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Physiological and Nutritional Determinants of Stunted Odontogenesis: Associations with Parathyroid Hormone, Calcium, and Weaning Practices in a Community-Based Study

Salma Farukh Memon[1], Hajira Naila Rahu[2], Aqeela Memon[3], Shakil Ahmed Shaikh[4], Sidra Jabeen[5], Aneeb Mengal[6]

1 *Professor, Department of Physiology, Liaquat University of Medical & Health Sciences, Jamshoro Pakistan*
Critical Analysis, Final approval

2 *Professor, Department of Physiology, People's University of Medical & Health Sciences, Nawabshah Pakistan*
Data analysis

3 *Assistant Professor, Department of Community Medicine& Health Sciences, Suleman Roshan Medical College, Tando Adam Khan Pakistan*
Data collection

4 *Associate Professor, Department of Physiology, Suleman Roshan Medical College, Tando Adam Khan Pakistan*
Write-up, Data analysis

5 *Assistant Professor, Department of Physiology, Suleman Roshan Medical College, Tando Adam Pakistan*
Data collection

6 *Assistant Professor, Department of Physiology, Jhalawan Medical College, Khuzdar Pakistan*
Data collection

CORRESPONDING AUTHOR
Dr. Shakil Ahmed Shaikh
Associate Professor, Department of Physiology, Suleman Roshan Medical College, Tando Adam Khan Pakistan
Email: sshakilonly@hotmail.com

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ABSTRACT

Background: Stunted odontogenesis in children has been linked to disturbances in mineral metabolism, nutrition, and hormonal regulation. **Objective:** This study investigated the relationship between parathyroid hormone (PTH), serum calcium, and related biochemical parameters with stunted odontogenesis in children, with a special focus on the impact of weaning age. **Study Design:** Cross-sectional study. **Settings:** Dental outpatient department (OPD) and pediatric clinics of the Liaquat University of Medical and Health Sciences (LUMHS), Jamshoro, Pakistan. **Duration:** July 1, 2024, to December 31, 2024. **Methods:** Among 250 children attending dental outpatient and pediatric clinics. BMI and MUAC assessed nutritional status. Serum calcium, PTH, vitamin D, Magnesium, and other biochemical markers were measured. Participants were grouped by weaning age (6 months, 1 year, and 2 years) to explore differences in biochemical parameters. **Results:** This study population exhibited a lower-normal mean BMI (17.39 ± 2.89 kg/m²) and MUAC (14.91 ± 3.90 cm). Children weaned at 1 year had higher mean serum calcium (8.58 ± 1.01 mg/dL) and Magnesium (1.81 ± 0.32 mg/dL) compared to those weaned earlier or later. Statistically significant differences were found among the weaning groups for PTH ($p = 0.048$), Magnesium ($p = 0.038$), calcitonin ($p = 0.001$), and folic acid ($p = 0.004$). A moderate male predominance (60.4%) was noted, reflecting local healthcare utilization patterns. **Conclusion:** The findings highlight a critical interplay between disturbances in the calcium, vitamin D–PTH axis and stunted odontogenesis. Severe vitamin D deficiency and hypocalcemia likely contribute to the defective mineralization of enamel and dentine. At the same time, the timing of weaning appears to modulate levels of mineral-regulating hormones and micronutrients essential for normal dental development.

Keywords: *Stunted odontogenesis, Parathyroid hormone, Serum calcium, Vitamin D deficiency, Weaning age.*

INTRODUCTION

Tooth eruption and odontogenesis (the process of tooth formation and mineralization) are dynamic developmental events shaped by a complex interplay of genetic, endocrine, and nutritional factors. Central among these are the roles of serum calcium, vitamin D, and parathyroid hormone (PTH) in maintaining mineral homeostasis, which is crucial for the proper formation of enamel and dentin.[1] Disruptions in this calcium–vitamin D–PTH axis can impair mineralization, leading to delayed tooth eruption, enamel hypoplasia, or broader stunted odontogenesis, which may affect oral function, esthetics, and long-term dental health.[2]

In many low- and middle-income countries, including Pakistan, children commonly face hypocalcemia and vitamin D deficiency due to limited dietary intake, reduced sun exposure, and socioeconomic barriers.[3] These deficiencies may trigger secondary

hyperparathyroidism, in which PTH levels rise to restore calcium balance—an adaptive response that can influence both skeletal and dental development.[4] Additionally, other micronutrients, such as Magnesium and folic acid, play synergistic roles in bone metabolism and tooth mineralization.[5]

Feeding practices during infancy, particularly the timing of weaning and introduction of complementary foods, have been reported to affect nutritional status and hormone levels related to calcium metabolism.[6] Early or delayed weaning can impact micronutrient stores and subsequently alter biochemical pathways involved in odontogenesis.[7] However, research exploring these associations in local pediatric populations, especially in children presenting with clinical signs of stunted dental development, remains limited. Previous studies have highlighted the critical role of the calcium–vitamin D–PTH axis in tooth mineralization and eruption. Chronic hypocalcemia, often accompanied by severe vitamin D deficiency, can impair the activity of odontoblasts and ameloblasts, leading to enamel hypoplasia and delayed tooth eruption.[8] Compensatory secondary hyperparathyroidism may develop in response to persistent hypocalcemia, as reflected by elevated PTH levels.[9]

Emerging evidence also suggests that feeding practices—such as the timing of weaning—can significantly affect children's micronutrient status. A study reported that the inappropriate timing of weaning may contribute to deficiencies in calcium and other minerals, thereby indirectly affecting dental and skeletal growth.[11] Additionally, gender differences in eruption timing are well documented, with females typically showing earlier tooth eruption than males.[12]

Despite these findings, region-specific data remain scarce, particularly in Pakistan, where the burden of micronutrient deficiencies is high and cultural practices surrounding infant feeding vary widely. By focusing on these gaps, the current study aims to deepen the understanding of the physiological and nutritional factors contributing to stunted odontogenesis, offering insights that may guide early interventions to improve pediatric dental health.

This study was designed to bridge this knowledge gap by evaluating the relationship between PTH, serum calcium, vitamin D, and related biochemical parameters with stunted odontogenesis in children, while also assessing whether weaning age influences these variables.

METHODS

This cross-sectional analytic study was conducted after approval from the departmental research ethics committee, letter No: DREC/105, dated 10/06/24. This study was conducted at the dental outpatient department (OPD) and pediatric clinics of the Liaquat University of Medical and Health Sciences (LUMHS), Jamshoro, Pakistan. Data were collected over a defined study period from July 1, 2024, to December 31, 2024. The study included 250 children aged between 5 and 15 years who presented with clinical signs of stunted odontogenesis, such as delayed tooth eruption or enamel hypoplasia, confirmed through clinical dental examination by a trained pediatric dentist. Children aged 6 months to 2 years attending the dental OPD or pediatric clinic at LUMHS. Clinically confirmed delayed tooth eruption or enamel/dentine developmental defects. Children whose parents/guardians provided written informed consent were included in the study.

Children with diagnosed systemic illnesses affecting calcium metabolism (e.g., chronic kidney disease, hypoparathyroidism). Children on medications known to influence mineral metabolism (e.g., corticosteroids, anticonvulsants). Children with known genetic syndromes affecting dental development were excluded from the study.

Sampling was performed using a non-probability consecutive sampling technique until the target sample size was reached.

Data collection included age, gender, and weaning age (categorized as weaned at 6 months, 1 year, or 2 years), which were collected using a structured questionnaire completed by parents/guardians. Nutritional status was assessed by measuring Body Mass Index (BMI) and Mid-Upper Arm Circumference (MUAC) using standard WHO techniques.

Blood samples (~3–5 mL) were collected via venipuncture under aseptic conditions and analyzed for the following biochemical parameters: Serum calcium (mg/dL), Parathyroid hormone (PTH, pg/mL), Vitamin D (ng/mL), Magnesium (mg/dL), Sodium (mmol/L), potassium (mmol/L), iron (µg/dL), Folic acid (ng/mL), Calcitonin (pg/mL), Urea and creatinine (to assess renal function)

Data were analyzed using SPSS version 26.0. Continuous variables were presented as mean ± standard deviation (SD), and categorical variables as frequencies and percentages. To explore differences in biochemical parameters by weaning age groups, one-way ANOVA was performed. A p-value of <0.05 was considered statistically significant.

RESULTS

This study included children with an average age of 9.24 ± 3.55 years, indicating a sample predominantly in late childhood. Nutritional status, assessed by Body Mass

Index (BMI) and Mid-Upper Arm Circumference (MUAC), showed a mean BMI of 17.39 ± 2.89 kg/m², and MUAC of 14.91 ± 3.90 cm. These values suggest a tendency toward lower-normal nutritional indices, relevant in the context of stunted odontogenesis. (Table 1)

Biochemical parameters directly related to mineral metabolism revealed the following: The mean serum calcium level is notably below the normal reference range, highlighting significant hypocalcemia in this population. Parathyroid hormone (PTH) levels, which may reflect a compensatory physiological response to low calcium levels, are also notable.

Serum sodium is slightly below the standard lower limit. Potassium is below borderline. Magnesium levels are within normal limits, but at the lower end, consistent with urea and creatinine levels, which are within the normal range for pediatric renal function. Folic acid levels are below the standard sufficiency cut-offs. Vitamin D: 1.75 ± 0.34 ng/mL, markedly deficient (normal: ~20–50 ng/mL), indicating severe hypovitaminosis D.

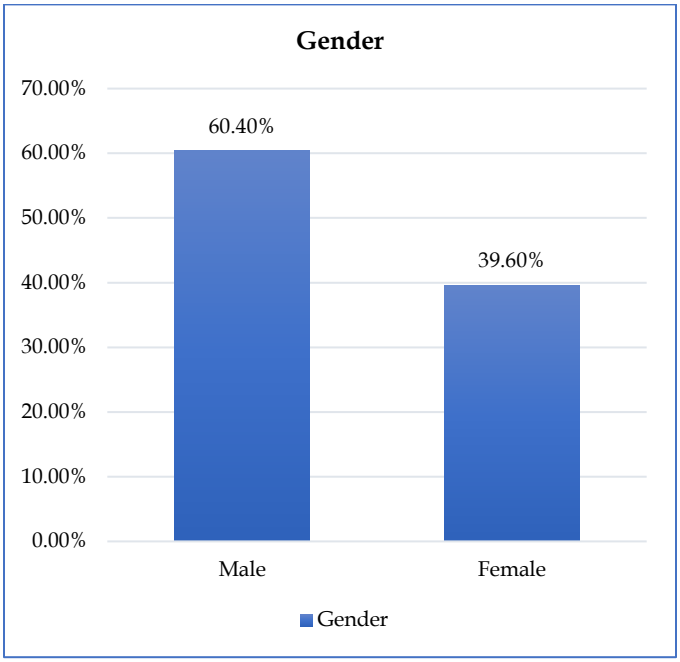
The data reveal that children with odontogenesis stunting who attend dental OPDs and pediatric clinics show markedly low serum calcium levels and vitamin D deficiency. A moderately increased PTH, likely reflecting secondary hyperparathyroidism due to chronic hypocalcemia. Mild deficiencies in other minerals and vitamins (e.g., folic acid) suggest broader micronutrient inadequacy. These findings highlight the crucial physiological role of PTH and serum calcium in tooth development, where disrupted mineral homeostasis appears to be associated with stunted odontogenesis in this pediatric group. (Table 1)

Table 1: Descriptive analysis of study population

Variable	Mean ± SD
Age	9.240 ± 3.5498
BMI	17.39 ± 2.89
MUAC	14.91 ± 3.90
Serum Calcium	6.98 ± 1.10
Parathyroid Hormone	10.90 ± 2.78
Sodium	134.90 ± 3.23
Potassium	3.33 ± 0.73
Magnesium	1.750 ± 0.34
Urea	30.56 ± 12.07
Creatinine	0.315 ± 0.11
Iron	1.34.90 ± 3.23
Folic Acid	3.33 ± 0.73
Vitamin D	1.750 ± 0.34

The present study comprised a sample of 250 children. As illustrated in the graph, the majority of participants were male, accounting for 60.4% of the sample, whereas females comprised 39.6%. This indicates a moderate male predominance among children attending the dental outpatient department and pediatric clinics. Such a distribution should be considered when interpreting the findings, as gender-related physiological and developmental differences may influence outcomes related to odontogenesis stunting and associated biochemical parameters. (Figure 1)

Figure: 1 Gender wise distribution



The analysis of biochemical parameters according to weaning time revealed several noteworthy differences among the study participants. Children weaned at 1 year had the highest mean serum calcium levels (8.58 ± 1.01 mg/dL), compared to those weaned at 6 months (7.48 ± 0.73 mg/dL) and 2 years (7.50 ± 1.04 mg/dL), with the difference approaching statistical significance (p = 0.071). Mean parathyroid hormone (PTH) levels were significantly different across groups (p=0.048), being higher in the 6-month (19.79 ± 23.63 pg/mL) and 1-year (19.47 ± 22.91 pg/mL) groups than in the 2-year group (15.29 ± 22.05 pg/mL).

Similarly, serum magnesium levels were significantly higher in the 1-year group (1.81 ± 0.32 mg/dL) compared to the other groups (p = 0.038). A significant decreasing trend was observed in serum calcitonin with later weaning age (p = 0.001): highest in the 6-month group (7.05 ± 0.75 pg/mL), followed by the 1-year group (6.85 ± 0.99 pg/mL) and the 2-year group (6.47 ± 1.03 pg/mL). Folic acid levels were also significantly different (p = 0.004), with the highest mean in the 2-year group (8.31 ± 2.52 ng/mL). (Table 2)

Table 2: Biochemical variables by weaning time

Variable		N	Mean	Std. Deviation	p-value
Serum Calcium	6 Months	63	7.478	0.73	0.071
	1 Year	113	8.575	1.01	
	2 Years	74	7.499	1.04	
	Total	250	7.980	1.10	
Parathyroid Hormone	6 Months	63	19.788	23.63	0.048
	1 Year	113	19.468	22.91	
	2 Years	74	15.289	22.05	
	Total	250	18.904	22.78	
Serum Sodium	6 Months	63	135.000	3.4688	0.653
	1 Year	113	135.035	3.1790	
	2 Years	74	134.608	3.1528	
	Total	250	134.900	3.2391	
Serum Potassium	6 Months	63	3.425	.7831	0.443
	1 Year	113	3.328	.7582	
	2 Years	74	3.265	.6553	
	Total	250	3.334	.7353	
Serum Magnesium	6 Months	63	1.676	.3031	0.038
	1 Year	113	1.808	.3157	
	2 Years	74	1.726	.4007	
	Total	250	1.750	.3433	
Serum Calcitonin	6 Months	63	7.051	.7541	0.001
	1 Year	113	6.851	.9948	
	2 Years	74	6.472	1.0291	
	Total	250	6.789	.9728	
Serum Iron	6 Months	63	101.460	29.7792	0.137
	1 Year	113	96.690	30.4953	
	2 Years	74	105.892	32.6033	
	Total	250	100.616	31.0836	
Folic Acid	6 Months	63	7.770	3.0913	0.004
	1 Year	113	6.997	2.5279	
	2 Years	74	8.314	2.5234	
	Total	250	7.582	2.7283	
Vitamin D	6 Months	63	35.968	4.3956	0.685
	1 Year	113	36.239	3.9827	
	2 Years	74	35.716	3.8160	
	Tota	250	36.016	4.0330	

DISCUSSION

The present study investigated the interplay between parathyroid hormone, serum calcium, and other biochemical parameters regarding delayed tooth eruption and stunted odontogenesis in children, revealing significant associations that deepen our understanding of how disturbances in mineral metabolism may affect dental development.

This cross-sectional study investigated the physiological role of parathyroid hormone (PTH) and serum calcium in stunted odontogenesis among children attending dental outpatient and paediatric clinics at LUMHS. The findings highlight a complex interplay between mineral metabolism, hormonal regulation, and nutritional status that appears to influence dental development in this pediatric population.

Our analysis revealed that the mean serum calcium level was notably below the normal reference range, accompanied by markedly low vitamin D levels (mean 1.75 ± 0.34 ng/mL) and moderately elevated PTH levels. This biochemical profile is consistent with secondary hyperparathyroidism, where chronic hypocalcemia leads to a compensatory increase in PTH to maintain calcium homeostasis. [13] These observations support prior evidence suggesting that disruptions in the calcium–vitamin D–PTH axis can adversely affect enamel and dentin mineralization, leading to developmental dental defects.[13]

Interestingly, our data showed that children weaned at 1 year had relatively higher mean serum calcium and magnesium levels, along with higher PTH and calcitonin levels, compared to those weaned at 6 months or 2 years. Statistically significant differences were observed for PTH (p=0.048), serum magnesium (p=0.038), calcitonin (p=0.001), and folic acid (p=0.004). These findings align with those of Jhou *et al*. (2021), who reported that the timing of complementary feeding can influence micronutrient stores and mineral-regulating hormones, ultimately affecting tooth eruption and mineralization.[14]

The present study involved 250 children, with a moderate male predominance: 60.4% male and 39.6% female, as shown in the corresponding graph. This sex distribution is comparable to findings from similar pediatric dental studies, which have also reported a higher proportion of male patients attending dental outpatient clinics.[15] While the reason for this male predominance remains multifactorial, some researchers suggest that it may reflect cultural, behavioral, or healthcare utilization patterns, where parents might be more likely to seek dental care for male children.[16]

From a physiological perspective, gender differences in dental maturation and eruption timing are well documented: females typically experience earlier tooth eruption and dental development than males.[17] Therefore, the male predominance in this cohort may partly explain the high prevalence of delayed tooth eruption observed, as males often exhibit later eruption even under normal conditions.[18] Additionally, hormonal

and metabolic differences between sexes can influence serum calcium regulation, PTH response, and vitamin D metabolism, potentially affecting mineralisation and odontogenesis.[19]

These considerations underscore the importance of accounting for sex as a biological and social variable when interpreting the relationship between biochemical findings and dental outcomes. Future studies could benefit from stratified analyses by sex to better understand whether boys and girls differ in their susceptibility to odontogenesis stunting related to nutritional and hormonal factors.

The analysis of weaning practices among the study participants highlights a substantial deviation from WHO recommendations, which advocate introducing complementary feeding at around 6 months of age.[20] In this cohort, only 25.2% of children were weaned at the recommended age, while the majority (74.8%) experienced delayed weaning, commencing at 1 year (45.2%) or even 2 years (29.6%). This delayed introduction of complementary foods may have significant consequences for micronutrient status and dental development. Recent studies have shown that postponing complementary feeding can limit early dietary sources of essential nutrients, notably calcium, vitamin D, iron, and folic acid, which are critical for mineralisation and normal tooth eruption.[21]

Inadequate weaning practices have been linked explicitly to hypovitaminosis D and hypocalcemia, both of which were prominent in our study and are well-recognized contributors to delayed tooth eruption and enamel defects.[22] Furthermore, extended exclusive breastfeeding without timely complementary feeding may fail to meet increasing nutritional demands beyond infancy, exacerbating secondary hyperparathyroidism as the body attempts to maintain serum calcium through elevated PTH secretion [23]

These findings underscore the importance of providing appropriate infant feeding education and public health interventions targeting caregivers, particularly in communities where cultural practices or a lack of awareness contribute to delayed weaning. Addressing this gap may be a practical strategy to improve not only general nutritional status but also specific outcomes, such as dental development and timing of dental eruption, in pediatric populations.

The analysis of biochemical parameters according to weaning time revealed meaningful differences that may have physiological relevance to odontogenesis and mineralization processes. Children weaned at 1 year exhibited the highest mean serum calcium levels (8.58 ± 1.01 mg/dL), compared to those weaned earlier at 6 months or as late as 2 years, with the difference approaching statistical significance ($p = 0.071$). This finding may reflect dietary transitions, as complementary foods introduced around one year often include calcium-rich items such as dairy products, potentially improving calcium intake compared to prolonged exclusive breastfeeding or delayed diversification [24]

Significant differences in parathyroid hormone (PTH) levels ($p = 0.048$) further underscore the impact of timing on mineral regulation. Elevated PTH in the 6-month and 1-year groups may indicate physiological adaptation to meet increased calcium demand during active dental and skeletal growth.[25] In contrast, lower PTH in the 2-year group may signal chronic adaptation to persistently inadequate intake, potentially limiting the hormone's protective effect on calcium homeostasis.[26]

The higher serum magnesium levels observed in the 1-year group ($p = 0.038$) may also reflect a more balanced diet introduced during timely weaning, which supports the mineralization of enamel and dentine.[27] Notably, the significant decline in calcitonin levels with later weaning ($p = 0.001$) suggests an altered dynamic in calcium metabolism, as calcitonin acts to reduce serum calcium by inhibiting bone resorption; lower levels may exacerbate the risk of mineral imbalance.[28] Elevated folic acid levels in the 2-year group, although statistically significant ($p=0.004$), may reflect selective supplementation or dietary intake unrelated to broader mineral deficiencies [29]

Notably, the lack of significant differences in serum sodium, potassium, iron, and vitamin D suggests that weaning time specifically influences calcium metabolism and related hormones, rather than general electrolyte or micronutrient status. These findings support the hypothesis that timely and appropriate complementary feeding is crucial for establishing the hormonal and mineral balance required for normal dental eruption and mineralization.[30]

CONCLUSION

This cross-sectional study investigated the physiological role of parathyroid hormone (PTH) and serum calcium in stunted odontogenesis among children attending dental outpatient and pediatric clinics. The study highlighted that the timing of weaning significantly affected biochemical parameters related to mineral metabolism: children weaned at 1 year had better calcium and magnesium profiles, while delayed or very early weaning appeared to be linked to less favorable hormonal and mineral patterns.

The study emphasises the importance of early nutritional assessment, appropriate complementary feeding practices, and targeted biochemical screening in children presenting with delayed tooth eruption. Such integrated

strategies may help address underlying metabolic disturbances, supporting timely and healthy dental development in pediatric populations.

LIMITATIONS

This study had several limitations that should be acknowledged. Firstly, its cross-sectional design limits the ability to establish causal relationships between biochemical disturbances and stunted odontogenesis; longitudinal studies would better clarify temporal effects. Secondly, the sample was drawn from children attending dental outpatient and pediatric clinics at a single tertiary care hospital, which may limit the generalizability of the findings to broader communities or rural populations. Additionally, dietary intake, sunlight exposure, and socioeconomic status factors, which are known to influence serum calcium, vitamin D, and overall nutritional status, were not quantitatively assessed, which potentially confounded the observed associations. Biochemical parameters were measured only once, which may not fully reflect chronic status due to daily physiological fluctuations. Finally, although we explored weaning age as a factor, other detailed feeding practices (such as diet quality and duration of breastfeeding) were not captured, which could influence mineral metabolism and dental development.

SUGGESTIONS / RECOMMENDATIONS

This study offers several notable strengths. It is among the few studies from the region to comprehensively examine the physiological role of parathyroid hormone (PTH), serum calcium, and related biochemical markers in stunted odontogenesis in a sizeable pediatric cohort. By including 250 children and analyzing data stratified by weaning time, the study provides valuable insight into how early nutritional practices may modulate mineral metabolism relevant to dental development. Additionally, the simultaneous assessment of multiple biochemical variables (e.g., vitamin D, magnesium, calcitonin, folic acid) allowed for a more holistic understanding of mineral and micronutrient status. The use of objective biochemical measurements rather than relying solely on clinical or radiographic dental assessments strengthens the validity of the findings.

Based on the study findings, it is recommended that routine biochemical screening for serum calcium, PTH, and vitamin D be incorporated into pediatric dental assessments for children with delayed tooth eruption, alongside early nutritional counseling that emphasizes timely weaning at 6 months and adequate intake of calcium- and vitamin D-rich foods. Closer collaboration between dentists, pediatricians, and nutritionists should be promoted to ensure comprehensive care. Future longitudinal and multicenter studies are needed to confirm these associations and explore causality across diverse populations. Additionally, integrating dental eruption monitoring and nutrition-focused education into community health programs and school screenings may help prevent stunted odontogenesis and improve overall child health outcomes.

CONFLICT OF INTEREST / DISCLOSURE

All authors declare no conflict of interest.

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