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Feeding practices and Jaw Development: A Comprehensive Literature Review of Their Interconnected Dynamics

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Abstract

Objective: Nutritive sucking plays a crucial role in infant growth and craniofacial development. This review examines the impact of breastfeeding, bottle-feeding, and non-nutritive sucking on jaw development and the risk of malocclusion, with a focus on early feeding practices, weaning and food consistency.

Methods: A comprehensive search was conducted across several databases, including PubMed/Medline, Scopus and Web of Knowledge. Studies involving human subjects published in English were selected. The review included observational studies, cross-sectional studies and clinical trials. Keywords used in the search included "nutritive sucking," "jaw development" and "malocclusion."

Results: The findings showed that breastfeeding promotes optimal jaw development and reduces malocclusion risks by engaging oral muscles. Bottle-feeding, including a more passive sucking action, does not provide the same benefits and is associated with misalignments like crossbite and open bite. Non-nutritive sucking habits, such as pacifier use and thumb-sucking, further contribute to malocclusion. The consistency of foods during weaning also plays a role, with harder foods encouraging jaw muscle development, while soft foods may hinder proper growth.

Conclusions: Breastfeeding supports healthy craniofacial development and lowers the risk of malocclusions. Bottle-feeding and non-nutritive sucking behaviours are linked to jaw misalignments. Early feeding practices, weaning and food texture are critical factors in jaw health and should be considered in craniofacial development strategies.

Keywords: Breastfeeding; Jaw development; Malocclusion; Nutritive sucking

Introduction

Nutritive sucking is a complex oral sensorimotor process that plays a fundamental role in infant growth and development. This process relies on the synchronized movements of the tongue, jaw, and facial muscles [1], which contribute to the structural and functional maturation of the craniofacial complex. Breastfeeding is often regarded as the most natural method of infant feeding, providing nutritional and immunological benefits while also engaging the oral musculature in ways that may support craniofacial growth [2]. The active effort required to extract milk from the breast is thought to stimulate the functional matrix of the oral cavity, potentially promoting proper alignment and development of the jaw and associated structures [3,4]. Conversely, bottle-feeding requires less effort, which some researchers suggest may lead

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to under-stimulation of the oral and facial musculature and an increased risk of developmental challenges, including malocclusion [5,6]. However, other studies indicate that bottle-feeding alone is not necessarily a determinant of malocclusion and that genetic and other environmental factors also play significant roles in craniofacial development [7,8].

Malocclusion is a multifactorial condition characterized by disruptions in the normal growth and alignment of facial bones and dental arches. While feeding practices have been proposed as a contributing factor, the condition is also influenced by genetic predispositions, oral habits, and other environmental factors [7,8]. Malocclusion can impact essential oral functions such as mastication, swallowing, and speech, and it has been associated with an increased risk of periodontal disease and dental trauma [9]. Additionally, the psychosocial effects of altered dentofacial aesthetics underscore the broader implications of malocclusion on quality of life.

Certain populations face unique challenges in craniofacial development. Infants with genetic syndromes, such as Down syndrome, may present with hypotonia of the tongue and oropharyngeal structures, affecting their ability to suck and swallow efficiently. Similarly, anatomical anomalies that disrupt oral and nasal cavity separation during feeding can further complicate nutritive sucking and craniofacial development [10,11]. These considerations highlight the need for individualized feeding strategies to support vulnerable infants.

Despite extensive research in this area, findings remain inconsistent, particularly regarding the long-term effects of different feeding practices on jaw and facial development. Some studies suggest a clear association between breastfeeding and optimal craniofacial outcomes, while others emphasize the multifaceted nature of these developmental processes. The purpose of this comprehensive literature review is to critically examine the existing research on the impact of nutritive sucking- including breastfeeding, bottle-feeding, feeding patterns, and weaning practices- on jaw development and the incidence of malocclusion.

Methods and Materials

A broad search of relevant studies was conducted across multiple databases, including PubMed/Medline, Scopus, Web of Knowledge, Embase, SciELO, and LILACS, as well as in gray literature to ensure a comprehensive inclusion of relevant studies, aiming to synthesize existing research on the relationship between nutritive and non-nutritive sucking and jaw development, with a focus on how different feeding practices impact craniofacial growth and the incidence of malocclusion

The search strategy utilized specific keywords and Boolean operators: ((nutritive sucking OR breastfeeding OR bottle-feeding OR feeding patterns) AND (jaw development OR malocclusion OR craniofacial growth)). Searches were refined to include studies published in English, focusing on human subjects, with no strict limitation on publication year to accommodate foundational and contemporary research.

The review included studies from diverse research methodologies, including observational studies, cross-sectional studies, and clinical trials, but excluded those focused-on adults or populations with specific medical conditions unrelated to early feeding behaviors. Non-nutritive sucking behaviors were also reviewed to understand their potential effects on jaw alignment and malocclusion. Relevant studies were selected based on their alignment with the review's focus on the early stages of feeding and jaw development. The review aimed to highlight trends and patterns across literature, identify knowledge gaps and provide a comprehensive narrative on how early feeding behaviours influence craniofacial health and development.

Results

I. Normal Jaw Development and Malocclusion

The development of the human jaw is a complex and highly coordinated process, critical to forming both functional and aesthetic oral structures. The harmonious interplay between static and dynamic components of the stomatognathic system ensures balanced relationships necessary for vital functions such as sucking, respiration, speech, chewing and swallowing. These activities shape the maxillofacial system and determine the positioning of teeth within the dental arches, forming the foundation of oral health [12,13]. However, disruptions in this intricate process can lead to malocclusion, a prevalent developmental disorder with far-reaching implications.

Normal Jaw Development: A Foundation for Oral and Facial Health

Jaw development begins during the early embryonic stages, with the first and second pharyngeal arches forming the mandible and maxilla. Initially cartilaginous, these structures ossify into bone and undergo extensive remodeling driven by genetic, hormonal and environmental factors [14]. The first four years of life are particularly crucial, while approximately 90% of facial growth is completed by age 12 [15]. During this time, key functional activities like sucking, chewing and swallowing generate biomechanical forces which shape the jaws. For example, nutritive sucking during breastfeeding promotes balanced growth of the maxilla and mandible, fostering harmonious occlusion and alignment of the dental arches.

Interestingly, although there may be differences between males and females regarding the absolute changes in maxillary and mandibular arch widths during growth, when

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the percent change is compared, no significant differences were observed. This lack of statistical or clinical significance suggests that studying male and female infants or newborns together remains valid for understanding overall jaw development trends [16]. These findings underscore the consistent influence of environmental and functional factors, regardless of gender, in shaping the development of the maxillofacial structures.

The maxilla, a complex anatomical structure, grows primarily through sutural expansion and is characterized by its downward and forward displacement. This growth follows an intramembranous pattern, influenced by the nasal septum and sutural activity, which is most prominent until around age 7 [17]. After this period, growth slows and involves a combination of apposition and resorption, as well as the effects of tooth eruption and surrounding muscular activity. As teeth erupt, the alveolar process develops, increasing the vertical dimension of the maxilla and contributing to overall maxillofacial balance. The mandible, a dynamic and adaptable bone, undergoes more complex growth. Like the maxilla, it grows downward and forward overall, but its posterior region, including the ramus, grows upward and backward through endochondral ossification at the condylar cartilage. This is complemented by remodeling along the posterior border of the ramus, which allows for elongation and adapts to the expanding facial skeleton. Initially, mandibular growth is concentrated at the condyle and posterior ramus, with significant remodeling that aligns the jaw with the craniofacial complex. Mandibular growth, like maxillary growth, is influenced by functional factors such as mastication, tooth eruption, and muscle activity. The eruption of the teeth increases alveolar ridge height, enhancing the vertical dimension and ensuring functional occlusion. While growth is most pronounced during early childhood, it gradually slows as skeletal maturity is reached, maintaining harmony within the craniofacial structure [17].

The mixed dentition phase, starting with the eruption of the first permanent molars around age 6, is a critical period for occlusion development. During this phase, the transition from primary to permanent dentition involves interconnected processes that establish the definitive arrangement of teeth. Notably, the width of the upper dental arch increases more significantly than that of the lower arch, particularly during the eruption of permanent posterior teeth. This differential growth ensures the proper alignment of the maxilla and mandible, enabling efficient function and aesthetics [18,19].

Nutritional adequacy, particularly the intake of calcium and vitamin D, plays a pivotal role in supporting bone growth during these developmental phases [20]. Disruptions such as congenital anomalies, trauma or habits like thumb-sucking and mouth breathing can interfere with the natural trajectory of jaw development. Understanding this progression is essential for identifying early deviations and implementing interventions to ensure optimal oral health and facial balance.

Malocclusion: A Common Disruption of Jaw Harmony

Malocclusion is a developmental disorder that impacts the relationship between the jawbones, teeth, and soft tissues. It manifests in various forms, ranging from minor crowding and spacing issues to significant skeletal discrepancies, such as underbites, overbites, or crossbites [21]. Dental crowding is among the most common presentations, while other forms, such as posterior crossbite and asymmetries, may result from transverse changes in maxillary growth. The upper intermolar distance is often used as a key indicator of transverse maxillary development, providing insight into potential risk factors for malocclusion [22].

The etiology of malocclusion is multifactorial, involving genetic predisposition, gender, socioeconomic status, feeding practices and oral behaviors such as prolonged pacifier use, thumb-sucking, or tongue thrusting [23]. Orofacial functions like suction, swallowing, mastication, and speech play a dual role, stimulating normal maxillofacial development while potentially influencing the positioning of teeth [24,25].

Untreated, malocclusion can result in a range of complications, including functional difficulties with chewing, impaired speech, and increased risk of temporomandibular joint (TMJ) disorders. Poor oral hygiene often accompanies severe misalignments, as crooked teeth are harder to clean, increasing susceptibility to decay and periodontal disease. Beyond functional concerns, severe malocclusions can affect facial aesthetics and self-esteem, highlighting their impact on overall well-being [26].

Intervention strategies depend on the severity and underlying causes of malocclusion. Early detection is critical, as orthodontic appliances or growth-modifying devices can guide jaw development and alignment during childhood and adolescence. Severe cases may require surgical intervention to restore balance and functionality. Monitoring jaw development from an early age and addressing deviations promptly are crucial for preventing complications and ensuring lifelong oral health [27].

Key insights

The development of the jaws and the establishment of occlusion are deeply interconnected processes shaped by genetic, environmental, and functional factors. Normal jaw development sets the stage for proper oral health and structural balance, while disruptions can lead to malocclusion and its associated complications. By understanding these dynamics, clinicians and caregivers can take proactive steps to identify and address deviations early, ensuring optimal outcomes for functional and aesthetic harmony in the maxillofacial region.

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II. Breastfeeding and Jaw Development

"In all mammalian species, the reproductive cycle comprises both pregnancy and breastfeeding: in the absence of the latter, none of these species, man included, could have survived," wrote pediatrician Bo Vahlquist in 1981 [28]. This statement underscores the essential role of breastfeeding in survival, development and overall health. The World Health Organization (WHO) recommends exclusive breastfeeding for the first six months of life to achieve optimal growth and development [29]. Beyond nutritional benefits, breastfeeding has been recognized as a protective factor against malocclusion in primary dentition [30]. Studies showed that breastfeeding stimulates the oral and perioral musculature- particularly the lips, cheeks, and tongue - enhancing harmonious growth and proper jaw development. This activity also establishes correct intermaxillary relationships and aids occlusal development [31,32].

Breastfeeding fosters physiologic suckling, a process distinctly different from bottle-feeding. During breastfeeding, the infant's jaw engages in a rhythmic forward motion and the tongue alternates between lifting and lowering to create under-pressure [33]. Geddes et al. [34] reported that this under-pressure fluctuates between approximately -64 mmHg when the tongue is lifted to -145 mmHg when it lowers, stimulating milk flow. The tongue and jaw movements, combined with nasal breathing, reinforce proper craniofacial development. Nasal breathing, a natural aspect of breastfeeding, supports physiological breathing pathways while strengthening the musculature needed for proper airway function [35].

Proper development of the deciduous dental arches—the foundation for permanent dentition—relies heavily on early orofacial activity. The inter-canine and inter-molar widths, critical for aligning permanent teeth, are largely established during the deciduous dentition phase and are positively influenced by prolonged breastfeeding [36]. Studies consistently link longer breastfeeding durations to a reduced incidence of malocclusions, emphasizing the importance of suckling in guiding craniofacial development [37].

Numerous studies provide robust evidence for the positive impact of breastfeeding on jaw and dental arch development. Research by Chen et al. [38] observed that breastfeeding for less than six months was associated with an increased prevalence of posterior crossbite. Similarly, Agarwal et al. [36], found that children who were breastfed for shorter durations exhibited higher rates of non-nutritive sucking behaviors, such as digit-sucking, which are strongly correlated with malocclusions. Galán-Gonzalez et al. [7], demonstrated that infants breastfed for at least six months showed more favorable occlusal parameters, including canine class I relationships and straight terminal planes, which promote normal occlusion in permanent dentition.

In a study by Sum et al. [39], breastfeeding was associated with enhanced primary dental arch development, particularly in the anterior sagittal dental segment and horizontal arch width. This finding highlights breastfeeding's critical role in ensuring balanced development of the primary dentition. Furthermore, Abate et al. [5] systematic review concluded that breastfeeding promotes adequate bone growth and muscle development, reinforcing nasal breathing and reducing malocclusion risks. This review also highlighted a dose-response relationship, indicating that longer breastfeeding durations yield stronger protective effects.

Additional research has emphasized the preventive role of breastfeeding in malocclusion development. Peres et al. [40] found exclusive breastfeeding to protect against anterior open bite and severe malocclusions, while Borrie et al. [41] noted that breastfeeding decreases the risk of posterior crossbites and class II malocclusion. Palmer et al. [42] highlighted that breastfed children are more likely to develop well-rounded, U-shaped dental arches, reducing the risk of snoring and sleep apnea later in life [43].

Despite that there is strong evidence supporting breastfeeding's protective role, some studies reveal confounding factors. For example, Abreu et al. [44] found it difficult to isolate the effects of exclusive breastfeeding due to the inclusion of bottle-fed and mixed-fed groups in their analyses. In addition, daily pacifier use often co-occurs with breastfeeding and is associated with increased risks of anterior open bite and abnormal sagittal dental relationships. However, research by Ling et al. [45] found that children breastfed for more than six months had significantly lower rates of daily pacifier use, which in turn reduced the prevalence of parafunctional habits.

The protective effects of breastfeeding extend beyond dental health. Prolonged breastfeeding encourages proper musculature development, which not only enhances craniofacial growth but also aids in maintaining a healthy airway [30]. More longitudinal studies with standardized methodologies are needed to confirm these associations. Specific focus on exclusive breastfeeding and its interplay with non-nutritive sucking behaviours could further elucidate its protective mechanisms.

Key insights

Breastfeeding is a cornerstone for proper jaw development, reducing the risk of malocclusions and promoting optimal dental arch alignment. While its benefits are clear, further research is essential to address confounding factors and inconsistencies, ensuring that its full impact on craniofacial development is understood. Encouraging prolonged and exclusive breastfeeding, along with educating parents on appropriate feeding practices, may significantly reduce the prevalence of malocclusions and associated complications.

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III. Bottle Feeding and Jaw Development

Bottle feeding, which involves sucking on an artificial bottle, is associated with specific patterns of muscle contraction in the orofacial region, potentially leading to malocclusion [31]. Studies have shown that early and prolonged bottle feeding can have detrimental effects on the development and function of oral and maxillofacial structures. It can interfere with the duration of exclusive breastfeeding, contribute to early weaning and encourage the formation of non-nutritive sucking habits [4]. These habits, in turn, can alter the morphology of facial bones and the dimensions of the palate, ultimately affecting the alignment of teeth and occlusion [46].

Early introduction of bottle feeding can lead to nutritional deficiencies, impacting bone growth and reducing space in the jaws for the eruption of teeth, due to smaller maxillary bones. Research has demonstrated a correlation between early bottle feeding and smaller transverse maxillary dimensions. Specifically, children who were introduced to bottle feeding at an earlier age showed reduced upper intermolar distance, indicating a limitation in maxillary expansion. This finding emphasizes that breastfeeding supports the natural and most beneficial growth of the craniofacial complex and the stomatognathic system [47].

One of the significant differences between breastfeeding and bottle feeding lies in the mechanics of milk extraction. In bottle feeding, the infant primarily compresses the teat, while breastfeeding involves more dynamic suckling. Bottle-fed infants exhibit lower oxygen saturation, reduced under-pressure in the mouth and different suck-swallow-breathe coordination compared to breastfed infants. These differences can affect the overall coordination and function of the mouth and jaw [32]. Additionally, the material and hole size of the bottle teat play a role in the infant's tongue movement, which influences jaw and facial development [32]. Unlike breastfeeding, which promotes more natural and functional tongue movements, bottle feeding may limit these vital developmental processes.

Several studies have highlighted the negative impact of bottle feeding on dental and maxillofacial development. A cross-sectional study by Chen et al. [37] found that children who were bottle-fed for more than 18 months were more likely to develop non-mesial step occlusion and class II canine relationships compared to children who were bottle-fed for only 6 to 18 months. This indicates that prolonged bottle feeding increases the risk of developing malocclusions, specifically misaligned teeth and jaw issues. Furthermore, Galán-Gonzalez et al. study [7] demonstrated that infants exclusively bottle-fed showed significantly higher rates of distal step occlusion, class II canine relationships, anterior open bite, and dental crowding.

Zhu H et al. [48] explored the effects of bottle-feeding positions on jaw development. When the bottle is held perpendicular to the mouth, it exercises balanced pressure on the maxilla and mandible, promoting normal jaw growth. When the bottle is tilted upward or downward it may contribute to malocclusions such as anterior crossbite and excessive overjet. The study highlighted the potential of proper bottle-feeding techniques to correct malocclusions through counterbalancing forces. However, sample size limitations restricted definitive conclusions.

A systematic review conducted by Andrea Abate et al. [5] concluded that artificial feeding, including bottle feeding, can lead to insufficient mandibular development. The rigid nature of the bottle teat induces lower muscle activity during feeding, limiting the functional development of the jaw. This decreased muscle engagement contributes to inadequate transverse growth of the palate and misalignment of the teeth, both of which are closely associated with malocclusions. Similarly, Cudziło et al. [49] noted that different feeding methods, such as breastfeeding versus bottle feeding, influence the anatomical structure of the maxillofacial complex. They emphasized that after the first year of life, it is important for children the transition to spoon feeding, open cup drinking and solid food chewing. These activities encourage more natural muscle engagement and promote healthy craniofacial development.

However, when examining the relationship between bottle feeding and craniofacial development, it is essential to account for various confounding factors. Factors such as gender, genetics, socioeconomic status, feeding practices and non-nutritive sucking habits can all influence the development of malocclusion [42]. Failure to adjust for these variables in epidemiological studies can lead to biased results and incorrect conclusions. For instance, non-nutritive sucking habits, such as thumb sucking or pacifier use, often coexist with bottle feeding and may further exacerbate malocclusions. Additionally, socioeconomic factors can impact both feeding practices and access to dental care, highlighting the importance of considering these factors when studying the effects of bottle feeding on jaw development.

Key insights

While bottle feeding may be a necessary alternative for some infants, its prolonged use can negatively impact craniofacial development, contributing to malocclusions and jaw misalignment. The altered sucking mechanism involved in bottle feeding disrupts the natural muscle engagement required for proper craniofacial growth. The evidence strongly supports breastfeeding as the optimal feeding method for promoting healthy jaw and facial development. Furthermore, after the first year of life, transitioning to spoon feeding, open cup drinking and solid food chewing is essential for continued healthy craniofacial growth and the prevention of developmental issues.

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IV. Non-Nutritive Sucking Habits and Jaw Development

Non-nutritive sucking habits, such as thumb-sucking and pacifier use, can have significant impacts on jaw development, particularly when these behaviors persist beyond infancy [50]. These habits exert continuous pressure on the teeth, palate, and jaw, potentially altering the natural growth patterns of the craniofacial complex. When these sucking behaviours are prolonged, they can lead to the development of malocclusions, including open bites, crossbites and overbites, by displacing the teeth or changing the position of the dental arches. The pressure exerted on the upper and lower jaws can prevent them from growing symmetrically, leading to alignment issues that may require orthodontic intervention later in life [51].

Moreover, non-nutritive sucking habits interfere with the proper function of the oral muscles responsible for chewing, swallowing and speaking. As these habits alter the normal muscle dynamics, they can impact the overall development of the stomatognathic system. The longer these habits are allowed to continue, the greater the risk of developing jaw misalignment and facial asymmetry, which can lead to more serious dental and speech issues in childhood and beyond [52].

Key insights

Non-nutritive sucking habits, when prolonged, can significantly disrupt the jaw development and contribute to malocclusions and misaligned teeth. These habits alter the natural growth of the dental arches and can prevent proper oral muscle function. Early intervention to eliminate these behaviours is critical in promoting healthy jaw development and preventing long-term dental and functional complications.

V. Feeding Patterns and Jaw Development

Feeding patterns during the early stages of life significantly influence the development of the jaw and craniofacial structures. Whether a child is fed on-demand or on a scheduled basis can affect how the muscles and bones in the orofacial region develop [53]. On-demand feeding, which mimics the natural rhythm of breastfeeding, has been shown to positively impact jaw development by promoting healthy oral muscle engagement and facilitating optimal craniofacial growth. This approach allows infants to be fed at their own pace, providing more opportunities for the necessary movements that support proper maxillary and mandibular development. In contrast, scheduled feeding, which involves set intervals, can lead to less frequent muscle activation and may not support optimal jaw growth [54].

Feeding frequency also plays a vital role in shaping dental arches. More frequent and natural feeding methods, such as breastfeeding, allow the regular use of oral muscles, which is essential for the proper alignment and growth of the dental arches [4]. These feeding practices encourage the even growth of the maxilla and mandible, supporting appropriate space for teeth eruption and helping prevent malocclusions. Moreover, irregular feeding patterns or the use of feeding practices that fail to engage the muscles in a natural way can lead to issues such as underdevelopment or misalignment of the jaws, which may result in long-term dental concerns [3].

Key insights

The pattern and frequency of feeding in the early stages of life are crucial to the development of the jaw and oral structures. Natural, frequent feeding methods, such as breastfeeding, support optimal jaw growth by encouraging the proper use of oral muscles and facilitating balanced craniofacial development. In contrast, irregular or unnatural feeding habits can hinder the alignment and growth of the dental arches, potentially leading to malocclusions and other dental problems in the future. More research on these fields is needed.

VI. Weaning Practices

Weaning is a crucial stage in an infant's development, marking the transition from exclusive milk feeding to the introduction of solid foods. The way this transition happens, can have a significant impact on jaw development and the overall craniofacial structure. Traditionally, weaning involves spoon-feeding pureed foods to infants, a practice that provides necessary nutrition but may not offer the same benefits for jaw development as other methods. Spoon-feeding encourages limited jaw movement, as it does not require significant chewing or muscle engagement, potentially leading to underdevelopment of the jaw muscles and misalignment of the dental arches. While traditional weaning is a safe and common practice, it may not stimulate optimal oral muscle function [3,4].

In contrary, baby-led weaning (BLW) is an approach that encourages infants to eat by themselves with whole foods, promoting chewing and more natural jaw development. By allowing babies to self-feed, BLW encourages the development of stronger jaw muscles and better coordination of oral functions, such as chewing and swallowing. Chewing a variety of food strengthens the muscles involved in jaw movement, supporting the growth of the maxilla and mandible. This practice not only enhances muscle tone but also fosters the proper alignment of the dental arches, potentially reducing the risk of developing malocclusions in the future. BLW may also have a more favorable impact on craniofacial growth by encouraging a broader, more natural expansion of the palate, which is vital for the correct positioning of the teeth [55,56].

Comparative studies between traditional weaning and BLW suggest that the latter may be more beneficial for long-term jaw development. Infants who practice BLW tend to

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develop stronger jaw muscles and demonstrate better dental arch development. The natural chewing motion required in BLW supports balanced craniofacial growth and may help prevent issues such as narrow arches, which are often linked to malocclusions. As such, BLW presents a promising alternative to traditional weaning methods, with the potential to enhance jaw alignment and reduce the need for orthodontic intervention later in life [54].

While the benefits of BLW are evident in many studies, there is still a need for more research to fully understand its long-term effects on jaw development. Future studies should explore the specific relationship between different weaning methods and craniofacial growth. Investigating the role of BLW in preventing orthodontic issues and its overall impact on dental health will help provide more conclusive evidence on its advantages over traditional weaning methods.

Key insights

Weaning practices play a pivotal role in shaping the development of an infant's jaw and craniofacial structure. Baby-led weaning, by promoting natural chewing and muscle engagement, offers potential advantages over traditional spoon-feeding in terms of jaw strength, dental arch development, and reduces the risk of malocclusions. Further research is needed to clarify these benefits and establish definitive guidelines for the best weaning practices to support optimal jaw development.

VII. Impact of Food Consistency on Jaw Development

The consistency of foods introduced during the weaning process plays a crucial role in the development of a child's jaw muscles, bones and overall craniofacial structure [54]. As infants transition from milk to solid foods, the type of food they are exposed to can have significant long-term effects on their oral and facial growth. Chewing is a natural, essential activity that helps to strengthen the muscles of the jaw and stimulate bone growth. Harder foods, which require more effort to chew, promote better jaw muscle development and enhance the proper alignment of the teeth [57]. On the other hand, softer foods, which are easier to swallow, place less demand on the jaw muscles, potentially leading to underdeveloped muscles and facial bones. This lack of proper muscle engagement can result in suboptimal jaw development and may contribute to issues like malocclusion, where the teeth do not align correctly [58].

Research supports the idea that introducing harder foods during the weaning process is beneficial for jaw development. Harder foods, such as raw vegetables, fruits and more textured items, require the use of a broader range of jaw muscles to chew. This increased muscle activity stimulates bone growth and strengthens the structures necessary for proper dental alignment. In contrast, a diet primarily consisting of softer foods, such as pureed or mashed foods, offers less stimulation for the jaw and facial muscles. Without the need to chew extensively, the jaw muscles may remain underdeveloped, and the proper growth of the maxilla and mandible may be hindered. This can lead to dental arch constriction, smaller jaw structures and an increased likelihood of malocclusion in the future [59].

The correlation between food consistency and the development of malocclusion has been increasingly recognized. Studies have shown that infants who consume a diet primarily of soft foods are at a higher risk of developing malocclusions, particularly those linked to underdeveloped jaw structures. The lack of adequate chewing required by softer foods may not provide sufficient stimulation for the growth of the maxilla and mandible. Introducing harder, more challenging foods at the appropriate developmental stage may help prevent such issues, promote healthy jaw development, and support the proper alignment of the teeth. By encouraging the use of the jaw muscles in the early stages of weaning, parents can help ensure that the jaw and dental arches develop in a balanced, functional manner [60,61].

Key insights

The consistency of foods introduced during the weaning process has a significant impact on jaw development. Harder food, which requires more chewing, helps strengthen the jaw muscles and stimulate proper bone growth, promoting better dental arch development and reducing the risk of malocclusions. In contrary, a diet reliant on soft foods may hinder jaw development, leading to underdeveloped jaw structures and potential alignment issues. Therefore, incorporating harder foods into an infant's diet at the appropriate developmental stage is key to fostering optimal jaw growth and preventing dental complications later in life. Further research into the precise effects of food consistency on jaw and dental development will be valuable in refining guidelines for optimal weaning practices.

Discussion

The findings of this literature review highlight the profound influence that nutritive sucking behaviors, such as breastfeeding and bottle-feeding, exert on jaw development and the risk of malocclusion. Functions involving the stomatognathic apparatus- including sucking, respiration, speech, chewing, and swallowing- appear to be the primary factors influencing maxillofacial development and the positioning of teeth in a child's dental arch, consistent with findings from previous research [62-65]. The genesis of malocclusion is typically associated with disruptions to eugnathic growth, which may affect the mandible, maxilla, and functional matrix, including the tongue and facial muscles [66].

The results of this review align with those found in previous research, which emphasize the protective effects

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of breastfeeding on craniofacial development and its role in preventing malocclusions [65,67]. As established in the literature, breastfeeding involves a coordinated effort of the tongue, jaw and facial muscles, which promotes proper alignment and growth of the jaw and dental arches. It is a cornerstone of healthy maxillofacial development, fostering a proper lip seal, optimal mandibular function and correct tongue positioning against the palate [68]. Breastfeeding requires the child to actively extract milk through the synergistic action of the tongue and facial muscles, while bottle-feeding demands less effort, leading to under-stimulation of the functional matrix [69,70]. This active muscle engagement during breastfeeding stimulates optimal jaw development, helping to prevent common malocclusions such as anterior open bite, posterior crossbite and Class II malocclusion [45,67].

In contrast, the passive nature of bottle-feeding is identified as a potential risk factor for developing malocclusion. Unlike breastfeeding, bottle-feeding does not require the same level of muscle coordination or engagement, leading to under-stimulation of the oral musculature. Prolonged bottle-feeding, particularly when introduced early, has been linked to an increased risk of Class II malocclusion, anterior open bite, and posterior crossbite [40,65,71]. This discrepancy between the two feeding practices suggests that the active and dynamic muscle activity associated with breastfeeding is integral to shaping the craniofacial structures in a way that bottle-feeding does not replicate.

Additionally, non-nutritive sucking behaviours, such as pacifier use and thumb-sucking, have been shown to exacerbate the risk of malocclusion. Based on a study with a sample of 1099 preschool children [70], nonnutritive sucking activity rather than the type of feeding in the first months of life seems the main risk factor for development of altered occlusion. While these behaviours may offer comfort to infants, prolonged use, especially beyond six months of age, is linked to an increased risk of Class II incisor and canine relationships, as well as anterior open bite [40,45]. These habits interfere with the natural development of the oral musculature, contributing to misaligned teeth and jaw issues. The combination of these non-nutritive sucking habits with bottle-feeding, particularly when continued for prolonged periods, can further increase the likelihood of developing malocclusions.

The review also identified the significant role that food consistency during the weaning phase plays in jaw development. Introducing solid foods with varied textures, particularly harder foods that require more chewing, has been associated with stronger jaw muscles and more balanced jaw growth [31]. In contrast, a diet primarily consisting of softer foods, which require less chewing, may not provide the necessary stimulation for optimal jaw and dental arch development. This finding reinforces the notion that the transition to solid foods should be carefully managed, with an emphasis on encouraging the development of strong, functional jaw muscles that promote proper craniofacial growth.

While the literature consistently supports the protective role of breastfeeding against malocclusions, several gaps remain in the existing research. For example, most studies do not distinguish between breast milk fed directly from the breast and from a bottle, which may influence the outcomes of craniofacial development. Moreover, the impact of breastfeeding duration and exclusivity on different types of malocclusions requires further exploration. The role of socio-economic status, genetics and other environmental factors must also be considered when analyzing the effects of feeding practices on craniofacial development, as these factors may act as confounders in the relationship between feeding habits and malocclusion [40]. While the existing evidence is compelling, future research, particularly prospective longitudinal studies, is essential to clarify the long-term effects of breastfeeding on jaw development. Such studies should focus on various aspects, including breastfeeding duration and characteristics (exclusive vs. mixed breastfeeding), as well as other influencing factors like non-nutritive sucking habits. Moreover, evaluating occlusal status at different stages of dentition (primary, mixed, and permanent) would provide valuable insights into the enduring impact of feeding practices on craniofacial growth and help address the potential biases and confounding factors in existing research.

Concluding, the available evidence underscores the importance of early feeding practices, particularly breastfeeding, in promoting healthy jaw and craniofacial development. As such, policies and public health initiatives that support breastfeeding and discourage prolonged use of bottle-feeding and pacifiers may have a significant role in preventing the development of malocclusion and promoting overall child health. However, as the literature suggests, further longitudinal studies are necessary to fully understand the long-term effects of feeding practices on craniofacial development and to establish concrete guidelines for optimal feeding practices that support the prevention of malocclusions.

Conclusion

The reviewed literature in this study consistently highlights the protective role of breastfeeding in promoting healthy jaw and craniofacial development, particularly in reducing the risk of malocclusion. Based on the findings of this review, the authors recommend exclusive breastfeeding for at least the first 4 to 6 months of life as an essential preventive measure against malocclusions. To further strengthen public health strategies, it is important for health professionals to collaborate in actively promoting breastfeeding, emphasizing its long-term benefits for craniofacial and oral health. Encouraging breastfeeding, alongside minimizing the use of pacifiers, can

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play a crucial role in reducing the risk of malocclusion and supporting an overall healthy oral development.

Conflicts of interest

The authors declare no conflicts of interest related to this work.

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