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# Accelerated Tooth Eruption in Children With Diabetes Mellitus

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## What's Known on This Subject

Very limited and dated information is available on the effects of diabetes on dental development in children. Conflicting reports from previous studies, conducted nearly 35 years ago, have reported both delayed and accelerated tooth eruption using data from small cohorts.

## What This Study Adds

This study clearly establishes the effects of diabetes mellitus on tooth eruption. In addition, several dental markers, BMI, physical growth and diabetes-related variables were studied. The findings reported derive from the largest cohort to date.

## ABSTRACT

**OBJECTIVE.** The objective of this study was to evaluate tooth eruption in 6- to 14-year-old children with diabetes mellitus.

**METHODS.** Tooth eruption status was assessed for 270 children with diabetes and 320 control children without diabetes. Data on important diabetes-related variables were collected. Analyses were performed using logistic regression models.

**RESULTS.** Children with diabetes exhibited accelerated tooth eruption in the late mixed dentition period (10–14 years of age) compared to healthy children. For both case patients and control subjects the odds of a tooth being in an advanced eruptive stage were significantly higher among girls than boys. There was also a trend associating gingival inflammation with expedited tooth eruption in both groups. No association was found between the odds of a tooth being in an advanced stage of eruption and hemoglobin A<sub>1c</sub> or duration of diabetes. Patients with higher body mass index percentile demonstrated statistically higher odds for accelerated tooth eruption, but the association was not clinically significant.

**CONCLUSIONS.** Children with diabetes exhibit accelerated tooth eruption. Future studies need to ascertain the role of such aberrations in dental development and complications such as malocclusion, impaired oral hygiene, and periodontal disease. The standards of care for children with diabetes should include screening and referral programs aimed at oral health promotion and disease prevention.

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### Key Words

children, diabetes, tooth eruption, dental development, oral health

### Abbreviations

HbA<sub>1c</sub>—hemoglobin A<sub>1c</sub>  
OR—odds ratio

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**D**ENTAL ERUPTION IS the gradual movement of a tooth from its formative position in the osseous crypt through alveolar bone and into functional occlusion in the oral cavity. Tooth emergence is the first appearance of a tooth in the mouth and is often synonymous with eruption. Although many theories have been presented, specific mechanisms that are responsible for tooth eruption remain largely unknown. Several factors ranging from molecular signaling to osteoclastic activity, root development, nutrition, and hormonal influences have been implicated.<sup>1,2</sup> Disturbances in dental development (ie, timing or sequence of eruption) may contribute to a chain of complications such as malocclusion, crowding, impaired oral hygiene, periodontal disease, and associated dental and orthodontic treatment needs.<sup>3–10</sup>

The developing occlusion during the mixed dentition period (ages 6–14 years) is characterized by a specific chronologic sequence of deciduous tooth exfoliation and concurrent permanent tooth eruption.<sup>11</sup> These events are shown to be influenced by gender, race, and ethnicity but are unaccounted for in established dental growth and development charts.<sup>10,12</sup> Hence, deviations >6 months from these accepted norms are not unusual but may indicate an underlying local or metabolic disturbance,<sup>10</sup> as in the case of diabetes mellitus.

Although the role of hyperglycemia-associated periodontal destruction is well documented in the medical and dental literature,<sup>13</sup> very little and dated information is available about the effects of diabetes on tooth eruption. Studies on this subject by Adler et al<sup>14</sup> and Bohátka et al<sup>15</sup> in 1973 reported accelerated dental development in children who were younger than 11.5 years and had diabetes, whereas older children with diabetes exhibited a delay

**TABLE 1 Stages of Tooth Eruption**

Eruptive Stage	Description	Corresponding Developmental Phase
1	Presence of primary tooth overlying unerupted permanent tooth bud in bony crypt	Primary dentition phase/intraosseous phase of eruption
2	Exfoliating primary tooth (mobility of >1 mm); erupting permanent tooth bud within alveolar bone.	Primary dentition phase/intraosseous phase of eruption
3	Absence of tooth at site (transient edentulism); erupting permanent tooth bud within alveolar bone.	Edentulous interval/intraosseous phase of eruption
4	Permanent tooth begun eruption (tooth emergence—cusp tips now visible in the oral cavity)	Permanent dentition phase/supra-alveolar phase of eruption
5	Permanent tooth in eruption (clinical crown partially visible)	Permanent dentition phase/supra-alveolar phase of eruption
6	Permanent tooth fully erupted and in occlusion	Permanent dentition phase/supra-alveolar phase of eruption

Adapted from Logan and Kronfeld.<sup>18</sup>

in dental development. These findings were attributed to local and systemic effects of the disease and possibly a “prediabetic state” influencing tooth eruption. These studies were in agreement with White,<sup>16</sup> who had previously observed a similar “biphasic” effect of the diabetic state on dental development. In contrast, Ziskin et al<sup>17</sup> reported a small and nonsignificant influence of diabetes on dental development.

The intention of this study was to examine tooth eruption patterns in children with and without diabetes. In addition, the effects of gingival inflammation, hemoglobin A<sub>1c</sub> (HbA<sub>1c</sub>), duration of diabetes, and BMI percentile on dental development were studied.

## METHODS

The study protocol was approved by the institutional review board at Columbia University Medical Center. Study patients/legal guardians/parents provided consent before participation.

### Study Population

The total cohort in this study was 700 children in the age range of 6 to 18 years (350 patients with diabetes and 350 healthy control subjects). Of this total, data from 590 children in the mixed dentition stage, ages 6 to 14 years, were used for these analyses. Children in both groups were excluded when they were undergoing active orthodontic therapy. This subcohort consisted of 270 patients with diabetes, examined at the Naomi Berrie Diabetes Center at Columbia University Medical Center, and 320 children who did not have diabetes and belonged to the same age group examined at the Columbia University College of Dental Medicine.

### Oral Examination Protocol

Participants and/or guardians responded to questions related to medical and dental history. All dental measurements were performed by 3 calibrated examiners.

All teeth were evaluated and categorized into 1 of 6 stages of eruption. Specific criteria describing each stage appear in Table 1 and were derived from standard dental development data.<sup>18</sup> Stage 1 of eruption was assigned to unerupted permanent teeth that had their primary tooth predecessor present. Stage 2 of eruption was assigned to unerupted permanent teeth with an overlying primary tooth that was exfoliating (mobile). Stage 3 corre-

sponded to an unerupted permanent tooth that had shed its overlying primary tooth. Stage 4 was assigned to permanent teeth that had recently emerged with one fifth of the clinical crown (or cusp tips) visible. Stage 5 was recorded for permanent teeth that were partially erupted and exhibited more than one fifth of their clinical crown but were not yet in occlusion. Stage 6 was assigned to permanent teeth that were fully erupted and/or in occlusion.

Plaque and gingival inflammation were evaluated in 2 randomly assigned quadrants at 4 sites per tooth (mesiobuccal, distobuccal, mesiolingual, and distolingual) for all nonexfoliating primary and fully erupted permanent teeth (third molars excluded) using a manual periodontal probe. Each site was given a score from 0 to 3, according to the gingival index by Löe and Silness.<sup>19</sup> In this index, a gingival index score of 0 denotes normal gingiva, 1 represents no bleeding but mild inflammation present, 2 represents moderate inflammation and bleeding on probing/pressure, and 3 denotes severe inflammation and spontaneous bleeding. Plaque index was also assessed; each site was given a score from 0 to 3, as described by Silness and Löe.<sup>20</sup> In this index, a score of 0 denotes no plaque, 1 represents mild accumulation of plaque that is seen on the point of a probe drawn across the tooth surface at the level of the gingival crevice, 2 denotes moderate accumulation of plaque that can be seen with naked eye, and 3 represents abundance of plaque.

### Diabetes-related Variables

The information collected from medical charts included type of diabetes and duration (years since diagnosis); insulin regimen (multiple daily insulin injections or continuous subcutaneous insulin infusion) and/or oral hypoglycemic medications; mean HbA<sub>1c</sub> results during the 2-year period preceding inclusion in the study; and BMI percentile, computed using a SAS (SAS Institute Inc, Cary, NC) program for Centers for Disease Control and Prevention growth charts.

### Data and Statistical Analyses

Each stage of tooth eruption was classified as 1 through 6 (Table 1). Five dichotomized versions of the eruption stages were considered (see Tables 2 and 3). For each dichotomized version, a logistic regression model was

**TABLE 2 OR of Case Patients Over Control Subjects for Various Versions of Dichotomized Eruption Status**

Dichotomized Eruption Status	OR (95% CI) <sup>a</sup>	P
Stage ≥ 2 vs 1	1.10 (0.93–1.30)	.267
Stage ≥ 3 vs ≤ 2	1.11 (0.94–1.31)	.226
Stage ≥ 4 vs ≤ 3	1.17 (1.00–1.36)	.054
Stage ≥ 5 vs ≤ 4	1.18 (1.01–1.37)	.035
Stage 6 versus ≤ 5	1.18 (1.02–1.37)	.031

<sup>a</sup> From generalized estimating equation logistic regression model fit, controlled for age, gender, ethnicity, proportion of sites with gingival bleeding, and dental examiner.

used to compare case patients and control subjects. The analysis was adjusted for age, gender, ethnicity, dental examiner, and proportion of bleeding sites. For case patients, the association between the eruption process and diabetes-related variables such as mean HbA<sub>1c</sub>, BMI percentile, and duration of diabetes was also studied using logistic regression models. In all of the analyses, generalized estimating equation method was used in the parameter estimations to account for correlations among teeth within a patient.

### RESULTS

Demographic and gingival parameters of the study population are presented in Table 4. Mean age of control subjects was 10.37 years and for case patients was 9.96 years. The plaque index was comparable for the 2 groups (1.14 ± 0.37 for control subjects; 1.16 ± 0.35 for case patients; unadjusted *P* = .653). Children with diabetes had significantly more gingival bleeding than control subjects in permanent teeth (unadjusted *P* = .023). The vast majority of children with diabetes had type 1 diabetes (98%), and the mean duration of disease was 3.52 years. Nearly 18% of case patients had poorly controlled diabetes, with mean HbA<sub>1c</sub> measures >9.5%. The number of children with a BMI percentile of ≥85% (overweight and at risk for overweight) was 101 (38%).

Logistic regression analyses showed that the odds for a tooth's being at an advanced stage of eruption was

**TABLE 3 OR of Case Patients Over Control Subjects Versions of Dichotomized Eruption Status for Patients Aged 6 to 10 Years (Early Mixed Dentition Period) and Patients Aged 10 to 14 Years (Late Mixed Dentition Period)**

Dichotomized Eruption Status	Dentition Period	OR (95% CI) <sup>a</sup>	P
Stage ≥ 2 vs 1	Early	0.92 (0.79–1.06)	.256
	Late	1.25 (0.83–1.89)	.281
Stage ≥ 3 vs ≤ 2	Early	0.92 (0.79–1.06)	.244
	Late	1.29 (0.86–1.93)	.219
Stage ≥ 4 vs ≤ 3	Early	0.95 (0.81–1.10)	.489
	Late	1.35 (0.98–1.85)	.063
Stage ≥ 5 vs ≤ 4	Early	0.94 (0.81–1.10)	.458
	Late	1.38 (1.02–1.86)	.039
Stage 6 versus ≤ 5	Early	0.95 (0.80–1.14)	.598
	Late	1.36 (1.06–1.75)	.017

<sup>a</sup> From generalized estimating equation logistic regression model fit, controlled for age, gender, ethnicity, dental examiner, and proportion of gingival bleeding.

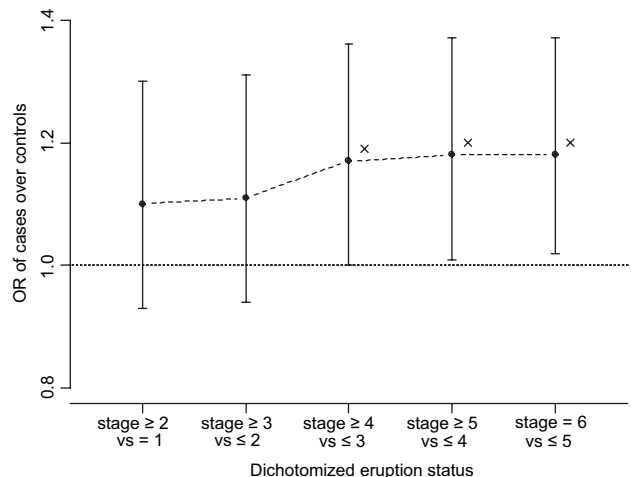
**TABLE 4 Demographic and Gingival Characteristics of Study Population (N = 590)**

Characteristic	Controls (N = 320)	Cases (N = 270)	P <sup>a</sup>
Age, mean ± SD, y	10.37 ± 1.97	9.96 ± 2.57	.033
Female gender, n (%)	167 (52)	127 (47)	.213
Ethnicity, n (%)			<.001
Hispanic	267 (83)	84 (31)	
Non-Hispanic	53 (17)	186 (69)	
Proportion of primary sites with bleeding, mean ± SD	0.13 ± 0.20	0.14 ± 0.22	.926
Proportion of permanent sites with bleeding, mean ± SD	0.14 ± 0.18	0.18 ± 0.20	.023

<sup>a</sup> Unadjusted.

significantly higher among case patients than control subjects, indicating an expedited eruption process among case patients. This difference becomes statistically significant starting from stage 4 through 6 (Table 2, Fig 1). Separate analyses for the 2 age subgroups (6–9 years of age and 10–14 years of age) revealed that older children in the late mixed dentition period exhibited this accelerated eruption and not the younger, early mixed dentition group (Table 3). Also, in both groups, the odds for a tooth's being in an advanced eruptive stage was significantly higher among female patients than male patients (odds ratio [OR]: 1.3; *P* < .001). There was also a trend in both groups, approaching significance, indicating gingival bleeding's being associated with an expedited eruption process (OR: 1.25–1.38; *P* = .110–.235).

Among the case patients, children with higher BMI percentiles showed statistically higher odds for expedited tooth eruption, although not clinically significant (OR: 1.0041–1.0051; *P* = .061–.027). No association was found between odds for a tooth being in advanced stages of eruption and mean HbA<sub>1c</sub> or duration of diabetes.



**FIGURE 1**

OR of cases over controls for various versions of dichotomized eruption status. Black circles indicate estimated odds ratios; vertical bars, 95% CIs; x, estimated ORs significantly >1 (*P* < 0.05). Dashed line and dotted horizontal line are reference lines for OR comparisons.

## DISCUSSION

Disturbances in the developing occlusion can occur as a result of delayed tooth eruption, accelerated tooth eruption, or an altered sequence of eruption. Although delayed tooth eruption is most common, any aberration in tooth eruption is of clinical significance and may be a consequence of an underlying local or systemic condition.<sup>10</sup> In this study, children with diabetes exhibited significant accelerated tooth eruption associated with increasing age (Table 3). As expected, girls were more advanced in their dental development than boys. Although intraosseous tooth movement (stages 1, 2, and 3 in Table 1) was similar for both case patients and control subjects, supra-alveolar axial movement of clinically visible tooth crowns (stages 4, 5, and 6 in Table 1) was accelerated for individuals with diabetes.

These findings suggest a dual complement of mechanisms influencing the intra- and extra-alveolar phases of eruption, the latter being modified in diabetes. Whereas the intra-alveolar phase of eruption is shown to be primarily governed by molecular signals generated by the dental follicle proper, extra-alveolar eruption seems to depend more on root development and bone apposition in the apical region of the erupting tooth.<sup>21,22</sup> Although the exact mechanisms responsible for tooth eruption remain unclear, recent findings in murine models demonstrated enhanced tooth eruption by colony-stimulating factor-1, which upregulates the immunoreactivity of bone marrow mononuclear cells to growth hormone receptor and insulin-like growth factor-I.<sup>23</sup>

Although the growth hormone receptor–insulin-like growth factor-1 mechanism may be modified and account for the effects of diabetes on the developing occlusion, certain local effects of the disease may play a role as well. Gingival inflammation was found to be greater among case patients and correlated with expedited eruption, although the association did not reach statistical significance. This exaggerated inflammatory response to bacterial plaque, a hallmark of hyperglycemia-associated periodontal disease, may contribute to localized osseous changes, resulting in diminished quality and quantity of surrounding bone. It is interesting that in the premolar region, every millimeter of bone overlying the erupting tooth bud corresponds to 4 to 5 months of eruption time (ie, time taken for a premolar to traverse through 1 mm of bone)<sup>24</sup>; therefore, even the slightest bone loss secondary to periodontal infection would shorten the distance to eruption, thereby accelerating tooth emergence.

More extensive bone loss would contribute to premature loss of the primary tooth, an effect recognized in children with diabetes<sup>25</sup>; however, no differences in the primary exfoliation status were seen between case patients and control subjects. Radiographic assessments confirming alveolar changes in the primary dentition were not feasible in this study. Conventional clinical measurements of attachment loss are unreliable in the primary periodontium, especially during tooth exfoliation, and were not performed.

Dental decay in the primary dentition was assessed using the dfs caries index (diseased, filled surfaces—

primary teeth). The control group exhibited significantly more dental caries in the primary dentition than the case group (OR: 0.30;  $P < .001$ ). Although our analyses adjusted for dental caries, premature tooth loss secondary to dental decay was not a confounding variable in this study because, as reported already, no differences in primary tooth exfoliation status were noted.

The association of accelerated eruption with age in case patients was noteworthy. Children with diabetes in the late mixed dentition period (ages 10–14) had a higher propensity for advanced tooth eruption than their counterparts without diabetes (Table 3). This dynamic period, marked by puberty and growth, may potentiate the systemic effects of diabetes on expedited dental development. No changes in tooth eruption were seen in the early mixed dentition group (ages 6–10); however, children in the control group were older ( $10.37 \pm 1.97$  vs  $9.96 \pm 2.57$ ). This difference of nearly 4 to 5 months in mean age would further amplify overall eruption time among case patients across all stages of eruption. There were also significant ethnic differences in our sample, with the control group being predominantly Hispanic and the case patients being non-Hispanic. Limited data from previous studies comparing primary dental development in these groups indicated mild acceleration among Hispanic children or no significant differences at all.<sup>26,27</sup> All of our regression analyses adjusted for ethnicity and age, although accelerated eruption among Hispanic children would further support our findings.

An additional, fully adjusted formal logistic regression analysis that focused on the sequence of eruption was done. The results revealed statistically significant differences between case patients and control subjects (OR: 1.90;  $P = .008$ ); however, this outcome is subject to interpretation given the limitations of our cross-sectional study design and warrants additional investigation.

The general, physical growth and development in children with diabetes may also display altered trends. Conflicting reports of increased height at diagnosis in children with type 1 diabetes compared with their peers without diabetes have been published.<sup>28,29</sup> Although these children will have normal final heights, some evidence of suboptimal peripubertal growth exists and is not correlated with their metabolic control.<sup>30</sup> It is interesting that in this study, case patients with higher height percentiles exhibited higher odds for expedited tooth eruption (OR: 1.007–1.008;  $P < .05$  for all; data not shown). Furthermore, the expedited eruption among case patients with higher height percentile was more pronounced in the older group (OR: 1.014–1.019;  $P < .001$  for all) than the younger group (OR: 1.004–1.005,  $P < .05$  for all).

Last, there was no correlation between eruption disturbances and other diabetes-related parameters such as HbA<sub>1c</sub>, height, and duration of disease, although a weak association was seen between accelerated eruption and increased BMI percentile. A recent study confirmed this association,<sup>31</sup> further suggesting the influence of a pre-diabetic and “proinflammatory” state on dental develop-

ment that may precede the onset of clinical parameters of diabetes.

## CONCLUSIONS

These findings derive from a case-control comparison using fully adjusted regression models and not a simple comparison with standard dental growth and development charts that were developed from observations in mainly white children 70 years ago.<sup>18</sup> Although a range of  $\pm 6$  months was offered to address variations, these previously established tooth eruption charts, long considered as the “gold standard,” do not adequately represent multiethnic populations. Future studies should aim at updating dental growth and development data to reflect better today’s diverse US population. Furthermore, effects of accelerated dental development on complications such as malocclusion, crowding, impaired oral hygiene, and periodontal disease need to be ascertained. As previously suggested, oral hygiene maintenance and routine follow-up dental care should be emphasized for children with diabetes.<sup>13</sup>

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