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ORIGINAL RESEARCH

Evaluation of tooth development in children with molar-incisor hypomineralization using the Cameriere and Haavikko methods: a case-control study

Canan Bayraktar Nahir[1,*], Sümeyra Akkoç[2], Esra Ergün[1]

[1]Department of Pediatric Dentistry, Faculty of Dentistry, Tokat Gaziosmanpaşa University, 60010 Tokat, Türkiye
[2]Department of Pediatric Dentistry, Faculty of Dentistry, Kütahya Health Sciences University, 43100 Kütahya, Türkiye

***Correspondence**
canan.bayraktar@gop.edu.tr
(Canan Bayraktar Nahir)

Abstract

Background: Tooth development in children with a healthy tooth structure can be determined using dental age estimation methods; however, the accuracy of these methods in children with molar-incisor hypomineralization (MIH) remains uncertain. The purpose of this study was to assess tooth development in children with MIH using the Cameriere and Haavikko methods and to determine the accuracy of these methods. **Methods**: Panoramic radiographs of 136 children (8–12 years) with MIH (Group 1) and 140 matched controls (Group 2) were obtained. Dental age was determined using the Cameriere and Haavikko methods. The mean differences between chronological age and dental age were analyzed in Groups 1 and 2. **Results**: Dental age, estimated using the Cameriere and Haavikko methods, did not show a statistically significant difference between the groups ($p > 0.05$). In both groups, the Cameriere and Haavikko methods underestimated dental age by 0.2 and 0.5 years, respectively ($p < 0.05$). The Haavikko method was more accurate in dental age estimation in both groups. **Conclusions**: This study found that MIH did not impact tooth development and that the Haavikko method was more reliable in dental age estimation regardless of the presence of MIH. **Clinical Trial Registration**: NCT06639815.

Keywords

Dental age estimation; Molar-incisor hypomineralization (MIH); Haavikko method; Cameriere method; Children

1. Introduction

Molar-incisor hypomineralization (MIH) is a developmental enamel defect that affects one or more permanent first molars and, often, permanent incisors. Clinically, these defects present as opacities ranging in color from cream and white to yellow and brown [1].

Epidemiological studies conducted worldwide have reported that the prevalence of MIH, as diagnosed under the criteria determined by the European Academy of Paediatric Dentistry (EAPD), ranges from 2.8% to 40.2% [2, 3]. Although EAPD criteria are widely used, the prevalence of this defect is often underestimated due to the varying criteria used in epidemiological studies. It has been reported that an estimated 878 million people worldwide suffer from MIH, with 17.5 million new cases reported each year [4].

Despite extensive research efforts, the etiology and pathogenesis of MIH, a common condition worldwide, remain unclear. The prevailing view is that the ameloblasts responsible for enamel formation during amelogenesis are damaged due to various factors and deviations [5]. In response to this view, the mineralization-poisoning model was posited by Hubbard *et al*. [6]. This model is based on the discovery of serum albumin in biochemical analyses of hypomineralized permanent first molars on the contrary normal healthy enamel [7]. Generally, these discoveries suggest that localized failure in enamel hardening is due to developmental exposure to serum albumin, which "poisons" the growth of mineral crystals [6–9]. Childhood illness is thought to be among the factors that cause injuries to ameloblasts, which is the prevailing view on the etiology of MIH [5]. In the newly proposed mineralization-poisoning model, a connection with childhood illness was established when the source of serum albumin was evaluated [5, 6]. The childhood illness, which is included in both etiological views, may also affect tooth development [10].

Various methods are used to determine tooth development in children. Some methods evaluate the mineralization and eruption stages of teeth on panoramic radiographs because they are simple, reproducible, and reliable [11, 12]. The Demirjian, Nolla, Williems, Cameriere, Haavikko and London Atlas methods have been evaluated in the Turkish population in studies that emphasize population-specific characteristics [13–16]. The Cameriere method involves a measurement approach based on the ratio of the open apices to the total length of the teeth [17]. The Haavikko method, developed in 1974, relies on the assessment of tooth calcification by evaluating one of 12 radiological developmental stages [18]. This method is especially recommended for children with mineralization disorders such as amelogenesis imperfecta (AI) and dental agenesis [19]. Although dental age estimation studies are generally conducted on children with an healthy tooth structure, the usability of the Cameriere and Haavikko methods in children with enamel developmental disorders is stand out [19–21]. However, the accuracy of these methods in children with MIH remains uncertain due to the limited information available in the literature [21, 22].

The aim of this study was to evaluate tooth development in children with MIH using the Cameriere and Haavikko methods on panoramic radiographs and to evaluate the accuracy of these methods. The null hypotheses are as follows: (1) There is no difference in tooth development between children with MIH and children with healthy tooth structure. (2) The Cameriere and Haavikko methods estimate dental age with the same accuracy.

2. Materials and methods

Approval for this study was obtained from the Clinical Research Ethics Committee of the Faculty of Medicine at Tokat Gaziosmanpaşa University (Approval No. 23-KAEK-113, 11 May 2023). This study was conducted in accordance with the principles of the Declaration of Helsinki and complies with the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) guidelines.

The sample was determined using G*Power version 3.1.9.2 (Heinrich-Heine-University, Düsseldorf, NRW, Germany). An independent t-test was performed with a significance level of 0.05, a power of 95%, and an effect size of 0.397. According to these parameters, a minimum of 276 participants was necessary for the study [21].

This study was designed to evaluate tooth development in a cohort of children aged 8–12 years diagnosed with MIH who sought dental examinations or treatment at the Department of Pediatric Dentistry, Faculty of Dentistry, Tokat Gaziosmanpaşa University between 01 June 2023 and 01 June 2024.

The study group (Group 1) consisted of children selected according to sex and chronological age; it consisted of children diagnosed with MIH following a dental examination. The control group (Group 2) consisted of children selected to match the MIH cases according to sex and chronological age, without signs of hypomineralization and with completely healthy teeth.

The inclusion criteria for both groups were as follows: having parental consent and high-quality panoramic radiographs adequate for tooth development evaluation. The exclusion criteria were as follows: developmental enamel defects (*e.g.*, AI or dental fluorosis) caused by local trauma or systemic conditions, tooth agenesis or hyperdontia, and receiving orthodontic treatment.

All dental assessments were performed by a pediatric dentist (CBN) with 10 years of experience. Examinations were performed in the Department of Pediatric Dentistry using a standard mouth mirror and dental probe under a reflector in the dental unit. The diagnosis of MIH was determined according to the diagnostic criteria recommended by the EAPD [3]. After clinical examination, panoramic radiographs were taken from patients who required radiography for diagnosis and treatment and were recorded. Treatment plans for patients with MIH were created according to the clinical flow independent of the study.

The children's chronological age was determined using Microsoft Excel 2016 (Microsoft, Redmond, WA, USA) and the following formula:

$$[(\text{date of panoramic radiography}) - (\text{documented date of birth})]/365.25$$

Tooth development was determined on panoramic radiographs taken with a single device (J. Morita Mfg. Corp., Kyoto, Japan) using the Cameriere and Haavikko methods [17, 18]. In the Cameriere method, dental age was estimated by measuring the distances between the open apices and from the cusp to the root apex of the seven permanent mandibular teeth (excluding the third molars) on the left side. For single-rooted teeth, a single measurement was taken for the open apex, while for multi-rooted teeth, separate measurements were taken for each root. The number of teeth with completely closed apices was recorded as N_0. All measurements were analyzed at 200× magnification with ImageJ software (Maryland, USA). The analyzed data were then transformed to age according to Cameriere's Excel formula [17]. The calcification status of seven permanent mandibular teeth on the left side, excluding the third molars, was evaluated according to Haavikko's calcification diagrams. The degree of calcification of each tooth was then converted to age using Haavikko's sex-specific tables [18].

Radiographic calibration for the dental age estimation was performed by researchers (CBN and EE) who were blinded to the participants' age and sex. To establish interobserver reliability, a random subset of 28 radiographs (10% of the sample) was evaluated by both researchers. Intraobserver reliability was evaluated by having the researchers reassess the same radiographs after a two-week interval.

The data were analyzed using IBM SPSS Statistics for Windows version 26.0 (SPSS Inc., Chicago, IL, USA). The data from the two dental age estimation methods were analyzed according to age and sex in Groups 1 and 2. Normality was checked using the Kolmogorov-Smirnov test. The relationship between chronological age and dental age was assessed using the Spearman correlation coefficient. A paired samples t-test and a Wilcoxon signed-rank test were used to determine the differences between chronological age and dental age. An independent samples t-test and Mann-Whitney U test were used to compare chronological age and dental age between the groups. Inter- and intraobserver reliability were determined by calculating the intraclass correlation coefficient (ICC). Statistical significance was set at $p < 0.05$.

3. Results

The ICC values for both inter- and intraobserver reliability of dental age estimation were 0.98 and 0.97 for the Cameriere method and 0.95 and 0.92 for the Haavikko method, respectively, indicating high reliability, with no statistically significant difference between the methods.

Among the 153 children diagnosed with MIH during the dental examination, three were excluded due to the presence of systemic diseases, 12 due to tooth agenesis, and two due to insufficient panoramic radiograph quality. A total of 276 children aged 8–12 years, 136 in Group 1 and 140 in Group 2, were included in the study. The distribution of children according to group, chronological age, and sex is shown in Table 1.

Chronological and dental ages determined using the Cameriere and Haavikko methods were analyzed for Groups 1 and 2. There was no statistically significant difference between the groups in their dental ages estimated using the Cameriere and Haavikko methods (p = 0.785 and p = 0.611, respectively; Table 2).

TABLE 1. Distribution of children according to the group, chronological age and sex.

Chronological age groups (yr)	Group 1		Group 2		Total
	Female n (%)	Male n (%)	Female n (%)	Male n (%)	
8–8.99	14 (10.3%)	14 (10.3%)	14 (10.0%)	14 (10.0%)	56 (20.3%)
9–9.99	14 (10.3%)	14 (10.3%)	14 (10.0%)	14 (10.0%)	56 (20.3%)
10–10.99	14 (10.3%)	14 (10.3%)	14 (10.0%)	14 (10.0%)	56 (20.3%)
11–11.99	14 (10.3%)	12 (8.8%)	14 (10.0%)	14 (10.0%)	54 (19.6%)
12–12.99	12 (8.8%)	14 (10.3%)	14 (10.0%)	14 (10.0%)	54 (19.6%)
Total	136 (49.3%)		140 (50.7%)		276 (100.1%)

n (%) for categorical data.

TABLE 2. Evaluation of dental development of Group 1 and 2 according to sex and dental age estimation methods.

Sex	Group 1	Group 2	p
CA			
Female	10.5 ± 1.4	10.5 ± 1.5	0.964[a]
Male	10.4 ± 1.4	10.4 ± 1.5	0.977[a]
Total	10.4 ± 1.4	10.4 ± 1.5	0.972[b]
C			
Female	10.5 ± 1.5	10.2 ± 1.6	0.378[b]
Male	9.9 ± 1.3	10.0 ± 1.5	0.568[a]
Total	10.2 ± 1.4	10.1 ± 1.6	0.785[b]
H			
Female	10.0 ± 1.7	9.8 ± 1.7	0.653[b]
Male	9.6 ± 1.7	10.0 ± 1.9	0.276[b]
Total	9.8 ± 1.7	9.9 ± 1.8	0.611[b]

CA: Chronological age; C: Cameriere method; H: Haavikko method.
Statistically significant at p-value < 0.05.
The data are presented as the mean ± standard deviation (SD) for continuous data.
[a]*: The p-value was obtained by the independent t-test.*
[b]*: The p-value was obtained by the Mann-Whitney U Test.*

In Group 1, the Cameriere and Haavikko methods underestimated dental age by 0.2 and 0.5 years, respectively, compared to chronological age ($p < 0.05$). In Group 2, these methods underestimated dental age by 0.3 and 0.5 years, respectively ($p < 0.05$). The details of the data obtained from both groups according to sex are provided in Table 3.

In females, a significant difference was found between the mean dental age determined by the Cameriere method and chronological age in the 8–8.99 and 9–9.99 age groups of Group 1 ($p < 0.05$). In Group 1, dental age was underestimated by 0.2 years only in the 12–12.99 age group, while it was overestimated by 0–0.2 years in other age groups. In Group 2, dental age was consistently underestimated by 0.1–0.4 years across all age groups. The Haavikko method also revealed significant differences between chronological and dental age in various age groups of both groups, with dental age being underestimated by 0.3–0.7 years in Group 1 and 0.3–0.9 years in Group 2 ($p < 0.05$; Table 4).

In males, significant differences were observed between chronological and dental age determined using the Cameriere method in Group 1 at ages 10–10.99, 11–11.99 and 12–12.99 ($p < 0.05$) and in Group 2 at ages 9–9.99, 10–10.99, 11–11.99 and 12–12.99 ($p < 0.05$). In Group 1, dental age was underestimated by 0.1–0.8 years in all age group ($p < 0.05$). In Group 2, no statistically significant difference was observed between dental and chronological age in the 8–8.99 age group ($p > 0.05$), and dental age was underestimated by 0.3–0.8 years in the other age groups ($p < 0.05$). Statistically significant differences were found between chronological age and mean Haavikko dental age in all age groups of Group 1 and in the 9–9.99 and 10–10.99 age groups of Group 2 ($p < 0.05$). In Group 1, dental age was found to be 0.5–1.2 years lower than chronological age ($p < 0.05$). In Group 2, dental age was found to be 0.5–0.8 years lower than chronological age in the 8–8.99, 9–9.99 and 10–10.99 age groups, while no significant differences were observed between dental and chronological age in the 11–11.99 and 12–12.99 age groups ($p > 0.05$; Table 5).

When agreement between dental and chronological age was evaluated based on sex and the methods used for dental age estimation between the groups, the Cameriere and Haavikko methods showed the same accuracy for females in Group 1, while the Haavikko method was identified as more accurate for males. When the Haavikko method was considered without sex discrimination, it yielded more accurate results in both groups (Table 6).

4. Discussion

MIH has become a significant concern in pediatric dentistry due to its uncertain etiology, high prevalence, challenging clinical management and limited evidence-based treatment options [23, 24]. In light of this, there is a need for a better understanding of the etiology and characteristics of MIH, although it is a highly debated topic in the current literature. The aim of this study was to investigate tooth development in children with MIH. This study is the first assessment of the effects of MIH on tooth development in Turkish children in the northern region using the Cameriere and Haavikko methods.

Many different methods have been used to estimate dental age in children from different regions of Turkey. Tunc and Koyuturk [13] reported that dental age determined using the Demirjian method overestimated dental age and concluded that it is not suitable for children in northern Turkey. Gulsahi *et al*. [14] tested the Cameriere method on radiographs of Turkish children and concluded that it can be utilized for age estimation [25]. In a study conducted on a similar population, Hato *et al*. [15] estimated dental age in northeastern Turkish children using several dental age estimation methods (Nolla, Willems and Cameriere) and concluded that the Cameriere method provided the most accurate results. Comparing the different dental age estimation methods (London Atlas, Haavikko and Cameriere) in Turkish children, Sezer and Çarıkçıoğlu [16] reported that the Haavikko method provided more accurate results in children living in northern Turkey. In research assessing tooth development in children with enamel defects, the Cameriere and Haavikko methods were observed to be prominent [19, 21]. Therefore, both the Cameriere and Haavikko methods, whose applicability and reproducibility have been separately validated in previous studies, were used in this study.

Studies evaluating tooth development in children with AI, an enamel defect of genetic origin, were analyzed [19, 20, 26]. While Aren *et al*. [20] stated that there was a delay in tooth development in children with AI, Seow [26] revealed that there was acceleration in tooth development. According to a study conducted by Kirzioglu *et al*. [19], tooth development was not affected in children with AI. Tunc *et al*. [22] evaluated tooth development using the Demirjian method in children with severe MIH and reported no statistically significant differences in tooth development between children with MIH and children with healthy tooth structure. Sezer *et al*. [21] reported that whereas the Willems method identified slower tooth development in children with MIH, the London Atlas and Cameriere methods identified no differences in tooth development between the two groups. In line with the limited existing literature on developmental enamel defects, particularly MIH, using the Cameriere and Haavikko methods, we found no statistically significant difference in tooth development between children with MIH and those with healthy tooth structure. Therefore, the first null hypothesis that there would be no difference between these two groups in terms of tooth development is accepted.

As the gap between chronological age and estimated dental age narrows, the reliability and thus the effectiveness of the estimation method increases. We found a statistically significant difference between dental age estimated using the Cameriere and Haavikko methods and chronological age. Dental age estimates in children with MIH were 0.2 and 0.5 years behind the chronological age, whereas in children with healthy tooth structure, they were 0.3 and 0.5 years behind (according to the Cameriere and Haavikko methods, respectively). Tunc *et al*. [22] found that dental age was estimated to be 0.5 years behind chronological age in the MIH group and 0.6 years behind in the control group.

TABLE 3. Comparison of chronological age and dental age estimated by Cameriere and Haavikko methods according to groups and sex.

Sex	Group 1					Group 2				
	Methods	CA Med (Min–Max)	DA Med (Min–Max)	ΔAge Med (Min–Max)	*p*	Methods	CA Med (Min–Max)	DA Med (Min–Max)	ΔAge Med (Min–Max)	*p*
Female										
	C	10.6 (8–12.8)	10.2 (7.8–12.8)	0.1 (−1.9–1.7)	0.682	C	10.6 (8.1–13.0)	10.2 (7.1–12.9)	−0.2 (−1.9–1.5)	**0.001**
	H		10.3 (6.5–12.5)	−0.3 (−2.6–1.1)	<**0.001**	H		10.3 (6.5–12.5)	−0.5 (−2.2–1.2)	<**0.001**
Male										
	C	10.3 (8–12.7)	9.9 (6.9–13.3)	−0.6 (−2.0–1.6)	<**0.001**	C	10.2 (8.0–12.9)	10.1 (7.5–13.2)	−0.3 (−2.1–2.0)	<**0.001**
	H		9.4 (6.5–13.4)	−0.8 (−2.3–0.7)	<**0.001**	H		9.7 (6.9–13.4)	−0.5 (−2.5–2.2)	<**0.001**
Total										
	C	10.5 (8–12.8)	10.0 (6.9–13.3)	−0.2 (−2.0–1.7)	**0.001**	C	10.5 (8.0–13.0)	10.1 (7.1–13.2)	−0.3 (−2.1–2.0)	<**0.001**
	H		9.8 (6.5–13.4)	−0.5 (−2.6–1.1)	<**0.001**	H		9.9 (6.5–13.4)	−0.5 (−2.5–2.2)	<**0.001**

CA: Chronological age; DA: Dental Age; C: Cameriere method; H: Haavikko method; ΔAge: The change of age (DA−CA); Med: Median; Min: Minimum; Max: Maximum. Statistically significant at p-value < 0.05 (statistically significant is indicated in bold).

TABLE 4. Comparison of chronological age and dental age according to dental age estimation by Cameriere and Haavikko methods in Group 1 and 2 for different age groups in females.

Age Groups (yr)	Group 1					Group 2				
	Methods	CA Mean ± sd	DA Mean ± sd	ΔAge Mean ± sd	*p*	Methods	CA Mean ± sd	DA Mean ± sd	ΔAge Mean ± sd	*p*
8–8.99										
	C	8.6 ± 0.3	8.8 ± 0.6	0.2 ± 0.6	0.198[a]	C	8.4 ± 0.3	8.2 ± 0.9	−0.2 ± 0.8	0.301[a]
	H		7.9 ± 0.7	−0.7 ± 0.8	**0.012**[a]	H		7.8 ± 0.8	−0.6 ± 0.7	**0.005**[a]
9–9.99										
	C	9.4 ± 0.3	9.5 ± 0.6	0.0 ± 0.5	0.791[a]	C	9.4 ± 0.3	9.0 ± 1.0	−0.3 ± 0.8	0.168[a]
	H		8.9 ± 0.9	−0.5 ± 0.8	**0.045**[a]	H		8.5 ± 0.8	−0.9 ± 0.8	**0.001**[a]
10–10.99										
	C	10.7 ± 0.3	10.6 ± 0.9	0.0 ± 1.0	0.969[a]	C	10.6 ± 0.2	10.5 ± 0.8	−0.1 ± 0.9	0.300[b]
	H		10.3 ± 0.9	−0.4 ± 1.0	0.147[a]	H		10.3 ± 0.7	−0.3 ± 0.8	0.193[a]
11–11.99										
	C	11.4 ± 0.2	11.4 ± 0.9	0.0 ± 0.8	0.875[b]	C	11.4 ± 0.3	11.0 ± 0.9	−0.4 ± 0.7	**0.023**[a]
	H		11.2 ± 0.8	−0.3 ± 0.8	0.220[a]	H		10.8 ± 0.7	−0.6 ± 0.6	**0.004**[a]
12–12.99										
	C	12.5 ± 0.3	12.3 ± 0.7	−0.2 ± 0.9	0.937[b]	C	12.5 ± 0.3	12.1 ± 0.8	−0.4 ± 0.7	**0.001**[a]
	H		12.0 ± 0.8	−0.5 ± 1.0	0.813[b]	H		11.8 ± 0.7	−0.7 ± 0.6	**0.001**[b]

CA: Chronological age; DA: Dental Age; C: Cameriere method; H: Haavikko method; sd: Standard deviation; ΔAge: The change of age (DA−CA).
Statistically significant at p-value < 0.05 (statistically significant is indicated in bold).
[a]: The p-value was obtained by the paired samples t-test.
[b]: The p-value was obtained by the Willcoxon Signed Rank Test.

TABLE 5. Comparison of chronological age and dental age according to dental age estimation by Cameriere and Haavikko methods in Group 1 and 2 for different age groups in males.

Age Groups (yr)	Group 1					Group 2				
	Methods	CA Mean ± sd	DA Mean ± sd	ΔAge Mean ± sd	*p*	Methods	CA Mean ± sd	DA Mean ± sd	ΔAge Mean ± sd	*p*
8–8.99										
	C	8.5 ± 0.3	8.4 ± 1.0	−0.1 ± 0.9	0.589[a]	C	8.4 ± 0.4	8.4 ± 0.9	0.0 ± 1.0	0.551[b]
	H		7.6 ± 0.6	−0.9 ± 0.6	**<0.001**[a]	H		7.9 ± 0.9	−0.5 ± 0.9	0.056[b]
9–9.99										
	C	9.5 ± 0.3	9.3 ± 0.6	−0.2 ± 0.6	0.204[a]	C	9.3 ± 0.2	9.0 ± 0.6	−0.3 ± 0.6	**0.042**[a]
	H		8.5 ± 0.7	−1.0 ± 0.7	**0.001**[b]	H		8.6 ± 0.6	−0.8 ± 0.5	**0.002**[b]
10–10.99										
	C	10.4 ± 0.3	9.8 ± 0.6	−0.7 ± 0.6	**0.002**[a]	C	10.4 ± 0.3	9.9 ± 0.6	−0.4 ± 0.5	**0.007**[a]
	H		9.3 ± 0.6	−1.2 ± 0.7	**0.001**[b]	H		9.6 ± 1.0	−0.7 ± 0.9	**0.007**[a]
11–11.99										
	C	11.4 ± 0.3	10.6 ± 0.5	−0.8 ± 0.5	**0.002**[b]	C	11.4 ± 0.4	11.1 ± 0.8	−0.3 ± 0.9	**0.009**[b]
	H		10.9 ± 0.7	−0.5 ± 0.6	**0.013**[a]	H		11.5 ± 0.9	0.0 ± 1.0	0.202[a]
12–12.99										
	C	12.4 ± 0.2	11.5 ± 0.9	−0.8 ± 0.9	**0.048**[b]	C	12.5 ± 0.3	11.7 ± 1.1	−0.8 ± 1.1	**0.041**[b]
	H		10.9 ± 0.7	−0.6 ± 0.9	**0.035**[a]	H		12.4 ± 1.0	0.0 ± 0.9	0.925[b]

CA: Chronological age; DA: Dental Age; C: Cameriere method; H: Haavikko method; sd: Standard deviation; ΔAge: The change of age (DA−CA).
Statistically significant at p-value < 0.05 (statistically significant is indicated in bold).
[a]: *The p-value was obtained by the paired samples t-test.*
[b]: *The p-value was obtained by the Willcoxon Signed Rank Test.*

TABLE 6. The agreement between dental age and chronological age according to sex and dental age determined by Cameriere and Haavikko methods in Groups 1 and 2.

Sex	Group 1		Group 2	
	ICC^C (95% CI)	ICC^H (95% CI)	ICC^C (95% CI)	ICC^H (95% CI)
Female	0.92	0.92	0.94	0.95
Male	0.91	0.94	0.91	0.93
Total	0.91	0.93	0.92	0.93

ICC: Intraclass Correlation Coefficient; CI: Confidence Interval.
^{C}: Cameriere method; ^{H}: Haavikko method.

According to the study conducted by Sezer *et al.* [21], which was similar to this study in terms of the patient group and partially in terms of the methods used, the Cameriere, London Atlas and Willems methods underestimated dental age by 0.09, 0.09 and 0.23 years, respectively, in the MIH group and overestimated dental age by 0.07, 0.09 and 0.31 years, respectively, in the control group. As in this study, it is thought that the method used, age and community characteristics are effective in revealing significant differences between dental age and chronological age in the results of the studies.

Sezer *et al.* [21] reported that the Cameriere method was most accurate in the 7–12.99 age group among children with MIH. In this study, the Cameriere method was more accurate in all age groups among females with MIH and in the 8–9.99 age group among males with MIH, whereas the Haavikko method was more accurate in females 10 years or older and low accuracy in all age groups among males. It has been reported that this difference between the sexes evaluated according to age groups can be explained by early prepubertal and pubertal growth changes occurring between 8–15 years of age in females [27]. In addition, the significant decrease in accuracy in the older age group can be attributed to the almost complete root development of the teeth in these age groups [18, 28].

Hato *et al.* [15] reported that the closest estimate of chronological age in children aged 6–14 years was the Cameriere method, followed by the Nolla and Willems methods. Sezer and Çarıkçıoğlu [16] emphasized that the Haavikko method generated the lowest mean absolute error value in the total sample (0.33 ± 0.26 years), followed by the London Atlas and Cameriere methods, respectively. In this study, the Haavikko method yielded more accurate results than the Cameriere method. Thus, the second null hypothesis that the Cameriere and Haavikko methods would predict dental age with the same accuracy is rejected.

MIH, which is widespread worldwide, has common clinical outcomes, particularly dental caries, hypersensitivity and post-eruption fractures, which negatively affect the quality of life of patients and their families [9, 24]. It also entails considerable social and economic burdens, and further studies should demonstrate the evidence of MIH [24, 29]. In this study, which was carried out with children in northern Turkey of similar ethnic origin, a wide age group and equal age distribution, it was demonstrated that dental development was not affected in children with MIH. Considering that Weerheijm *et al.* [30] recommendation for an optimum age of 8 years for the diagnosis of MIH and Würzburg MIH Concept [23] emphasizing the evaluation of the optimal time when considering extraction for MIH treatment, the fact that tooth development is not affected may enable clinician diagnosis and treatment decisions. We believe that the absence of a difference between the groups may also be important in terms of the etiology of MIH. These findings may provide a new context for the investigation of childhood illness, which is involved in both main views of the etiology of MIH. There are studies in the literature on conditions that may affect tooth development [10, 31–33]. In the case of possible childhood illness affecting tooth development, the researchers should consider together with the results showing that tooth development is not affected by MIH. However, the fact that other dental tissues is not affected may also contribute to the mineralization-poisoning model, which needs further investigation [6].

One limitation of this study is that it was conducted in only one region. Another is that MIH cases were not grouped according to severity, and tooth development was not evaluated in this respect. There is an ongoing need for new research exploring the effects of nutrition, sociocultural, socioeconomic and environmental factors on dental development in different geogpraphical regions. Additionally, incorporating the severity of MIH into these studies remains a crucial area for future investigation.

There is a need for further studies with larger sample sizes using different age estimation methods which dental age estimation method provides the most accurate estimations of chronological age.

5. Conclusions

The findings of this study indicate that tooth development is not affected by MIH in children with enamel defects. Additionally, the Haavikko method was shown to be a more reliable method for estimating dental age compared to the Cameriere method, regardless of the presence of MIH.

AVAILABILITY OF DATA AND MATERIALS

The data used to support the findings of this study can be made available upon request to the corresponding author.

AUTHOR CONTRIBUTIONS

CBN and SA—conceived the idea; wrote. CBN and EE—collected the data; analysed the data. All authors reviewed, read and approved the final manuscript.

ETHICS APPROVAL AND CONSENT TO PARTICIPATE

This study's clinical examinations and data collection were carried out at the Department of Pediatric Dentistry, Faculty of Dentistry, Tokat Gaziosmanpaşa University, Turkey. Ethical approval was granted by the Clinical Research Ethics Committee of the Medical School at Tokat Gaziosmanpaşa University (Approval No. 23-KAEK-113, dated 11 May 2023). Informed written consent was obtained from the children and their parents for this study. The study has been registered in ClinicalTrials.gov (ID: NCT06639815).

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CONFLICT OF INTEREST

The authors declare no conflict of interest.

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