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Deciduous teeth eruption, gross motor skills, and feeding in children with down syndrome: A cross-sectional study

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ABSTRACT

Introduction: Down syndrome (DS) is often associated with delayed teeth eruption, gross motor skill acquisition, and feeding difficulties. In typically developing (TD) children, changes in weaning food texture with deciduous teeth eruption and motor skill acquisition, which improves feeding skills. However, in DS, these processes are delayed, and age alone is not a reliable predictor for such changes. Therefore, we investigated the association between these parameters in children with DS.

Methods: We administered questionnaires to parents of 56 children with DS aged 0–3 years. The survey items included timing of deciduous tooth eruption, physical development, acquired gross motor skills, and texture of weaning foods being consumed. The included children were allocated to two groups according to the confirmed eruption of mandibular deciduous central incisor by or after 12 months.

Results: The groups significantly differed in height, Kaup index, and acquisition age of pulling to stand, as determined by Mann–Whitney *U* test. Furthermore, multiple regression analysis revealed a significant association between the age of mandibular central incisor eruption and height along with that of acquisition age of pulling to stand. However, no significant difference was observed in the texture of weaning foods.

Conclusion: The observed associations between the eruption of mandibular central incisor, height, and acquisition age of pulling to stand suggest an association between teeth eruption, physical development, and motor development. Despite no differences in weaning food texture, most patients developed dysphagia habilitation, indicating the need to adjust food texture based on delays in physical and motor development.

1. Introduction

Down syndrome (DS) is a chromosomal disorder caused by trisomy 21. Its specific features are intellectual disability, hypotonia, and specific facial features [1,2]. In Japan, about 2200 new DS births are recorded annually, and the overall population is estimated to be 80,000; therefore, DS is considered to be one of the most common congenital diseases [3,4].

Oral findings in DS indicate delayed eruption in deciduous and permanent dentitions. Previous studies have reported a considerable delay in the eruption of some types of deciduous teeth in children with DS compared with typically developing (TD) children [5–8]. Since these studies, the data from large-scale research on the eruption of deciduous teeth in DS has been limited [9]. Furthermore, compared with TD children, those with DS have significantly more delayed acquisition of gross motor skills owing to hypotonia and heart disease [10–13].

The texture of weaning foods sequentially changes with the eruption of deciduous teeth and acquisition of gross motor skills as these factors promote an increase in chewing power [14]. However, it is inappropriate to follow the guidelines and wean children with DS who experience delayed eruption of deciduous teeth and acquisition of gross motor skills strictly according to their monthly age. If a weaning food texture is decided solely based on a child's age without considering the possibility of these delays, there may be a higher risk of oral disorders, such as tongue protrusion or difficulties in masticating solid foods and swallowing, which are commonly observed in children with DS [7,15–17].

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Tooth eruption is a significant milestone for both children and parents, and the mandibular deciduous central incisor often is the first to appear, making it an easily visually identifiable development. Previous studies have reported an association between the eruption of deciduous teeth and physical growth [18–21]. Finding an association among the eruption of deciduous teeth, acquisition of gross motor skills, and a texture of weaning foods can be beneficial for the care of children with DS. Therefore, we determined whether the timing of mandibular deciduous central incisor eruption is associated with the acquisition of gross motor skills and the textures of ingested weaning foods.

2. Material and methods

2.1. Study design

This cross-sectional study was conducted using questionnaires regarding deciduous tooth eruption and acquisition of gross motor skills. The questionnaires were administered to parents of children with DS starting from November 2022. The study was conducted at various institutions, including the Department of Hygiene and Oral Health at Showa University School of Dentistry, the Department of Special Needs Dentistry at Nihon University School of Dentistry at Matsudo, and the Department of Pediatrics at Tokyo Teishin Hospital. To investigate the timing of deciduous tooth eruption, children with DS aged 0–3 years were enrolled. At each facility, when applicable, we explained the study to the parents of children with DS during their visits for dental appointment, dysphagia habilitation, occupational therapy, etc. Those who consented to participate were requested to sign a consent form. For deciduous teeth that had already erupted, we asked the parents to enter information only if they knew the exact eruption time, for example, if they had recorded it in their mother–child handbooks. Children in whom oral assessment was difficult, who had a complicated medical history, or with uncertain deciduous teeth eruption were excluded from the study. The filled-out questionnaires were collected in May 2024 either during patient visits to each facility or via mail (Fig. 1).

2.2. Questionnaire

We defined the timing of deciduous tooth eruption as when part of the tooth was becoming visible. We also included photos in the questionnaire to ensure accurate recording by parents. At the time of eruption of each deciduous tooth, the main items evaluated in the questionnaire were the acquisition of gross motor skills and texture of weaning foods provided. The items under gross motor skills covered fixed neck, turning over, sitting, crawling, pulling to stand, and walking. As regards the texture of weaning foods, we asked to check all stages for main and side dishes: initial, middle, later, and final. Fig. 2 presents the description of the textures of weaning food [22]. This detailed division of weaning foods according to different textures is unique to Japan. It serves as a guideline for changing the textures of the ingredients, starting from the initial stage, followed by the middle, latter, and final. According to the Breastfeeding and Weaning Support Guide published by the Ministry of Health, Labour and Welfare in 2019 [23], the initial stage is from around 5 or 6 months old; middle stage, from around 7 or 8 months old; latter, from around 9 to 11 months old; and final, from around 12 to 18 months old.

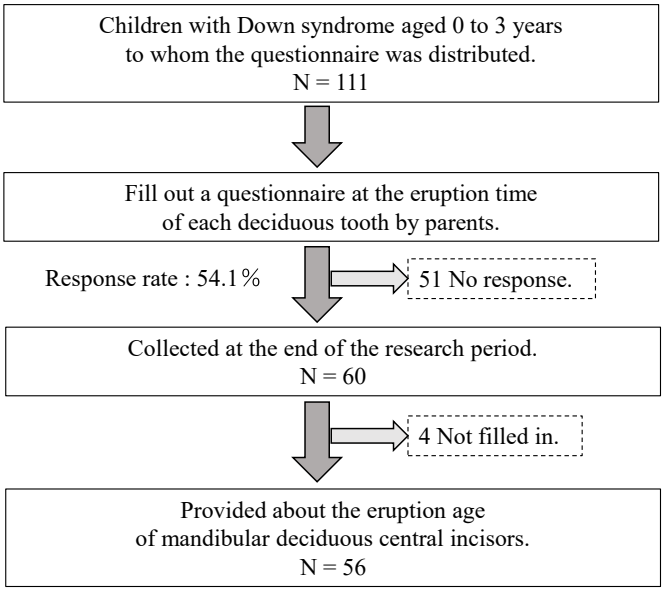


Fig. 1. Flow diagram of the final subjects of this study.

Subendpoints were represented by date of birth, birth weight and height, gender, number of weeks of gestation, presence of heart disease, visual impairment, and hearing impairment. Furthermore, we included a question about whether the patients had ever undergone dysphagia habilitation.

2.3. Statistical analysis

The data from the returned questionnaires from each facility were compiled into a single database and analyzed. First, the eruption age of mandibular deciduous central incisors was compared with that of TD children reported by the Japanese Society of Pediatric Dentistry in 2019 [24]. In addition, the acquisition age of pulling to stand was compared with that in the Infant Physical Growth Survey conducted by the Ministry of Health, Labour and Welfare every 10 years [25].

The data from the returned questionnaires were first stratified by gender and comparatively analyzed. Gestational age, birth height and weight, eruption age of the mandibular deciduous central incisor, and acquisition age of pulling to stand were evaluated using the Mann–Whitney *U* test, whereas the presence of heart disease as well as visual and hearing impairments was analyzed using Fisher's exact test.

The included patients were allocated to two groups based on whether their mandibular deciduous central incisors had erupted by 12 months of age or later. The age of 12 months is a significant milestone, and in the Japanese Breastfeeding and Weaning Support Guide, it is described as the time for transitioning to solid foods. Considering that the median eruption age of mandibular deciduous central incisors in this study is 12 months, this age was set accordingly for all patients. The eruption timing of LA in children with DS has been reported to vary, with averages of 13 months [8] or 14–15 months [5]. Eruption of LA before 12 months can be considered early for children with DS. Therefore, in this study, we divided the subjects into two groups: those with early eruption of LA before 12 months of age and those with eruption after 12 months, which is typical for children with DS, and performed analyses. Additionally, although not widely implemented, some municipalities offer voluntary health checkups for 12-month-old children. These checkups include the assessment of LA eruption, assessment of weaning practices including feeding difficulties, and confirmation of acquisition of gross motor skills. There is also a designated section in the mother–child handbooks for recording these observations, emphasizing the importance of 12 months milestone from the perspective of health guidance.

In the two groups, the median values for gestational age, birth height and weight, eruption age of the mandibular deciduous central incisor, height and weight at the time of eruption of the mandibular deciduous central incisor, Kaup index, and acquisition age of pulling to stand were also analyzed using the Mann–Whitney *U* test. The gender distribution, presence of heart disease, and visual and hearing impairments were assessed using Fisher's exact test. In addition, the texture of weaning foods consumed at the time of the eruption of the mandibular deciduous central incisor, divided into two groups according to stage: I: initial, middle, latter, and II: final, was analyzed using Fisher's exact test. The reason for dividing the patients into two groups was that the median

Weaning begins

	Food Textures	Eating function
Initial stage	Smooth and creamy	Baby can open mouth to take in or swallow food.
Middle stage	Can be crushed with tongue	Baby can bite down with the upper and lower jaws.
Latter stage	Can be crushed with gums	Baby can mush objects with the gums.
Final stage	Can be chewed with teeth	Baby can use teeth.

Weaning complete

Fig. 2. Description of the food textures of weaning foods.

eruption age for the mandibular deciduous central incisors in this study was 12 months, which is recommended by the Japanese Breastfeeding and Weaning Support Guide as the time for transitioning to the final stage involving the teeth. However, because mandibular deciduous central incisors alone are insufficient for this transition, it is considered to be more appropriate to preserve the latter stage, where food is chewed using gums. Multiple regression analysis was conducted using the eruption age of mandibular deciduous central incisors as the dependent variable to analyze factors related to eruption age.

Furthermore, the correlation between the acquisition age of pulling to stand and the presence of heart disease was analyzed using Spearman's rank test.

Data analysis was conducted using SPSS version 27.0 (IBM, Tokyo, Japan). $P < 0.05$ was considered to indicate statistical significance.

Ethical approval

The study protocol was approved by the Ethics Review Board of Showa University and all the facilities where the questionnaires were distributed (22-107-B). Furthermore, the study was conducted in accordance with the Helsinki Declaration. Data were anonymized to maintain confidentiality.

3. Results

The survey response rate was 54.1%, with 60/111 copies returned. Of the 60 copies, 56 had the eruption month of mandibular deciduous central incisors recorded. Table 1 presents the characteristics of the patients, which consisted of 33 boys and 23 girls. It shows the median and range of gestational weeks, the birth weight and height of the patients, and the number and percentage of children with heart disease as well as visual and hearing impairments. In addition, the median eruption age of mandibular deciduous central incisors for boys was 12 months, whereas for girls, it was 11 months. The total median age in the sample was 12 months. The median acquisition age of pulling to stand was 17 months for boys, girls, and total sample. The Mann–Whitney *U* test and Fisher's exact test were conducted to compare between boys and girls, and no significant differences were observed in all items. Therefore, we analyzed without stratifying by gender.

The 56 respondents were divided into two groups: those whose mandibular deciduous central incisors erupted by 12 months (BE) and those after 12 months (AE). Table 2 presents the number of boys and girls in each group, the median and range of gestational weeks, birth weight and height, eruption age of the mandibular deciduous central incisor, weight and height at the time of eruption of the mandibular deciduous central incisor, Kaup index, acquisition age of pulling to stand, and percentages of those with heart disease as well as visual and hearing impairments. Furthermore, the proportions of the textures of weaning foods consumed at the time of the eruption of mandibular deciduous central incisors were categorized according to stage: initial, middle, latter, and final. The results of the analysis conducted using the Mann–Whitney *U* test and Fisher's exact test were also presented. Significant differences were observed between the groups in terms of the eruption age of the mandibular deciduous central incisor ($P < 0.001$), height at the time of eruption of the mandibular deciduous central incisor ($P = 0.033$), and Kaup index ($P = 0.001$). Furthermore, a

Table 1
Characteristics of participants.

	Boys (N=33)	Girls (N=23)	Total (N=56)	p-value	
Gestational weeks (weeks)	38 (28-40)	38 (35-40)	38 (28-40)	0.551	†
Birth height (cm)	48 (42-54)	48 (42-55)	48 (42-55)	0.815	
Birth weight (g)	2587 (638-3322)	3018 (1878-3718)	2724 (638-3718)	0.072	
Age of mandibular deciduous central incisor eruption (months)	12 (7-23)	11 (6-24)	12 (6-24)	0.323	
Age of acquiring pulling to stand (months)	17 (8-25)	17 (11-25)	17 (8-25)	0.756	
Heart diseases	18 [55%]	12 [52%]	30 [54%]	0.456	††
Visual impairment	7 [21%]	5 [22%]	12 [21%]	0.614	
Hearing impairment	4 [12%]	5 [22%]	9 [16%]	0.283	

Median (range)
† Mann-Whitney U test
†† Fisher's exact test
*p<0.05

Table 2
The median response for BE and AE.

	BE (N=33)	AE (N=23)	p-value	
Sex	Boys 18 [54.5%] Girls 15 [45.5%]	Boys 15 [65.2%] Girls 8 [34.8%]	0.302	††
Gestational weeks (weeks)	37 (34-40)	38 (28-39)	0.154	†
Birth weight (g)	2778 (1797-3718)	2628 (638-3490)	0.507	
Birth height (cm)	48 (42-54)	47 (44-55)	1.000	
Age of mandibular deciduous central incisor eruption (months)	10 (6-12)	15 (13-24)	<0.001**	
Weight at the time of mandibular deciduous central incisor eruption (g)	8000 (6400-9500)	7900 (6345-12500)	0.960	
Height at the time of mandibular deciduous central incisor eruption (cm)	69 (64-74)	72 (65-79)	0.033*	
Kaup index	17.1 (14.6-18.8)	15.5 (13.7-17.6)	0.001*	
Age of acquiring pulling to stand (months)	15 (8-23)	20 (13-25)	0.008*	
Heart disease	21 [63.6%]	9 [45.0%]	0.120	††
Visual impairment	8 [25.0%]	4 [20.0%]	0.475	
Hearing impairment	6 [18.8%]	3 [15.0%]	0.519	

Median (range)
† Mann-Whitney U test
†† Fisher's exact test
*p<0.05 **p<0.001
N=56

BE: the lower deciduous central incisor erupted by 12 months
AE: the lower deciduous central incisor erupted after 12 months

significant difference was observed in terms of the acquisition age of pulling to stand ($P = 0.008$).

Fig. 3 presents the percentages of the textures of main and side dishes that the children with DS were consuming at the time of eruption of the mandibular deciduous central incisor. The textures of the weaning foods were somewhat more advanced in the AE than in the BE group. However, Table 3 demonstrates that when dividing the food texture into two categories, I and II, in the BE and AE groups, the main ($P = 0.670$) and side dishes did not significantly differ ($P = 0.666$). Moreover, 55 of the 56 respondents had undergone dysphagia habilitation.

Multiple regression analysis was conducted to analyze the factors associated with the eruption of mandibular deciduous central incisors (Table 4). The factors included height at the time of eruption of mandibular deciduous central incisors, acquisition age of pulling to stand, and texture of weaning foods consumed at the time of eruption. Significant differences were observed in terms of height at the time of eruption of the mandibular deciduous central incisor ($P = 0.041$) and acquisition age of pulling to stand ($P = 0.012$).

Finally, Spearman's rank test showed no correlation between the acquisition age of pulling to stand and the presence of heart disease ($P = 0.156$).

Table 3
The texture of weaning foods that DS fed at the time of eruption of mandibular deciduous central incisor.

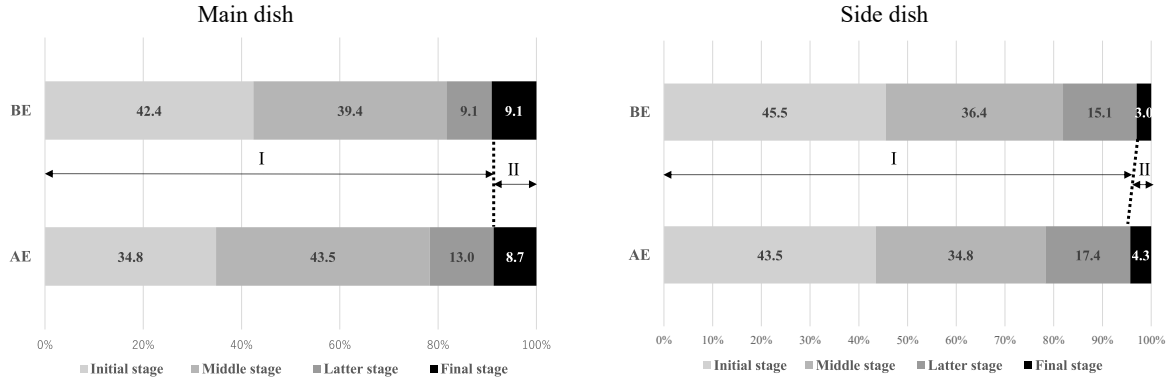
	BE (N = 33)	AE (N = 23)	p-value
Main dish	I 30 [90.9%] II 3 [9.1%]	I 21 [91.3%] II 2 [8.7%]	0.670
Side dish	I 32 [97.0%] II 1 [3.0%]	I 22 [95.7%] II 1 [4.3%]	0.666

Fisher's exact test.
*p < 0.05.
N = 56.
BE: the lower deciduous central incisor erupted by 12 months.
AE: the lower deciduous central incisor erupted after 12 months.
I: initial, middle, latter stages of weaning foods, II: final stage of weaning foods,
DS: Down syndrome.

4. Discussion

4.1. Delayed eruption of deciduous teeth and acquisition of gross motor skills

This study demonstrates that the eruption of mandibular deciduous



BE: the lower deciduous central incisor erupted by 12 months, AE: the lower deciduous central incisor erupted after 12 months
I: initial, middle, latter stages of weaning foods, II: final stage of weaning foods, DS: Down syndrome

Fig. 3. The texture of weaning foods that DS fed at the time of eruption of mandibular deciduous central incisor.

Table 4
The relationship between the eruption age of mandibular deciduous central incisors and other factors.

	β	95%CI		p-value
		Lower	Upper	
Height at the time of mandibular deciduous central incisor eruption (cm)	0.323	0.016	0.661	0.041*
Age of acquiring pulling to stand (months)	0.393	0.079	0.596	0.012*
Food textures DS fed when the mandibular deciduous central incisor eruption	0.282	−0.043	2.423	0.058

*$p < 0.05$.
DS: Down syndrome.
Multiple regression analysis.
The dependent variable：The eruption age of the mandibular deciduous central incisor.

central incisors was delayed by approximately 6 months in children with DS compared with TD children [24]. Moreover, due to the delay in deciduous tooth eruption, all 56 respondents had already achieved developmental milestones, such as fixed neck, turning over, and sitting, by the time their mandibular deciduous central incisors erupted. Therefore, the analysis was conducted based on age at which they acquired the ability to pull to stand. Compared with the Infant Physical Growth Survey [25], the acquisition of this ability was delayed by approximately 6 months in children with DS compared with TD children. Previous studies have reported that both the deciduous teeth eruption and acquisition of gross motor skills were delayed in children with DS compared with TD children [6–14]. Although the mechanism behind delayed deciduous teeth eruption has not been fully elucidated, delayed motor development in children with DS is attributed to the characteristic symptom of hypotonia [11]. Furthermore, these children are well known to often experience various complications, particularly a high incidence of congenital heart disease, which was reported in approximately 50% of them in previous studies [2] and in our study. This percentage is significantly higher than the nationwide prevalence of congenital heart disease in Japan, which is 1.43% [26]. A previous study has reported that children with heart conditions tend to experience delays in acquiring gross motor skills [27]. Many of those with DS undergo early heart surgery, but it has been shown that the presence of heart disease continues to cause delays in gross motor development even after surgery [28–30]. However, in this study, no correlation was observed between the acquisition age of pulling to stand and the presence of heart disease. This could be attributed to the fact that this study did not investigate details such as the severity of heart disease or surgical outcomes.

4.2. The association between deciduous teeth eruption and physical growth and gross motor development

The results of the multiple regression analysis indicated a significant difference between the eruption age of the mandibular deciduous central incisor and height at that time, indicating a correlation. Moreover, the Mann–Whitney *U* test revealed a significant difference between the BE and AE groups in terms of height at the time of eruption of the mandibular deciduous central incisor and the Kaup index. Therefore, it can be inferred that there is an association between the eruption of the mandibular deciduous central incisor and the parameters of physical development, particularly height. While some studies have demonstrated that teeth eruption is an independent process unrelated to physical development [31], the present study confirmed that there is an association between deciduous teeth eruption and physical development, similar to previous findings [18–21]. Previous research mainly focused on TD children, but present study found that in children with DS, deciduous teeth eruption also influences growth parameters, particularly height. Furthermore, a significant difference was observed between the eruption of the mandibular deciduous central incisor and the acquisition age of the ability to pull to stand, suggesting that in children with DS, earlier teeth eruption was indicative of earlier acquisition of the ability to pull to stand. There are few studies that directly investigated the association between teeth eruption and the acquisition of gross motor skills, such as the ability to pull to stand [32]. However, numerous studies have discussed the association between obesity, which relates to physical growth, and gross motor skills [33–35]. Additionally, the WHO stated that gross motor skills and physical growth are somewhat associated [36]. These findings indicate an association between deciduous teeth eruption and physical and motor development. In this study, we analyzed the eruption age of the mandibular primary central incisor. Previous research has indicated that faster physical growth, including height, is associated with earlier tooth eruption in typically developing children [21]. Therefore, when focusing on physical development, it can be said that there is an association with tooth eruption. Moreover, there are few studies that directly examine the relationship between motor development and tooth eruption. Some studies report that the eruption of primary teeth begins once a child can sit up unsupported [37], and that the overall body balance, which is important for motor development, is related to occlusal force [32]. These results suggest that when focusing on motor development, there is also an association with tooth eruption. In this study, a relationship was observed between the eruption of the mandibular deciduous central incisor and physical and motor development. Moreover, based on the previous research, it is suggested that these relationships may be bidirectional.

4.3. Feeding

In this study, the texture of food did not significantly differ between the BE and AE groups, and no significant association was observed between the age of mandibular deciduous central incisor eruption and the texture of food consumed by the children with DS at that time. The delayed eruption of deciduous teeth in children with DS often leads to a slower transition to solid foods that require chewing compared with TD children [15]. Furthermore, many children with DS have intellectual disabilities, and even if their deciduous teeth and gross motor skills are sufficiently developed, sensory issues may cause them to refuse solid foods, thereby hindering the transition to other food textures [15]. In addition, in children with DS, underdevelopment of the midface and hypotonia can result in immature use of perioral muscles, leading to the emergence of oral habits, such as tongue protrusion [38]. Therefore, it is considered appropriate to slowly proceed with weaning in children with DS, adjusting to their physical development. In the AE group of children with DS, where the eruption of mandibular deciduous central incisors was delayed, the median eruption age suggested that it was an appropriate time to transition to the final stage. However, it was thought that the texture of food was adjusted based on dysphagia habilitation, taking into account the delays in teeth eruption and physical development. Furthermore, the food textures are influenced by environmental factors. Among these, the accessibility of environments where dysphagia habilitation is provided can be considered one of the factors. Although this does not directly pertain to weaning food, previous studies have reported that the number of schools offering dysphagia habilitation varies by prefecture, and the types of professionals performing such habilitation differs as well [39]. Moreover, in some developmental support centers, which are frequently used by infants and toddlers, there are centers that provide dysphagia habilitation and others that do not. Additionally, the number of developmental support centers itself varies across regions. In addition, previous research has shown that diet is also influenced by family characteristics, family nutritional knowledge and cultural customs, such as social, educational, economic or political disadvantage making it difficult to make optimal food choices [40]. Thus, when determining the texture of weaning foods for children with DS, it is imperative to provide guidance that considers not only their age

but also the delays in deciduous teeth eruption, physical development and the environment.

4.4. Limitations

This study has several limitations. First, it heavily relied on the cooperation of parents who were not dental experts to record the information on each page whenever a deciduous tooth erupted. The response rate for the survey was low, which was likely due to the difficulty of participating in the study because of being busy with childcare, particularly for children with DS aged 0–3 years. Second, the short survey period further contributed to the small sample size. In this study, the analysis was based on the eruption of mandibular deciduous central incisors, but if the eruption timing of mandibular deciduous first molars had been known, it would have provided deeper insights into feeding. The fact that the data were recorded by parents and the relatively small sample size likely resulted in the significant variability of the outcomes. The reason for conducting a comparative analysis between two groups despite the small sample size was that comparisons between DS and TD have been well documented in the past [5.6.10.11], with many studies focusing on physical development and dentistry. In addition, the degree and speed of development varies highly between individuals with the same condition, Down syndrome [41]. Therefore, in this study, although the sample size was small, we divided the DS group into two subgroups, as we thought that comparisons within DS might provide more detailed information on the development of DS. Third, the study investigated neither the severity of heart disease, which could have significantly affected physical growth and motor development, nor did it examine oral habits, such as tongue thrusting or psychological aversions, which could have affected feeding.

5. Conclusions

In this study, it was found that children with DS, who often experience delays in motor development and the eruption of deciduous teeth, acquisition age of pulling to stand earlier if their mandibular deciduous central incisors, which typically erupt first, emerged by the age of one compared with those, whose teeth had erupted after the age of one. Furthermore, an association was observed between the eruption of mandibular deciduous central incisors and physical development, particularly the birth height and the acquisition age of pulling to stand. Therefore, in children with DS, early eruption of deciduous teeth is associated with early physical development and acquisition of gross motor skills.

As many children with DS in this study had undergone dysphagia habilitation and the changes in food texture were slow, it is important to ensure that the texture of weaning foods is adjusted according to the eruption of deciduous teeth, physical growth, and motor development rather than solely relying on chronological age.

Author contributions

Nami Hisamoto: Conceptualization, Methodology, Software, Validation, Formal analysis, Investigation, Data Curation, Writing-original draft preparation, Visualization.

Masahiro Watanabe: Conceptualization, Methodology, Investigation, Resources, Supervision, Project administration, Writing-review & editing.

Sachiyo Hayashi, Akiko Chigira, Satoko Otsuka, Masae Ono, Akemi Utsumi, Akiko Ishizaki, Luna Osakabe, Mami Ota, Satoko Yamaguchi, Kentaro Ishikawa, Kazutaka Noda: Investigation.

Shouji Hironaka: Conceptualization, Methodology, Investigation, Supervision, Project administration, Writing-review & editing.

Data availability

The data that support the findings of this study are available on request from the corresponding author. The data are not publicly available due to the privacy or ethical restrictions.

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Conflict of interest

Not declared.

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