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Original Article

Impact of thumb sucking on salivary melatonin, *Candida albicans*, and dental caries in children

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Abstract

Introduction: Salivary melatonin is a critical antioxidant that contributes to oral health by mitigating oxidative stress. Psychological stress linked to thumb sucking may disrupt oral homeostasis, leading to conditions such as dental caries and fungal infections.

Aim: This study explores the relationships between thumb sucking, salivary melatonin levels, dental caries, and the presence of *Candida albicans* (CA) in children.

Materials and methods: A case-control study was conducted with 60 children aged 4-5 years at the University of Baghdad's College of Dentistry. Participants were divided into thumb-sucking (n=30) and non-thumb-sucking (n=30) groups. Salivary melatonin levels were measured using enzyme-linked immunosorbent assays (ELISA), dental caries were assessed via the dmfs index, and CA counts were quantified on Sabouraud dextrose agar (SDA). Statistical analyses were performed, including t-tests, ANOVA, and correlation assessments.

Results: Thumb-sucking children exhibited significantly lower salivary melatonin levels (28.620±2.278 pg/mL) compared to controls (34.525±2.142 pg/mL; p=0.044). The thumb-sucking group also had higher dmfs scores (15.033±1.449 vs. 8.667±0.899; p=0.000) and greater CA counts (18.900±1.048 vs. 13.583±0.549; p=0.000). Negative correlations were observed between salivary melatonin levels and the severity of dental caries, while positive correlations linked CA with dental caries.

Conclusions: Thumb sucking adversely affects pediatric oral health by reducing salivary melatonin, increasing dental caries risk, and promoting fungal overgrowth. Early intervention to curb thumb-sucking behaviors may mitigate these risks and improve oral health outcomes.

Keywords

candidiasis, melatonin, oral habit, saliva, tooth decay

Introduction

Thumb sucking is an instinctive reflex in children, often commencing shortly after birth and serving as a natural self-soothing mechanism.[1] However, if this habit persists, it can pose significant challenges to oral health. These challenges include alterations in the oral microbiome, an increased risk of malocclusion, and a predisposition to dental caries and oral infections.[2] Furthermore, thumb-sucking can disrupt sleep patterns and contribute to dysfunctional breathing during both sleep and wakefulness.[3,4]

Melatonin is a hormone that is central to sleep regulation and is increasingly recognized for its role in oral health. Its antioxidants and immunomodulatory properties protect oral tissues from oxidative damage and inflammatory responses.[5] Recent research has revealed significantly higher salivary melatonin concentrations in healthy individuals than those with periodontitis.[6] Other studies corroborate these findings, demonstrating a marked reduction in salivary melatonin levels among periodontitis patients.[7,8] These observations suggest that salivary melatonin could serve as a valuable biochemical marker for periodontal tissue destruction, potentially facilitating earlier diagnosis and improved management of periodontal diseases.

Emerging evidence suggests that melatonin may contribute to the prevention of microbial infections and the modulation of inflammation within the oral cavity. However, in children who engage in thumb sucking, factors such as disrupted sleep, increased oral inflammation, and altered immune responses may influence salivary melatonin concentrations, potentially compromising its protective effects.[9] A correlation between delayed bedtimes and dental caries has been established.[10]

Dental caries remains a prevalent oral health concern affecting both children and adults. Children who habitually suck their thumbs face a substantially elevated risk of caries due to the interplay of mechanical and microbial factors involved in caries development. This habit can induce malocclusions, such as anterior open bites and overjet, which impede oral hygiene and encourage dental plaque accumulation. Moreover, thumb sucking may impair salivary flow, reducing its natural buffering capacity and fostering an environment conducive to the proliferation of cariogenic bacteria, including *Streptococcus mutans*.[11]

Candida albicans (CA) is a ubiquitous commensal organism within the oral cavity. However, as an opportunistic pathogen, it can colonize various oral surfaces, and many factors can predispose individuals to CA colonization, ultimately leading to clearance, persistence, or infection. Studies indicate that thumb sucking can introduce exogenous pathogens into the oral cavity, disrupting the delicate balance of the oral microbiota and increasing the risk of oral candidiasis.[12] This fungal overgrowth is particularly concerning in young children, as it can exacerbate oral infections and elevate the risk of dental caries.[13]

While some studies have explored the association between salivary melatonin levels and oral inflammatory diseases of microbial origin, such as gingivitis and aggressive periodontitis, research specifically investigating this relationship in the context of dental caries in children who habitually suck their thumbs remains limited. Therefore, this case-control study compared salivary melatonin levels, dental caries severity, and the presence of CA in children who engage in thumb sucking to healthy controls.

Aim

This study aimed to investigate salivary melatonin levels, dental caries experience, and CA presence among children with and without the habit of thumb-sucking to elucidate the impact of this prevalent oral habit on pediatric oral health.

Materials and methods

Study design

This case-control study was conducted after obtaining ethical approval from the University of Baghdad's Ethical Committee (Project No. 951324; on October 14, 2024). The research was conducted at the College of Dentistry, University of Baghdad, within the Department of Pedodontics and Preventive Dentistry. Informed consent was obtained from the parents/guardians of all children participating in the study. Saliva samples were collected from fasting participants, comprising 30 children with thumb-sucking habits (study group) and 30 without (control group).

Inclusion and exclusion criteria

The study's inclusion criteria were children aged 4 to 5 years who were in good health, free of systemic disorders, and not on any medication or supplement regimens. Exclusion criteria included those with systemic diseases or those taking medication or dietary supplements.

Clinical assessment

Oral examinations were conducted under standardized conditions. The children were instructed to avoid all food or beverages (except water) for one hour before the test session. According to the World Health Organization criteria, dental caries was diagnosed using the decayed, missing, filled teeth index (dmfs/t for primary teeth).[14]

Sample collection

Unstimulated saliva samples (5 ml) were gathered from all participants in both groups during the early morning hours between 8:00 a.m. and 9:30 a.m., as salivary melatonin levels peak at night and decline throughout the day.[15] A fasting period of at least one hour before collection was mandated. Participants first rinsed their mouths with water to eliminate debris and waited 12 minutes to ensure clearance. Subsequently, they were instructed to allow saliva to accumulate in their mouths for 60 seconds before spitting it into a labeled test tube.[16] To prevent bacterial growth, samples were immediately stored in a compact cooling box after collection, and each tube was labeled with the participant's identification number.

Participants actively expectorated unstimulated saliva into sterile disposable caps, following the spitting method described by Khurshid et al.[17] They remained relaxed and still, allowing saliva to pool on the floor of their mouths before expectorating. Saliva samples were collected every 60 seconds and transported to the laboratory for microbiological and biochemical analyses. The samples were centrifuged at 3000 revolutions per minute for 15 minutes, and the clear supernatant was carefully aspirated with a disposable micropipette and saved at −20°C until the determination of salivary melatonin levels. The manufacturer's instructions were followed to estimate these levels using an enzyme-linked immunosorbent assay ELISA kit.

Sabouraud dextrose agar (SDA) was prepared and sterilized according to the manufacturer's instructions for isolation and enumeration of *Candida* species. Phosphate-buffered saline was used to prepare serial dilutions of the salivary samples. A 0.1 ml aliquot of the diluted sample was spread onto SDA plates and incubated aerobically at 37°C for 48 hours. Colonies of CA were examined and identified based on their morphological characteristics on SDA, and Gram stain properties, and further confirmed using the Vitek 2 system. The viable fungal count was expressed as colony-forming units per milliliter (CFU/ml).

Statistical analysis

Statistical analyses were conducted using SPSS software, version 22. Descriptive statistics for nominal variables included calculating means and standard deviations (SD). Inferential statistical methods comprised independent sample *t*-tests, one-way analysis of variance (ANOVA) with post hoc least significant difference tests, and Pearson correlation coefficients (*r*) to examine relationships between variables. The normality of the distributions for quantitative variables was assessed using the receiver operating characteristic (ROC) test. A *p*-value of less than 0.05 was considered statistically significant.

Results

The distribution of the total sample by groups according to age and sex is shown in **Table 1**. A total of 60 children were screened, and a distribution of 31 males (51.67%) and 29 females (48.33%) with ages ranging from 4 years old to 5 years old were enrolled. Statistical analysis revealed no significant associations between age, sex, and group allocation.

Among the subjects, all children in the thumb-sucking group exhibited dental caries (100%), 29 of the healthy controls (96.67%) were affected by caries, with one healthy subject remaining free of dental caries (3.33%). The analysis of the dental caries index revealed a statistically significant difference between the two groups. The mean decayed, missing, filled teeth (dmfs) value for the thumb-sucking group was significantly higher compared to the control group as shown in **Table 2**.

Significant differences were found in the comparison of salivary melatonin concentrations between the two groups. The thumb-sucking group had a mean melatonin concentration which was significantly lower than the control group's mean **(Table 3)**. Furthermore, the analysis of CA levels in saliva indicated a significant difference, with the thumb-sucking group showing a higher mean concentration compared to the control group.

Table 1. Distribution of age and gender by groups

		Thumb sucking		Control		Chi-square *p*-value	Total	
		N	%	N	%		N	%
Age (years)	4	16	53.33	13	43.33	0.438	29	48.33
	5	14	46.67	17	56.67		31	51.67
Sex	Male	14	46.67	17	56.67	0.438	31	51.67
	Female	16	53.33	13	43.33		29	48.33

Table 2. Descriptive and statistical test of caries experience among groups (ANOVA)

Vars.	Thumb sucking		Control		T-test	*P* value
	Mean	±SE	Mean	±SE		
DS	12.067	1.076	8.067	0.844	2.924	0.005*
MS	2.500	0.786	0.000	0.000	3.181	0.003*
FS	0.467	0.248	0.600	0.218	0.404	0.688
DMFS	15.033	1.449	8.667	0.899	3.734	0.000*

D: decayed; M: missed; F: filled; S: surface; * Significant at $p<0.05$

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Table 3. Descriptive and statistical test of melatonin and *Candida albicans* count among groups (ANOVA)

Vars.		Thumb-sucking	Control	t-test	*P* value
Oral melatonin	Mean	28.620	34.525	2.011	0.044*
	±SE	2.278	2.142		
Candida albicans	Mean	18.900	13.583	4.493	0.000*
	±SE	1.048	0.549		

* significant at $p<0.05$

Table 4 presents the correlation analysis, revealing a significant negative correlation between salivary melatonin levels and dental caries for both groups. These findings suggest that higher dental caries are associated with lower salivary melatonin concentrations.

Conversely, the correlation coefficients between CA levels and dental caries were significantly positive for both groups. These findings indicate a strong positive correlation, indicating that higher CA levels are associated with an increased occurrence of dental caries in both groups.

The ROC analysis results indicate that salivary melatonin demonstrates a statistically significant capability to differentiate between the two groups, with a sensitivity of 60% and specificity of 53.3%. In contrast, the count of CA exhibited a strong differentiation ability between the study and control groups, showing a highly significant result. This indicates good diagnostic performance, with both sensitivity and specificity at 73.3% as shown in **Table 5.**

Discussion

The dmfs index demonstrates a significant difference in the severity of dental caries between children who engage in thumb sucking and those in the control group. These findings underscore the potential impact of thumb sucking on oral health, suggesting that it may increase the risk of dental caries due to various factors, including altered oral hygiene practices, dietary habits, and changes in dental alignment.[18,19] The results demonstrate a significant difference; however, they do not establish causation. It is essential to consider other influencing factors, including socioeconomic status, access to dental care, and overall oral hygiene practices, which may also affect the observed caries rates. A more comprehensive study design, including these variables and the measurement of plaque index, would be beneficial, as the absence of plaque index data limits the exploration of the relationship between oral hy-

Table 4. Correlation between melatonin, *Candida albicans*, and caries experience (ANOVA)

Groups		Oral melatonin		*Candida albicans*	
		r	P value	r	*P* value
Thumb-sucking	ds	−0.770	0.000*	0.764	0.000*
	ms	−0.597	0.000*	0.663	0.000*
	fs	−0.305	0.101	0.227	0.227
	dmfs	−0.948	0.000*	0.966	0.000*
Control	ds	−0.902	0.000*	0.842	0.000*
	fs	−0.326	0.079	0.341	0.065
	dmfs	−0.926	0.000*	0.874	0.000*

* significant at $p<0.05$; The Pearson correlation coefficient (r) was used to examine relationships between variables; D: decayed, M: missed, F: filled, S: surface.

Table 5. Statistics of ROC (Receiver Operating Characteristic)

Vars.	The area under the curve (AUC)	*P* value	Optimal cut-off	%Sensitivity	%Specificity
Melatonin	0.651	**0.044***	30.87	60	53.3
Candida	0.771	**0.000***	15.25	73.3	73.3

The normality of the distributions for quantitative variables was assessed using the Receiver Operating Characteristic (ROC) test. * Significant at $p<0.05$

giene and caries progression. Not all children who suck their thumbs will have the same level of oral hygiene or dietary habits. Some children may engage in thumb sucking but maintain good oral hygiene, which could bias the results. Thus, individual differences should be accounted for. The study's context (geographical location, cultural practices regarding thumb sucking, and dental care access) can influence the results. Findings from one population may not be generalizable to others without similar cultural or environmental contexts.[20]

The analysis revealed a statistically significant difference in salivary melatonin concentrations between the two groups. Notably, the thumb-sucking group presented with diminished melatonin levels compared to the control group.

Melatonin, widely recognized for its pivotal role in regulating sleep-wake cycles and circadian rhythms, may also serve as a broader indicator of overall health and well-being. The lower melatonin levels observed in the thumb-sucking group could potentially signal compromised sleep quality or elevated stress levels. These factors, in turn, may predispose children to oral health challenges.

Our findings align with those of Permuy et al.[21], who underscored the significance of melatonin in maintaining oral health and established a correlation between reduced salivary melatonin and an increased risk of caries. However, our results differ from the conclusions of Liu et al.[22], whose investigation did not identify a direct association between salivary melatonin levels and oral health outcomes. This discrepancy suggests that a complex network of factors may influence the interplay between melatonin and oral health, warranting further investigation.

The results of this study showed revealed a statistically significant difference in CA levels between the two groups of participants, indicating a strong correlation. The children who habitually sucked their thumbs presented higher levels of CA in their saliva. This finding suggests that thumb sucking may alter the oral environment, creating conditions conducive to the overgrowth of this opportunistic fungus. Such an imbalance could disrupt the oral microbiome and potentially lead to oral thrush, compromising oral health.

This elevated presence of CA may be associated with the observed lower melatonin levels. It is plausible that factors such as stress, suboptimal hygiene practices, and thumb sucking itself could contribute to both increased fungal burden and reduced melatonin secretion. This observation aligns with the findings of Kılınçel Ö et al.[23] In contrast to the findings of Mousa et al.[24], who suggest that factors like diet and oral hygiene practices also play a role in influencing CA levels. This indicates that the increase in CA among thumb suckers may be multifactorial and not solely attributable to the habit itself.

Furthermore, this paper's data demonstrated a strong negative correlation between dental caries and melatonin levels. This indicates that as caries severity increases, melatonin levels decrease, implying a potential link between oral health status and melatonin secretion. The work of Najm and Al-Mizraqchi[25] provides supporting evidence for this concept. Their research, focusing on salivary melatonin and dental caries, postulates a negative correlation between these two measures and suggests that melatonin may exert anticaries effects through its antibacterial properties. Additionally, the strong positive correlation between CA levels and dental caries in both groups emphasizes the potential role of CA in oral health issues. This aligns with the findings of Al-Jboori et al.[26], who established a link between elevated levels of CA and an increased risk of dental caries. Although several studies[27-29] suggest this association, controlling for confounders is crucial, as is further research to identify the pathways by which these associations occur. Recognizing how the community of microorganisms interacts with each other in the oral cavity is key to devising effective preventive and therapeutic strategies for dental caries.

A ROC analysis was performed to determine the diagnostic performance of salivary melatonin and CA and differentiate between the thumb-sucking and control groups. Our results show that salivary melatonin can distinguish between the two groups, but that CA count has even better diagnostic performance, suggesting its potential as an ideal biomarker for monitoring the oral health status of thumb-sucking children in comparison to their non-thumb-sucking counterpart.

Moreover, the strong positive correlation between CA levels and dental caries severity highlights the need for further research into tailored preventive measures that address the unique challenges posed by this habit. Educating parents and caregivers about the oral health risks associated with thumb sucking and the benefits of early cessation could play a critical role in reducing the prevalence of dental caries and fungal infections in this population.

Future studies should explore the longitudinal impact of reduced melatonin and increased fungal colonization on the progression of oral diseases in children with persistent non-nutritive sucking habits. Integrating behavioral, microbiological, and biochemical approaches will be essential for developing comprehensive strategies that effectively address the multifactorial nature of these interactions.

Conclusions

Children who suck their thumbs are more likely to suffer oral health problems, including dental caries. Although thumb sucking does not directly affect salivary melatonin levels, it can interfere with sleep and may indirectly affect how a person secretes their melatonin hormone. This habit can lead to dental caries by causing misalignment of the teeth, reduced salivary flow, and disrupting oral microbiome balance. Additionally, thumb-sucking may promote fungal infection by introducing pathogens and creating favorable conditions for the growth of bacteria, particularly *Candida albicans*. This cascade of changes underscores the importance of early intervention strategies aimed at mitigating thumb sucking behaviors in young children to preserve oral health and prevent the establishment of pathogenic biomes.

References

1. Leung AK, Robson WL. Thumb sucking. Am Fam Physician 1991; 44(5):1724–8. PMID: 1950969.
2. Zhang JS, Chu CH, Yu OY. Oral microbiome and dental caries development. Dent J (Basel) 2022; 10(10):184. doi: 10.3390/dj10100184
3. Dave RD. Sleep-disordered breathing and dental sleep medicine. Arch Dent Res 2023; 13(1):34–40. doi: 10.18231/j.adr.2023.007
4. Al-Kinane SM, Al-Dahan ZA. The effects of thumb sucking habit on the development of malocclusions in preschool age children in Hilla city. J Bagh College Dent 2019; 31(3):44–9. doi: 10.26477/jbcd.v31i3.2700
5. Reiter RJ, Calvo JR, Karbownik M, et al. Melatonin and its relation to the immune system and inflammation. Ann N Y Acad Sci 2000; 9(17):376–86. doi: 10.1111/j.1749-6632.2000.tb05402.x
6. Waleed SK, Mohammed AT, Uthman AT. Effect of salivary melatonin on ionizing radiation worker and its effect on periodontal disease. J Faculty Med Baghdad 2024; 66(1):79–84. doi: 10.32007/jfacmedbagdad.6612183
7. Hassan RS, Salman SA. Evaluation of salivary melatonin and periodontal parameters in type ii diabetic patients with chronic periodontitis: a comparative study. Indian J Public Health Res Dev 2019; 10(10);2740. doi: 10.5958/0976-5506.2019.03283.2
8. Ali AM, Mohammed AN. Correlation of salivary melatonin levels and many periodontal parameters in cigarette smokers with periodontitis. Anb Med J 2023; 19(1):68–73. doi: 10.33091/amj.2023.138915.1058
9. Reiter RJ, Rosales- Corral SA, Liu XY, et al. Melatonin in the oral cavity: physiological and pathological implications. J Periodont Res 2015; 50(1):9–17. doi: 10.1111/jre.12176
10. Ali AA, Sahib DB, Samaneh R. Sleep disorders and dental caries related to salivary alpha-amylase among dental students. J Baghdad Coll Dent 2014; 36(2):63–9. doi: 10.26477/jbcd.v36i2.3679
11. Obayes NM, Al-Haidar AH. Impact of thumb sucking and nail biting on oral health status and malocclusion among 6-10 years old children in Hilla City. J Res Med Dental Sci 2021; 9(5):88–92. Available from: https://www.jrmds.in
12. Kamal FG, Bernard RA. Influence of nail biting and finger sucking habits on the oral carriage of *Enterobacteriaceae*. Contemp Clin Dent 2015; 6(2):211–4. doi: 10.4103/0976-237X.156048
13. Khachatryan LG, Allahbakhsi F, Vadiyan DE, et al. Investigating the association between *Candida albicans* and early childhood dental caries: A comprehensive systematic review and meta-analysis. Plos One 2024; 19(12):e0315086. doi: 10.1371/journal.pone.0315086
14. World Health Organization. Geneva, oral health survey (basic method), 3rd Edition, 1987: pp 53.
15. Cutando A, Gómez- Moreno G, Arana C, et al. Melatonin: potential functions in the oral cavity. J Periodontol 2007; 78(6):1094–102. doi: 10.1902/jop.2007.060396
16. Navazesh M. Methods for collecting saliva. Ann N Y Acad Sci 1993; 694(1):72–7. doi: 10.1111/j.1749-6632.1993.tb18343.x
17. Khurshid Z, Moin SF, Khan RS, et al. Human salivary protein extraction from RNAPro·SAL™, Pure·SAL™, and passive drooling method. Eur J Dent 2017; 11(03):385–9. doi: 10.4103/ejd.ejd_183_17
18. Mandinić Z, Stojanović J, Prokić A, et al. Oral hygiene, dietary habits, and saliva properties in relation to the decayed, missing, and filled teeth index of dental students: a pilot study. Medicina 2024; 60(12):2023. doi: 10.3390/medicina60122023
19. Kolawole KA, Folayan MO, Agbaje HO, et al. Digit sucking habit and its association with dental caries and oral hygiene status in children aged 6 months to 12 years residing in semi-urban Nigeria. PLoS One 2016; 11(2). doi: 10.1371/journal.pone.0148322
20. Bukmir RP, Paljević E, Pezelj-Ribarić S, et al. Association of the self-reported socioeconomic and health status with untreated dental caries and the oral hygiene level in adult patients. Dent Med Probl 2022; 59(4):539–45. doi: 10.17219/dmp/138908
21. Permuy M, López-Peña M, González-Cantalapiedra A, et al. Melatonin: A review of its potential functions and effects on dental diseases. Int J Molec Sci 2017; 18(4):865. doi: 10.3390/ijms18040865
22. Liu RY, Li L, Zhang ZT, et al. Clinical efficacy of melatonin as adjunctive therapy to non-surgical treatment of periodontitis: a systematic review and meta-analysis. Inflammopharmacology 2022; 30(3):695-704. doi: 10.1007/s10787-022-00959-3
23. Kılınçel Ö, Çalışkan E, Şahin İ, et al. The effect of melatonin on antifungal susceptibility in planktonic and biofilm forms of Candida strains isolated from clinical samples. Med Mycol J 2019; 57(1):45–51. doi: 10.1093/mmy/myx157
24. Mousa HRF, Abiko Y, Washio J, et al. (2025). Candida albicans and NCAC species: acidogenic and fluoride-resistant oral inhabitants. J Oral Microbiol 2025; 17(1), 2473938. doi: 10.1080/20002297.2025.2473938
25. Najm AZ, Al-Mizraqchi AS. The dental caries experience in relation to salivary flow rate, salivary melatonin and mutans *Streptococci* bacteria in smoker and non-smoker patients. Res J Pharm Biol Chem Sci 2018; 9(5):2079–87. doi: 10.26477/jbcd.v31i1.2579
26. Al-Mashhadani AT, Al-Obaidi WA, Al-Jboori ZJ. Salivary *Candida albicans* in relation to oral health status among 4-5 years old children in Baghdad city. J Bagh Coll Dent 2006; 18(3):73–77.
27. Zhang J, Wang Q, Duan Z. Preventive effects of probiotics on dental caries in vitro and in vivo. BMC Oral Health 2024; 24(1):915. doi: 10.1186/s12903-024-04703-x
28. Zhu Y, Wang Y, Zhang S, et al. Corrigendum: Association of polymicrobial interactions with dental caries development and prevention. Front Microbiol 2023; 14:1237596. doi: 10.3389/fmicb.2023.1237596
29. Zhang JS, Chu CH, Yu OY. Oral microbiome and dental caries development. Dent J 2022; 10(10):184. doi: 10.3390/dj10100184