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The Association of Childhood Iron Deficiency Anemia with Dental Caries - A Prospective Longitudinal Study

[1]Dr. Sushanth Bandi, Postgraduate Resident, Department of Paediatrics, Kempegowda Institute of Medical Sciences and Research Centre, Bangalore, Karnataka, India.

[2]Dr. Madhu G N, Professor, Department of Paediatrics, Kempegowda Institute of Medical Sciences and Research Centre, Bangalore, Karnataka, India.

[3]Dr. Chandan G, Professor, Department of Pedodontics, Vokkaligara Sangha Dental College and Hospital, Bengaluru, Karnataka, India.

[4]Dr. A. Radha Devi, Postgraduate Resident, Department of Paediatrics, Kempegowda Institute of Medical Sciences and Research Centre, Bangalore, Karnataka, India.

Corresponding Author: Dr. Madhu G N, Professor, Department of Paediatrics, Kempegowda Institute of Medical Sciences and Research Centre, Bangalore, Karnataka, India.

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Abstract

Nutritional iron deficiency is one of the commonest deficiencies of early childhood, and dental decay affecting the primary teeth is among the most prevalent chronic diseases of this age group. Emerging evidence suggests these two conditions may be linked, but data from prospective studies remain limited. This prospective longitudinal study was carried out at Kempegowda Institute of Medical Sciences and Research Centre, Bangalore, over eighteen months to examine the relationship between low iron stores and dental decay in young children and to assess change in blood and iron parameters after treatment of the dental disease. Ninety children below six years of age with clinical features of low iron stores and dental decay, fulfilling predefined eligibility criteria, were enrolled. Baseline clinical, growth, blood count and iron profile parameters were recorded, dental decay was treated, and children were reviewed fortnightly for three months, with repeat blood and iron studies at the end of follow-up. No iron supplementation was given during the study period. The mean age of participants was 3.68 ± 1.65 years, with 39% aged five to six years, and 58.89% were male. All ninety children met laboratory criteria for iron-deficient anemia at enrolment, with a mean baseline blood haemoglobin of 10.64 ± 1.12 g/dL and low mean red-cell volume (77.54 ± 8.48 fL). After treatment of dental decay alone, without iron supplementation, blood haemoglobin rose significantly to 11.11 ± 1.06 g/dL ($p = 0.004$), red-cell size variability fell significantly ($p < 0.0001$), and serum iron, ferritin, transferrin and total iron-binding capacity all changed significantly ($p < 0.0001$), whereas red-cell volume, red-cell haemoglobin concentration and unsaturated iron-binding capacity did not change significantly. These findings support a close and possibly bidirectional relationship between childhood dental decay and iron status, and suggest that treatment of dental disease may itself favourably influence iron metabolism. Early recognition and combined pediatric-dental management may help reduce the burden of both conditions in young children.

Keywords: Iron deficiency anemia; Dental caries; Early childhood caries; Children; Hemoglobin; Serum ferritin; Serum iron; Nutritional deficiency

Introduction

Iron deficiency remains the most common single-nutrient deficiency of childhood, and iron deficiency anemia is estimated to affect a substantial proportion of children under five years of age, particularly in low- and middle-income settings[1,2].

Iron is essential for oxygen transport, immune competence, cellular metabolism and neurodevelopment, and its deficiency in early life is associated with fatigue, behavioural change and impaired cognitive development, making it an important public health concern.

Dental caries is the most prevalent chronic disease of childhood worldwide and results from a multi factorial process involving cariogenic bacteria, fermentable carbohydrate exposure, host susceptibility and time[3]. Untreated caries in primary teeth affects several hundred million children globally, and the burden has shown little decline over recent decades despite improvements in oral healthcare in high-income settings [4, 5]. Early childhood caries can lead to pain, infection, and difficulty in eating, impaired nutrient intake and reduced quality of life.

Although iron deficiency anemia and dental caries have traditionally been studied as separate pediatric problems, recent systematic reviews and meta-analyses have reported a significant association between the two.

A 2024 meta-analysis pooling data from nine studies of children aged six months to eighteen years reported an odds ratio of 3.54 for dental caries in children with iron deficiency anemia compared with non-anemic children, although the certainty of evidence was rated low because of methodological limitations of the primary studies[6]. A subsequent umbrella meta-analysis similarly found that children with iron deficiency anemia were more than three times as likely to have dental caries as non-anemic children[7].

Cross - sectional studies have reported inverse cor relations between haemoglobin level and caries severity[8,9], and higher decayed-missing-filled scores among anemic children compared with healthy controls[10]. Several biological mechanisms have been proposed to explain this association. Severe caries can cause pain and chewing difficulty that alter eating habits and reduce iron intake, while chronic dental infection may generate inflammatory cytokines that suppress erythropoiesis[11].

Conversely, iron deficiency may impair salivary gland function and reduce salivary flow and buffering capacity, weakening the protective role of saliva against cariogenic acid attack[12], while iron also contributes to enamel acid resistance, so that low systemic iron may increase susceptibility to demineralization[13]. Local inflammatory cytokines have also been shown to be elevated in the saliva of children with early childhood caries[14]. These findings suggest that the relationship between the two conditions is likely bidirectional, with shared dietary and socioeconomic risk factors further contributing to their coexistence[15].

Given the public health importance of both conditions and the paucity of prospective data linking them, particularly from the Indian subcontinent, the present study was under taken to evaluate the association between childhood iron deficiency anemia and dental caries, and to assess change in haematological and iron-profile parameters following treatment of dental caries in children with baseline iron deficiency anemia.

Aim and Objectives

The aim of this study was to determine the association between childhood iron deficiency anemia and dental caries. The specific objective was to establish the correlation between childhood iron deficiency anemia and dental caries, and to evaluate change in hema to logical and iron-profile parameters over a three-month period following treatment of dental caries.

Materials and Methods

Study Design and Setting

This was a prospective longitudinal study conducted jointly at the Department of Paediatrics, Kempegowda Institute of Medical Sciences and Research Centre, Bangalore, and the Department of Pedodontics, Vokkaligara Sangha Dental College and Hospital, Bengaluru, over a period of eighteen months.

Sample Size

The sample size was calculated using the formula $n = 4PQ/d^2$, where P was taken as 65%, the prevalence of anemia reported among children with dental caries in a previous study [16], $Q = 1 - P$, and d (precision error) was set at 10%. This yielded a minimum sample size of 90, which was enrolled in the study.

Inclusion and Exclusion Criteria

Children below six years of age presenting with clinical features of anemia and dental caries, and diagnosed with mild-to-moderate anemia, were included. Otherwise, healthy children with no underlying chronic illness were eligible. Children with any chronic illness, known blood dyscrasias or haemoglobino pathies, those who had undergone major surgery within the preceding three months, those with malignancy, severe anemia (haemoglobin < 7 g/dL)[21], or those already receiving iron supplementation were excluded. Children who developed severe anemia during the three-month study period were withdrawn and treated appropriately; dropouts were considered lost to follow-up.

Study Procedure

Written informed consent was obtained from parents or legal guardians of all participants after explanation of the nature and purpose of the study. Eligible children underwent a baseline clinical assessment, anthro pometric evaluation and detailed dental examination. Venous blood samples were collected under aseptic precautions for a complete haemogram and iron profile, comprising haemoglobin, mean corpuscular volume (MCV), mean corpuscular haemoglobin concentration (MCHC), red cell distribution width (RDW), serum iron, serum ferritin, transferring, total iron-binding capacity (TIBC) and unsaturated iron-binding capacity (UIBC). Children found to have dental caries were treated accordingly by the paediatric dental team.

Participants were followed up for three months, with clinical review once every two weeks, and did not receive iron supplementation during this period. Repeat blood samples for complete haemogram and iron profile were collected under aseptic precautions at the end of the three-month follow-up.

Ethical Considerations

The study was approved by the Institutional Ethics Committee of Kempegowda Institute of Medical Sciences (Ref. No. KIMS/IEC/D 278/M/2024, dated 15 February 2024) and was conducted in accordance with the ethical principles of the Declaration of Helsinki. Written informed consent was obtained from parents or guardians of all participants, confidentiality of patient information was strictly maintained, and participation was entirely voluntary, with the right to withdraw at any time without affecting standard of care.

Statistical Analysis

Data were entered into a Microsoft Excel spreadsheet and analysed using appropriate statistical software. Descriptive statistics (mean, standard deviation, frequencies and percentages) were used to summarise demographic and clinical variables.

Paired comparisons of hematological and iron-profile parameters before and after treatment were performed using appropriate statistical tests for paired data. A p-value of less than 0.05 was considered statistically significant.

Results

Ninety children fulfilling the eligibility criteria were enrolled and completed the three-month follow-up. The mean age of participants was 3.68 ± 1.65 years; 35 children (39%) were aged five to six years, 28 (31%) were aged three to four years, and 27 (30%) were aged one to two years. There was a slight male predominance, with 53 children (58.89%) being male and 37 (41.11%) female (Table 1).

Table 1: Demographic Characteristics of Study Participants (n = 90).

Variable	Category	n	Percentage (%)
Age (years)	1–2	27	30.0
	3–4	28	31.0
	5–6	35	39.0
	Mean ± SD	3.68 ± 1.65 years	—
Gender	Male	53	58.89
	Female	37	41.11

The predominant clinical diagnosis among participants was upper respiratory tract infection (21%), followed by bronchopneumonia and simple febrile seizures (18% each), viral fever (13%), and acute tonsillitis, enteric fever and pneumonia (10% each) (Table 2).

Anthropometric assessment revealed a mean height of 102.67 ± 12.02 cm, mean weight of 15.92 ± 4.85 kg and mean body mass index of 12.34 ± 2.72 kg/m², reflecting overall suboptimal nutritional status in the study population (Table 3).

Table 2: Clinical Diagnosis of Study Participants (n = 90).

Diagnosis	n	Percentage (%)
Acute tonsillitis	9	10.0
Bronchopneumonia	16	18.0
Enteric fever	9	10.0
Pneumonia	9	10.0
Simple febrile seizures	16	18.0
Upper respiratory tract infection	19	21.0
Viral fever	12	13.0
Total	90	100.0

Table 3: Anthropometric Parameters of Study Participants (Mean ± SD).

Parameter	Mean ± SD
Height (cm)	102.67 ± 12.02
Weight (kg)	15.92 ± 4.85
Body Mass Index (kg/m²)	12.34 ± 2.72

Table 4: Comparison of Red Blood Cell Parameters before and After Treatment

Parameter	Before Treatment (Mean ± SD)	After Treatment (Mean ± SD)	p-value
Haemoglobin (g/dL)	10.64 ± 1.12	11.11 ± 1.06	0.004
MCV (fL)	77.54 ± 8.48	79.21 ± 7.01	0.15
MCHC (g/dL)	32.30 ± 9.15	33.00 ± 1.98	0.47
RDW (%)	15.24 ± 3.29	13.35 ± 1.21	<0.0001

Table 5: Comparison of Iron Profile Parameters before and After Treatment.

Parameter	Before Treatment (Mean ± SD)	After Treatment (Mean ± SD)	p-value
Serum iron (µg/dL)	19.29 ± 8.72	43.44 ± 13.42	<0.0001
Serum ferritin (ng/mL)	172.47 ± 81.07	65.86 ± 29.87	<0.0001
Transferrin (mg/dL)	14.88 ± 8.82	21.39 ± 4.33	<0.0001
TIBC (µg/dL)	248.58 ± 67.14	202.58 ± 33.03	<0.0001
UIBC (µg/dL)	212.31 ± 75.29	251.31 ± 378.79	0.33

Haemoglobin increased significantly after treatment ($p = 0.004$), and RDW decreased significantly ($p < 0.0001$), indicating improved erythropoiesis and reduced red-cell size variability, whereas the increases in MCV and MCHC were not statistically significant. Serum iron, ferritin, transferrin and TIBC all changed significantly ($p < 0.0001$), consistent with an overall improvement in iron status, while the change in UIBC did not reach statistical significance ($p = 0.33$).

Discussion

Iron deficiency anemia and dental caries are each highly prevalent in early childhood, and a growing body of evidence suggests that the two conditions frequently coexist and may influence one another bidirectionally.

In the present study, all enrolled children with dental caries met laboratory criteria for iron deficiency anemia at baseline, and treatment of dental caries alone, without any iron supplementation, was associated with significant improvement in haemoglobin, red-cell distribution width, and several iron-profile parameters over three months.

Most participants in the present study were in the preschool age group, with a mean age of 3.68 ± 1.65 years and the largest proportion aged five to six years, consistent with the recognised vulnerability of this age group to early childhood caries because of dietary habits, evolving oral hygiene practices and increasing exposure to cariogenic foods. This is comparable to a population-based study from Qingdao, China, in which the largest proportion of children were four to six years of age[17]. A male predominance (58.89%) was also observed, similar to the gender distribution reported in the same study[17], although a female predominance has been reported elsewhere[10], suggesting that gender is unlikely to be a major determinant of the association between caries and anemia.

Baseline anthropometric parameters in the present cohort suggested suboptimal nutritional status, in keeping with the recognised overlap between under nutrition, iron deficiency and early childhood caries. Baseline haemo globin (10.64 ± 1.12 g/dL) and micro cytic red-cell indices were consistent with iron deficiency anemia, similar to findings reported in children with severe early childhood caries in previous case-control studies[18]. Elevated baseline ferritin alongside low serum iron and trans ferrin most likely reflected a combination of true iron deficiency and an acute-phase inflammatory response related to chronic dental infection, an interpretation supported by the significant fall in ferritin and rise in serum iron and trans ferrin observed after treatment of caries.

The significant improvement in haemoglobin and red-cell distribution width, together with improvement in serum iron, ferritin, transferrin and total iron-binding capacity following dental treatment alone, is consistent with previous reports that surgical or restorative management of severe early childhood caries can improve iron-related nutritional status even without iron supplementation[19,20].

A similar bidirectional relationship was described by Shaoul et al., who found that children with severe caries had lower ferritin, iron and haemoglobin levels than caries-free children, and proposed that pain during mastication, reduced intake of iron-rich foods, occult blood loss from local infection, and inflammation secondary to dental disease could each contribute to iron deficiency in this setting[16].

A negative correlation between caries severity and haemoglobin has also been reported in cross-sectional studies from other populations[8], reinforcing the consistency of this association across different settings.

Taken together, these findings support the concept that dental caries is not merely a localized oral disease but has systemic nutritional and hematological con sequences, and that its management may form part of an effective strategy to address childhood iron deficiency anemia. Conversely, the possibility that iron deficiency itself predisposes to caries, through impaired salivary defence and reduced enamel resistance, cannot be excluded and likely operates alongside the mechanisms described above[12,13]. These findings support an integrated approach to child health, in which oral health screening is incorporated into paediatric anemia programmes and vice versa, with close collaboration between paediatricians, dentists and nutritionists for early detection and combined management of both conditions.

This study has certain limitations. The absence of a caries-free comparison group and of an untreated control arm limits the ability to attribute the observed hematological improvement solely to dental treatment rather than to natural variation or unmeasured dietary change over the study period. Additionally, formal caries severity indices such as the decayed-missing-filled score were not reported, and the relatively short follow-up period may not capture the full trajectory of iron-status recovery. Larger controlled longitudinal studies, ideally with a comparison group not undergoing dental treatment, are required to confirm causality and to clarify the direction of the relationship between childhood iron deficiency anemia and dental caries.

Conclusion

This prospective longitudinal study demonstrates a strong association between dental caries and iron deficiency anemia in young children, with all participants meeting laboratory criteria for iron deficiency anemia at baseline. Treatment of dental caries alone, without iron supplementation, was associated with significant improvement in haemoglobin, red cell distribution width, and key iron-profile parameters over three months. These findings suggest that dental caries has systemic implications beyond the oral cavity, and highlight the importance of early diagnosis and an integrated, multidisciplinary approach involving paediatricians, dentists and nutritionists in the management of childhood iron deficiency anemia and dental caries.

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