messer D (eds.) *Infant crying, feeding and sleeping*. New York: Harvester Wheatsheaf, 1993
50. Birch LL, Johnson SL, Andresen G, Peters JC, Schulte MC: The variability of young children's energy intake. *N Engl J Med 324:*(4)232–235, 1991
51. Shea S, Stein AD, Basch CE, Contento IR, Zybert P: Variability and self-regulation of energy intake in young children in their everyday environment. *Pediatrics 90:*542–546, 1992
52. Birch LL: Children, parents and food. *Br Food J 95:*11–15, 1993
53. Greene HL, Helinek GL, Folk CC, Courtney M, Thompson S, MacDonell Jr RC, Lukens JN: Nasogastric tube feeding at home: a method for adjunctive nutritional support of malnourished patients. *Am J Clin Nutr 34:*1131–1138, 1981
54. Benoit D, Wang EEL, Zlotkin SH: Discontinuation of enterostomy tube feeding by behavioral treatment in early childhood: A randomised controlled trial. *J Pediatr 137:*498–503, 2000
55. Harris G, Booth IW: The nature and management of eating problems in pre-school children. In: Cooper P J, Stein A (eds.) *Feeding problems and eating disorders in children and adolescents*. Chur: Harwood Academic Publishers, 1987, pp 61–84
56. Gutentag S, Hammer D: Shaping oral feeding in a gastrostomy tube-dependent child in natural settings. *Behav Modif 24:*395–410, 2000