The impact of feeding modalities on infants' orofacial development: Breastfeeding versus bottle-feeding in infancy, a scoping review

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ABSTRACT

Introduction: Exclusive breastfeeding is recommended for at least six months in infants and encouraged up to two years of age. However, only 35% of infants are breastfed up to six months in the US. This rate drops down to 16% for breastfeeding at 12 months. Some authors suggest that breastfeeding also plays an important role in optimal musculoskeletal development of the orofacial system in the infant. On the contrary, bottle feeding could negatively affect these musculoskeletal structures resulting in abnormal development of the stomatognathic system. This review aims to answer the question: "What are the musculoskeletal effects of bottle feeding versus breastfeeding in infants' orofacial development and function?" **Methods:** Online databases (PubMed, ResearchGate, Cochrane; ICL, EBSCO, SCielo) have been searched to identify relevant articles. No limit was set for date, study design and level. **Results:** The search resulted in identifying four systematic reviews and two case control studies. Four literature reviews highlighted great heterogeneity in methodology and findings. Authors agreed that exclusive breastfeeding and breastfeeding duration were associated with optimal development of palate, dentition and myofunctional habits. Bottle feeding, on the other hand, influenced the activity and function of masseter, tongue and temporalis muscles, leading to a V shaped palate and long-term malocclusions. **Conclusion:** There were few large-sample high-quality studies focusing specifically on infants' orofacial development; further research is needed to deepen the knowledge of factors relating to musculoskeletal development during infancy.

Key Words: Breastfeeding, bottle feeding, orofacial complex, stomatognathic development, infants.

Introduction

Exclusive breastfeeding provides multiple benefits, both short and long term, for mother and child.[1] These include immunological, nutritional, cognitive and psychological benefits.[2,3,4,5] Major health organizations such as the World Health Organization, recommend exclusive breastfeeding for at least the first six months of life and up to two years of age.[6] However, breastfeeding is not always initiated and sustained as the exclusive feeding method for infants, so that only 35% of infants appear to be exclusively breastfed at six months in the US and only 16% are still breastfeeding at 12 months of age.[7] Alternative feeding methods, such as bottle feeding, are used in combination with or instead of feeding at the breast.

The greatest craniofacial growth happens in the first four years of life, with facial structures, maxilla and mandible especially, developing more slowly than the cranial vault and cranial base.[8,9] Orofacial bone maturity is reached at 16 years of age. The shape and size of the maxilla and mandible are therefore subject to remodeling until that age. As the size of the skull base and vault are influenced by brain growth, the masticatory muscles and the myofunctional habits of the infant influence orofacial development. Since breastfeeding is one of the primary and most complex activities engaging the infant, this raises the question of whether infant feeding modalities could influence the malleable orofacial anatomy.[9]

This hypothesis is reflected by the medical literature as researchers suggest that breastfeeding influences the stomatognathic and maxillofacial development and function.[10] On the other hand, bottle feeding may engage these oral-motor structures differently and potentially cause changes in the function of those same structures.[11]

This hypothesis should be of interest to healthcare professionals caring for the pediatric patient, particularly from birth to four years of age.

By understanding the risks and benefits of breastfeeding versus bottle feeding, clinicians can effectively communicate to nursing mothers and help them to make an informed decision about feeding modalities. Furthermore, many chiropractors care and work with neonates with breastfeeding issues. This review supports the need for and importance of early resolution of breastfeeding difficulties. Finally, by identifying the oral-motor dysfunctions that contribute to poor orofacial development, the chiropractor can focus on investigating potential "corrective" techniques in order to restore competency and promote the correct musculoskeletal (MSK) function and development.

In order to give a comprehensive view of the musculoskeletal effects of feeding modalities, two aspects were highlighted in this report: the effect of breastfeeding versus bottle feeding on the muscle activation in healthy infants (without congenital conditions such as cleft palate or ankyloglossia) and the effects of prolonged and exclusive breastfeeding versus bottle-feeding on orofacial anatomy.

This literature review addressed the question: "What are the musculoskeletal effects of bottle feeding versus breastfeeding in infants' orofacial development and function?"

Methods

This is a scoping review addressing the question: "What are the musculoskeletal effects of bottle feeding versus breastfeeding in infants' orofacial development and function?"

Literature search

A primary literature search was carried out on PubMed, Cochrane database and ICL for peer reviewed literature. This primary search also aimed to identify correct terminology and background literature. Search terms included both free text terms and MeSH terms, used alone and in combination: "infants/infant"; "breastfeeding" AND/OR "bottle feeding" OR "feeding" "effect" OR "risk factors"; "orofacial" OR "stomatognathic"; "malocclusion."

A second search was carried out with EBSCOhost and ResearchGate to identify free full text articles, which were then critically appraised following the CASP checklist (Critical Appraisal Skills Program (CASP).[12]

Search terms included both free text terms and MeSH terms, used alone and in combination: "infants/infant"; "breastfeeding" AND/OR "bottle feeding" OR "feeding" "effect" OR "risk factors"; "orofacial" OR "stomatognathic"; "malocclusion."

A hand search was then carried out in order to identify relevant articles among the references of the selected studies.

Selecting sources of information

One author searched, critically appraised and selected articles for this paper; the author was not blinded to the research question.

Inclusion criteria consisted of English language research articles investigating breastfeeding and bottle feeding effects on the development of orofacial structures in terms of size and shape; articles providing data on feeding modalities, on consistency of breastfeeding and bottle feeding (duration, frequency and differentiation among different levels of breastfeeding and bottle feeding: exclusive, almost exclusive and partial) in infants and their influence on musculoskeletal structures. Studies investigating the effects of feeding practices on older subjects (children and toddlers > 12 months old) were consulted if providing retrospective data on the same subjects at <12 months old but not included in the results summary. Studies were excluded if not relevant; focusing on infants with congenital malformation or conditions linked to abnormal orofacial development; or if methodology was insufficiently described or absent. Other studies, such as commentaries and experts' reviews were consulted for background literature. Relevance was determined through title, abstract and full text. In order to decrease selection bias and avoiding exclusion of relevant articles no limit was set for level of evidence, study design, or date.

Results evaluation

There were 33 records selected for full-text evaluation and 27 were discarded due to lack of relevance. The articles included were appraised according to the CASP checklist. Studies were evaluated and presented according to their design. Two tables were produced: one for the observational studies, one for literature reviews. The tables identified authors; study design, year of publication, methodology, outcome. A "comment" section was included in the summary tables to define CASP grading and potential limitations of each study. CASP checklist is not a grading system. In this case it was used in order to highlight those areas of the studies which could lack of information or clear methodology. These areas were then discussed in the discussion paragraph of this paper.

Studies evaluated with CASP checklist:

- Inoue et al.,1996 Control study. CASP: 10/11 item 7 "can't tell"
- Gomes et al.,2006 Cross-sectional study. CASP 10/11 item 7 "can't tell"
- Abreu et al.,2016 Systematic review. CASP: 9/10 item 8 "no"
- Hermont et al., 2015 Systematic review. CASP 10/10
- Peres et al., 2015 Systematic review. CASP 10/10
- Thomas et al., 2018 Systematic review. CASP 10/10

Results

Six studies were included in the results summary; four systematic reviews and two case control studies were appraised with the CASP checklist.[12] See figure 1 (next page) for PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) chart.

Four systematic reviews endorsed a protective effect of breastfeeding against malocclusions (MOs) such as cross bite, posterior cross bite, over-jet and crowding.[13,14,15,16] These studies reported data from prospective and retrospective cohort studies about breastfeeding duration in infancy versus bottle feeding. The retrospective data, such as type of feeding received and duration, were primarily col-

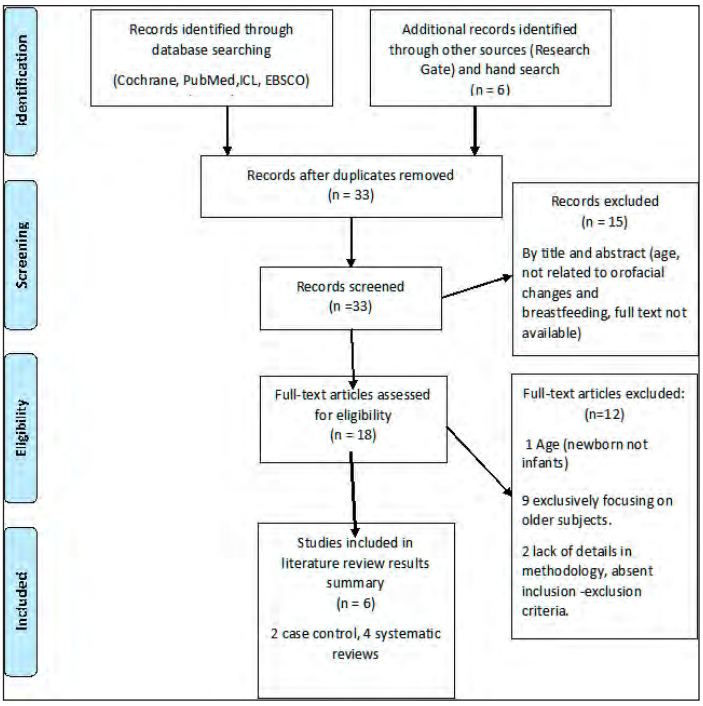

Figure 1. PRISMA 2009 Flow Diagram[32]

lected via questionnaires. The presence of musculoskeletal changes in the orofacial structures of children was assessed at different ages (3 to 12 years). These studies suggested that breastfeeding and duration of breastfeeding was inversely proportional to the development of MOs in childhood. All four of the reviews highlighted how the evidence available is heterogeneous in both findings and methodology.

Two case control studies focused on myofunctional changes on infants exclusively, during breastfeeding and bottle feeding.[17,18]

These studies reported significantly lower activation of masseter and temporalis muscles in bottle fed infants than breastfed infants.

In one double-blind cross-sectional study of 60 infants' (age 30 to 90 days) participants were divided into three groups, with a convenience sample of 20 subjects in each group. Group 1 (G1) who were exclusively breastfed by parents; group 2 (G2) was breastfed and bottle fed and group 3 (G3) was breastfed but could receive cup feeding during electromyography. The median age for each group was 83.50 days for G1, 82 days for G2 and 84 days for G3. Masseter, temporalis and buccinator were measured with EMG one time during the study. The statistical analysis showed that mean contraction of the masseter in the breastfeeding group (median of 80 µv) differed significantly from that of the bottle feeding group (median of 50 µv). Temporalis muscle activation differed between breastfeeding and bottle feeding groups too, showing higher mean activation of temporalis in the breastfeeding group (median of 111.25 µv) and cup feeding (median of 96.04 µv) groups VS lower activation in the bottle feeding group (median of 48.03 µv).[18]

Breastfeeding and cup feeding showed similar and higher activity of masseter and temporalis muscles (mean contraction measurements and range of contraction measurements) on EMG compared to bottle feeding. On the other hand, bottle fed infants showed higher activation of buccinator muscle, however this difference was only observed when measuring range of contraction and was not statistically significant.[18]

In another study, 36 infants (two to six - months of age) were divided into three groups. It included one experimental group who had never experienced breastfeeding or abandoned it within two months after birth and used a chewing type bottle mimicking breast shape and two control groups. These control groups included 12 exclusively breastfed infants and 12 infants who were already accustomed to bottle feeding only before the research started. Mean age for each control group at time of measurement was not reported. The EMG measurements showed higher masseter activation in the breastfed (56.3 µv) and chewing-type bottle groups (55.7 µv). In the bottle fed group, the masseter showed lower activation (27.9 µv) and its activity occasionally disappeared during feeding.[17] The research concluded that higher masseter activation is present in breastfed and chewing-type artificial teat fed infants and this muscle activity was significantly lower in bottle feeding.

Additionally, one narrative review and two commentaries on craniofacial development in association with feeding modalities in infants were included.[8,10,19]

Palmer described how, in breastfeeding, oral vacuum pressure required for milk extraction is given by higher energetic jaw compression and peristaltic motion of the tongue.[8] During bottle feeding, the tongue exerts a strong piston-like movement and protrusion to stop milk overflow. This powerful suction activates the oral musculature in a non-physiological way and results in the cheeks being drawn in and pressed against the gums during feeding. This forceful suction is not required in breastfeeding as the entire oral and perioral musculature (including tongue, masseter, temporalis and pterygoids) assist suckling in a coordinated and physiological manner.[8,18,19]

Tables 1 and 2 (next page) provide a result summary of muscular impact of type of infant feeding.

Discussion

Studies evaluation

The purpose of this scoping review was to investigate the

AUTHOR	METHOD	OUTCOME	COMMENT
Inoue et al, 1996	Case control, EMG study of masseter activation in three groups of infants aged 2-6 months: GA)12 subjects offered bottle teats chewing type; GB)12 s breastfed exclusively; GC)12 bottle fed with sucking type bottle.	Significant P. 0.01 lower activation of masseter muscles in sucking type bottle feed subjects compared to breastfed and chewing type bottle fed subjects. In bottle feed subjects masseter activation occasionally disappeared during feeding.	CASP 10/11 — all but item 7: "can't tell" Very small subject group.
Gomes et al, 2006	Cross sectional study, surface EMG study of on 60 full term healthy infants aged two to three months. GA) breastfeeding only GB) breastfeeding plus bottle feeding GC) breastfeeding plus cup feeding.	Masseter and temporalis activation was smaller in bottle feeding group than BF and Cup feeding and BF groups (p. 0.05). Buccinator activation was slightly higher in bottle-fed group, but not statistically significant (P > 0.05).	CASP 10/11 Item 7 "can't tell" Very small subject group.

Table 1. Case-Control EMG studies. BF: Breastfeeding; G: Group; MOs: Malocclusion; MSK: Musculoskeletal.

AUTHOR	METHOD	OUTCOME	COMMENT
Abreu et al, 2016	Systematic review of epidemiological studies addressing BF, bottle feeding and mixed feeding (bottle and BF) and risk of MOs in mixed or/and permanent dentitions.	Six studies evaluated reveal heterogeneity of results. Evidence based on low-quality cross-sectional studies. The findings do not support an association between BF and bottle feeding and the occurance of MOs in mixed and permanent dentitions.	CASP – 9/10 all but item 8 "no." Limitations due to articles selected: heterogeneity of methodology, meta-analysis not possible, insufficient data. Does not report MSK changes at infant age.
Hermont et al, 2015	Systematic review of observational studies addressing BF and BF duration in association with MOs compared to bottle feeding.	Ten cohort studies evaluated revealing protective effect of BF against MOs and direectly proportional to duration of BF. Bottle feeding associated with posterior cross bite and overjet in a study. However, evidence and data are not sufficient.	CASP – 10/10 Limitations intrinsic to studies available: heterogeneity in methodology and findings. Does not report MSK changes at infant age.
Peres et al, 2015	Systematic review and meta analysis investigating protective effect of BF and BF duration on MOs in children.	Forty-one articles evaluated in the meta analysis revealing protective effect of BF against MOs.	CASP – 10/10 Limitations intrinsic to heterogeneity of single studies. Does not report MSK changes at infant age.
Thomas et al, 2018	Systematic review and met analysis of observational studies addressing BF and BF duration in association with MOs compared to bottle feeding.	Forty-two studies evaluated revealing protective effect of BF against MOs and directly proportional to duration of BF. BF children have adequate growth of maxillary and mandibular bone bases in frontal, transverse and sagittal planes. MOs associated with BF<6 months or bottle feeding.	CASP – 10/10 Potential recall bias, high statistical heterogeneity. Non-nutritive sucking habits could be interpreted as confounders or mediators. Does not report MSK changes at infant age.

Table 2. Systematic Reviews. BF: Breastfeeding; G: Group; MOs: Malocclusion; MSK: Musculoskeletal.

association between infant bottle and breastfeeding with the development of malocclusions (MOs) in childhood and adolescence.

All in all, there is a paucity of studies investigating abnormal orofacial development in infants (1 to 12 months). Most of the literature focused on the role of exclusive breastfeeding and bottle feeding on long term MSK changes. These changes were observable in an older age group (three to twelve years) and included different types of MOs : anterior and posterior cross bite, crowding, overjet and other forms of abnormal orofacial development, such as changes in tongue resting position and maxillary arch shape.[20,21,22]

Different activation of masseter and temporalis during breastfeeding

It goes without saying that the musculoskeletal structures in the infant are very malleable in the early stage, therefore repeated muscular action, changing the internal and external pressures applied, can affect the anatomy of the stomatognathic system.[19] The two electromyography (EMG) studies determined that masseter and temporalis activation was lower in bottle fed infants. It is important that we critically assess these studies because they were carried out on relatively small samples and consisted of a single measurement in time.[17,18] That said, these findings do corroborate other authors' description of breastfeeding mechanism compared to bottle feeding, with higher masseter and temporalis activation leading to energetic jaw compression.[8,19] On the other hand, a higher range of buccinator muscle activity was observed during bottle feeding, although this finding was not significant. The buccinator is not always considered a key breastfeeding muscle. This finding does correlate with statements by other authors who reported this higher activation with bottle feeding.[18]

This forceful suction would result in drawing inwards and thickening the cheeks, applying pressure to the malleable gums, thus compromising dentition.[23]

Tongue action during bottle feeding may promote malocclusions

Certain authors suggested that while in the breastfeeding infant the tongue executes a peristaltic motion with involvement of the intrinsic muscles of the tongue, in bottle feeding this is substituted with a forceful protrusion, mainly aimed to control milk overflow.[8,20]

We could speculate that in bottle feeding the genioglossus is highly activated and responsible for this protrusion. Although peristalsis of the tongue has been recorded in infants feeding from an artificial nipple, thus showing that intrinsic muscles are activated during bottle feeding too, there are no studies comparing the specific tongue's dynamics in bottle and breastfed infants.[24] Hypotonicity of the tongue in bottle fed infants would explain why bottle fed infants tend to rest the tongue on the mandibular arch. In the breastfeeding infant, the tongue rests on the maxillary arch.[20,21]

Tongue resting on mandibular arch is associated with maxillary arch atresia, a dentofacial deformity consisting of a narrowing of the upper arch and a deep gothic palate.

A "V" shaped palate is in fact seen in many MOs cases, especially posterior cross bite.[21] On the contrary, natural breastfeeding has been shown to directly enhance the development of the "U" shaped palate in two ways. First, by requiring optimal activation of the tongue by peristaltic motion,[19] and second, by exerting repeated pressure on the malleable infant's palate with the mother's breast, whose anatomy matches the infants' oral cavity.[8]

Long-term impact of feeding modalities

The literature points out how feeding modalities can affect children's orofacial development in the long term and that many MSK changes occur, they are gradual and develop over time.[25,31] The greatest changes and growth in orofacial structures, especially maxilla and mandibula, take place in the first four years of life. This leaves a broad time frame during which compensations leading to MSK changes can develop and perpetuate. This would possibly explain why MOs and myofunctional changes are observed after infancy and children > 5 years old.[26,27]

Other factors could influence the child's orofacial development after infancy in that time frame as well. Carrascoza reported that the suboptimal tongue resting position seen in bottle fed infants predisposes to suboptimal position of the incisors as well as posterior cross bite in children > 12 months. Their study on 202 children (age four years old) who were exclusively breastfed for the first six months of life and then switched to other type of feeding were divided into 101 bottle users and 101 cup users for drinking. The study reported how the subsequent bottle feeding was associated with suboptimal tongue resting position ($p < 0.0001$), mouth breathing ($p < 0.0001$) and maxillary arch atresia ($p = 0.0206$). These findings highlighted how, regardless of early breastfeeding, the use of bottle versus cup feeding can predispose to MSK changes even after infancy.

Furthermore, the same authors reported how hypertrophy of buccinator muscle, required for forceful suction in bottle feeding, would compromise optimal mandibular growth and function.[20,27]

Other oral habits, such as pacifier use, can influence orofacial development

Studies highlighted that, when evaluating risk factors for suboptimal orofacial MSK development, feeding modali-

ties such as breastfeeding and bottle feeding in the first year of life be the only factors considered. In fact, regardless of the protective role of exclusive breastfeeding in first six months of life, other oral habits can develop and influence this positive outcome.[20] The aetiologies of suboptimal MSK development have to be considered in their multifactorial and complex dynamics.

Peres demonstrated that children who used a pacifier regularly between 12 months and four years of age developed an anterior open bite 3.6 times greater than those who did not, while children with the habit of digital sucking at six years of age had a 1.4 times greater incidence than those who did not.[28] The same author stated that bottle feeding fails to promote optimal jaw movement and the natural swallowing mechanism, confirming the findings by Carrascoza.[20,28]

Breastfeeding as a protective factor against MOs

It is important to point out that two studies revealed how breastfeeding is protective against MOs.[29,30] Breastfeeding promotes optimal mandibular function and decreases the risk of anterior open bite, posterior cross bite and overjet.[29,30] Furthermore, it protects against the development of both non-nutritive sucking habits and it promotes nasal breathing.[29,30] This is in contrast to bottle feeding which promotes mouth breathing. Mouth breathing is associated with development of maxillary arch atresia and MOs.[20,21]

According to a literature review, children who breastfed over six months had lower chance of overjet, anterior and posterior cross bite.[19] This was an oral health study nested in a birth cohort study conducted on 1303 five year old participants.[25] The prevalence of anterior open bite was 43.0% lower in children who were exclusively breastfed up to six months of age compared with those who were not breastfed. Furthermore, duration of exclusive breastfeeding was found inversely proportional to the prevalence of MOs (72.0% lower in children who were breastfed up to 6 months, 43.0% lower in children breastfed between 3 and 5.9 months).[25]

The literature therefore highlighted how breastfeeding can have an important protective role against abnormal orofacial growth and development. The problem is that its beneficial effects could be buffered and minimized by other influencing factors taking place during or after cessation of lactation, including bottle feeding, thumb sucking, pacifier use and different causes of mouth breathing (from the non-pathological predisposition caused by bottle feeding to other pediatric conditions, such as adenoid hypertrophy and upper airway obstruction).[20,21,29,30,33] The literature also stressed how duration and consistency of feeding modality impact the orofacial development.[25,27]

Orofacial bone maturity is not reached until 16 years of age, with the first four years of life being the time of greatest orofacial growth and change. There is then a great span of time when minor and major MSK changes may occur. It is important to remember how a great heterogeneity of factors interact with each other over time, and how these factors could influence change at different times in the child's development.

Limitations

Limitations of this scoping review include the lack of systematic literature reviews on this topic related to infants specifically, the diversity of methods and findings present in the literature, the intrinsic limitation of certain study designs, which acquired data retrospectively and through questionnaires (this leading potentially to recall bas) and the paucity of literature on infants specifically. In fact, certain confounders, such as non-nutritive oral habits (pacifier, thumb sucking) could have influenced the results. Finally, literature search as well as appraisal of papers was carried out by a single, non-blinded author, thus increasing the risk of collection and inclusion bias.

Conclusion

Exclusive breastfeeding and longer duration of breastfeeding have been reported to be a positive influence on the development of orofacial structures during the first four years of life. Bottle feeding is instead associated with the development of malocclusions in childhood and disruptive myofunctional habits in infants. It is still the case that more research is required to reduce confounding factors since the child's craniofacial growth results from complex interaction between feeding techniques, their consistency, duration, presence or absence of non-nutritive sucking habits.

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