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Early Childhood Caries and Obesity

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List of Abbreviations

Abbreviation	Meaning
ECC	Early Childhood Caries
S-ECC	Severe Early Childhood Caries
BMI	Body Mass Index
Dmft index	Number of decayed, missing due to decay, and filled primary teeth index
Dmfs index	Number of decayed, missing due to decay, and filled primary tooth surface index
Dt score	Decayed Teeth score
Dft score	Decayed Filled Teeth score
Deft score	Decayed, extraction needed, filled teeth
ICADS	International Caries Detection and Assessment System
WHO	World Health Organization
IOTF	International Obesity Task Force
CDC	Centers for Disease Control and Prevention
SES	Socio-Economic Status
NAFLD	Nonalcoholic fatty liver disease
PEM	Protein – Energy Malnutrition
SD	Standard Deviation
ALARA	As Low As Reasonably Achievable

ABSTRACT

Title: Early Childhood Caries and Obesity

Objective: The aims of this review are 1) to identify the connection between overweight and dental caries in children, 2) to compare incidence of caries in two groups a) overweight and b) normal weight children. Furthermore, it aims 3) to identify risk factors.

Data Sources: Studies published during the last five years until 31. December 2023 and in the English language and accessible were searched in PubMed, Wiley, and Scopus. Search terms included *obesity, overweight, body mass index, dental caries, early childhood caries,* and *children*. Reference mining was performed in titles, abstracts, and full-text papers for additional references. A total of 347 studies were identified through database search and reference lists.

Study Selection: Database search was done, duplicates were removed, and a two-phase strategy was employed for the search. In the first phase, screening of articles and abstracts, followed by an assessment of the full-text of articles deemed suitable for inclusion and exclusion criteria. The search identified 20 studies that examined the association between early childhood caries and overweight and/or obesity; 7 studies met the inclusion criteria. In all included studies, the most commonly used dental assessment was the dmft index, and the most commonly used anthropometric measurement was body mass index.

Results: Children with overweight and obesity aged 6 years and younger had a significantly higher incidence of early childhood caries in comparison with children with normal weight (n=4). The study population revealed an association between dietary habits, low levels of parental income, and ethnicity with both conditions.

Conclusion: Based on the results obtained, majority of the studies showed that there was an association between ECC in children with overweight and/or obesity. However, due to various assessment measures to determine overweight/obesity and dental caries, the findings should be interpreted with caution.

Keywords: children, dental caries, early childhood caries, overweight, obesity

1. INTRODUCTION

Early childhood caries (ECC) and childhood obesity are two prevalent and interconnected public health concerns that significantly impact the well-being of young children worldwide. Despite considerable efforts to address these issues, they continue to pose significant challenges to healthcare systems and communities globally.

Early childhood caries, also known as tooth decay or cavities in children aged 71 months or younger, is a multifactorial disease influenced by various behavioral, environmental, and biological factors (1). It is not only limited to the oral health issues of children but also has a broader implication for their overall health and quality of life.

Alongside the increase in ECC, childhood obesity has become a significant public health issue worldwide. Childhood obesity is linked to a range of negative health effects that impact various bodily systems, such as the endocrine, gastrointestinal, cardiovascular, and musculoskeletal systems (2). The prevalence of childhood obesity worldwide is concerning, with an estimated 39 million children under the age of five being overweight or obese (3).

The co-occurrence of early childhood caries and overweight/obesity is a global epidemic and a significant public health challenge. Research indicates an association between overweight/obesity and dental caries. The causes of overweight and/or obesity and dental caries are multifactorial, but they are thought to share some common risk factors, suggesting a possible relationship between the two conditions.

Therefore, the aim of this review is to identify whether there is a connection of overweight young children with increased ECC and to compare incidence of caries in overweight children with a normal body weight children. Furthermore, it aims to identify the common risk factors associated with overweight or obesity and dental caries in children younger than 7 years old.

2. LITERATURE REVIEW

2.1 OVERVIEW OF DENTAL CARIES AND EARLY CHILDHOOD CARIES

2.1.1 DEFINITION OF CARIES

Dental caries "[…] is one of the most prevalent chronic diseases of people worldwide; individuals are susceptible to the disease throughout their lifetime" (4). Caries is the primary cause of oral pain and tooth loss. During early stages, it can be arrested and potentially reversed, but often it is not self-limiting. In severest cases, without proper care it can progress until the tooth is destroyed (4).

This widespread illness has been described to be of localized destruction of the affected hard dental tissues. This destruction is known to be originated by acid producing bacteria during fermentation mechanism. First signs of the carious demineralization are seen on the hard dental tissue covered by bacterial biofilm.

Dental caries is widely known to be considered as the result of multifactorial influence. The resulting microbiological shifts are within the complex biofilm. As well it is interacted by such factors as salivary flow and composition. Furthermore, fluoride exposure, the consumption of dietary sugars as well as the attained preventative behaviours must be taken into account. Dental caries can manifest in the crown (coronal caries) and root (root caries) of primary and permanent teeth, smooth, pitted, and fissured surfaces. Dental caries can affect enamel, outer covering of the crown; cementum; outermost layer of the root; dentine, tissue beneath both enamel and cementum (4).

Nevertheless, caries is initially reversible and can be halted at any stage, but it should be noticed that very early destructional changes in the enamel are hardly or not detected with traditional clinical and radiographic methods (4,5).

2.1.2 DEFINITION OF EARLY CHILDHOOD CARIES

Caries in primary teeth of preschool children is commonly referred to as early childhood caries (ECC). "The American Academy of Pediatric Dentistry defined Early Childhood Caries (ECC) as the presence of one or more carious (non-cavitad or cavitaded lesions), tooth missing (due to caries), or filled tooth surfaces in one or more primary teeth in children aged 71 months or younger"(1).

ECC is a type of dental caries that affects primary teeth in toddlers, progressing from mild to moderate and severe stages. ECC develop on tooth surfaces that are usually at low caries risk, first signs could be seen on the labial surfaces of maxillary incisors, lingual and buccal surfaces of maxillary and mandibular molars. Initial signs are dull white or brown spots on maxillary incisors along the gingival margin. These white sports are demineralized enamel that quickly advances to obvious decay, due to relative thinness of primary teeth enamel. Typically, the four anterior maxillary teeth are involved concurrently. In severe stages, it could result in complete destruction of the crown and finally in root stumps. During the moderate stage, caries begins to spread to the maxillary molars and during the

severe stage, it progresses to destroy the maxillary teeth and spread to the mandibular molars. Based on these clinical manifestations, several attempts were made to classify ECC (5).

Severe early childhood caries (S-EEC) is associated with atypical, progressive, acute, or rampant pattern of dental pain. Early childhood caries is classified as severe, if one of the following criteria is present (6)

- Any sign of caries on a smooth surface in children younger than 3 years
- Any smooth surface of an antero-posterior deciduous tooth that is decayed, missing (due to caries), or filled in children between 3 and 5 years
- Dmft index is equal or greater than 4 at the age of 3 years, 5 at the age of 4 years, and 6 at the age of 5 years

Severe early childhood caries (S-ECC) can be diagnosed as followed:

- Children < 3 years of age, any sign of smooth-surface caries is indicative of severe early childhood caries (S-ECC)
- From 3-5 years: 1 or more cavitated, missing (due to caries), or filled smooth surfaces in primary maxillary anterior teeth or a decayed, missing, or filled score of ≥ 4 (for children of age 3), ≥ 5 (age 4), or ≥ 6 (age 5) surfaces constitutes S-ECC

The child may suffer from considerable pain which may result in difficulty in talking or eating. In case there is extraction of the anterior teeth by the age 2 or 3 years, this may result in developmental delays like speech articulation and pattern and may lead to malocclusion. Furthermore, it could result in delay in physical development due to poor nutrition and the pain and discomfort may compromise their desire to eat (7).

2.1.3 PREVALENCE OF DENTAL CARIES AND EARLY CHILDHOOD CARIES

Dental caries is one of the most prevalent chronic diseases in people worldwide, affecting up to 2.44 billion people each year (8). Furthermore, it can exacerbate or induce systemic diseases. Results of the study (9) published by James, S.L.et al., in 2017, demonstrated that among 328 diseases, dental caries prevalence ranked as first, and incidence as second top disease. Around 2.44 billion individuals worldwide suffering from dental caries in permanent teeth (9).

Furthermore, the WHO mentioned that ECC is a highly prevalent global disease public health problem affecting an estimated 1.76 billion children with primary teeth suffering worldwide (11). A recent assessment of 194 United Nations, published data between 2007 and 2017, showed that the mean ECC prevalence was 23.8 % and 57.3%, in children younger than 3 years and children aged 3

to 6 years, respectively (12). Another study presented 2018 at the International Association of Pediatric Dentistry Conference on ECC, showed that the ECC prevalence was 17 %,36 %,43%, 55%, and 63% in children aged 1,2, 3, 4, and 5 years, respectively (13).

In addition, the common and traditional choice of caries treatment, dental restorations, has rather high failure rate. During a study, in follow-up cases, the total failure rate of 1821 restorations was 24.1%. The 10-year survival rates for class III and class IV restorations were reported to be 95 and 90%, respectively (14).

Conventional caries treatment in primary teeth often requires not only filling procedure but is occasionally involved with pulp treatment. The success is highly technique sensitive and depends upon several factors related to diagnosis, technique, final restoration and operators' experience, as well as the individual's age because a collaborative behaviour is needed (15). Despite that the prognosis of these treatments are questionable and can lead to diminished tooth longevity. Including without limitation, the main aim in conventional caries treatment in primary teeth is that the tooth remains in a functional and disease-free state until exfoliation (15,16).

2.1.4 PATHOGENESIS OF CARIES AND RISK FACTORS

Dental caries is a complex condition with multiple contributing factors. The etiology of dental caries can be related to three main factors: (17)

- Oral bacteria in dental plaque
- Presence of fermentable carbohydrates
- Available tooth surface (surface morphology)

Besides this, several other contributing factors are responsible for the process of demineralization and remineralization. These factors encompass oral hygiene habits, tooth shape, surface characteristics, dietary habits, as well as the quality and quantity of saliva (17).

Further individual risk factors can vary during their lifetime. There are several factors which play an important role in the development of dental caries. First, physical and biological factors which include the inadequate salivary flow and composition and the presence of a high number of cariogenic bacteria. Especially, in the development of caries in children, the presence of cariogenic bacteria is an important aspect to mention. The major reservoir from which a child can acquire *S.mutans* is the primary care-giver. Vertical transmission is known as the mother-to-child transmission (transmission of an infection or other disease from caregiver to child) (6). Furthermore, it could be due to horizontal transmission between individuals of the same generation, for example, sibling to sibling (17).

Other risk factors include insufficient fluoride exposure, because fluoride supports mineralization of enamel in case there is the presence of acids produced by cariogenic bacteria in dental plaque breaking down fermentable carbohydrates (18).
Further risk factors could be immunological components, need for special health care, and genetic factors.
Besides that, there are also some interactions of lifestyle and behaviour with dental caries.
Poor oral hygiene and poor dietary habits play an important role in the development of dental caries. These habits include frequent consumption of refined carbohydrates, frequent intake of oral medications that contain sugar and inappropriate methods of feeding (4).
Especially, inappropriate methods of feeding infants play a central role in the etiology and severity of ECC. Improper feeding practices can prolong the exposure of teeth to fermentable carbohydrates, which can increase the risk of ECC. According to recent research, bottle-feeding during bedtime or while sleeping has been linked to the onset and progression of caries in children (6).
"Feeding of high sugar containing food at night may increase the caries risk for infants and toddlers due to the low salivary flow rate" (19).
Socioeconomic factors also play an important role in the development of dental caries. Caries is more commonly found in individuals who live in poverty or in poor economic conditions who belong to racial and ethnic minorities. Especially in children, caries is more often seen in children whose parents have low educational level, especially illiterate parents and children who are born to single mothers (4,7).
These factors may also be a consequence of bad dietary habits and the high amount of sugar in the daily diet. Nevertheless, children whose primary caregiver or siblings have severe caries, are more prone to expect caries during their lifetime than others (4).
Other factors influencing the risk of dental caries are: dental insurance coverage, frequency with which patients attend for a dental check-up and the availability to seek dental treatment (4).

2.1.5 DIAGNOSIS

Diagnosing dental caries is often challenging. Several approaches have been made to detect and diagnose early caries lesions. In general, visual diagnosis is the standard of caries diagnosis. The visual-tactile examination is aided by a ball-ended explorer and should be carried out on clean and air-dried teeth (5).
Mostly, in cariology and contemporary dentistry the visual-tactile diagnosis of caries is combined with bitewing radiography (5).
The aim of bitewing radiograph is to detect proximal caries lesions that cannot be detected by visual inspection alone. The radiograph can provide information about approximal lesions and for occlusal

lesions in dentin, by estimating the depth of the lesion and by monitoring the lesion behaviour (20). Besides, there are some limitations when an occlusal lesion is detected, the lesion may already have reached the middle third of dentin due to superimposition of the enamel layer (21). Finally, there is no possibility to distinguish between active and inactive lesions and cavitated or non-cavitaded lesions. Nevertheless, dental radiography is a helpful diagnostic aid in oral examination of adults and children because it can provide essential information (22). In children, for example, the majority of dental X-rays are taken in pediatric dentistry and orthodontics (23). Nevertheless, the associated risk with dental radiology should not be neglected, and the dentist should follow the ALARA principle (24): “For the dentist the ALARA-principle entails the obligation to minimize the radiation dose to patient and surroundings to a level as low as reasonably achievable” (25). In general, before initiating a radiographic examination, each individual should undergo a clinical examination combined with an interpretation of previous radiographs (22). Furthermore, it should be considered if the radiograph is expected to alter the diagnosis or treatment or provide other significant information (22). In other words, radiographs should not be used for screening purposes only. Especially, in regard to pediatric dentistry, it is important to keep in mind that children and adolescents are particularly sensitive to ionizing X-rays (23). The younger the child is, the more susceptible they are to radiation, because of the division rate of cells, which is higher the younger the patient is (22,23). Infants also have a different distribution of red bone marrow compared to adults, especially in the skull area (23). Therefore, only radiographs which are beneficial are justified. Furthermore, the risk of ionization can be minimized by using the fastest image receptor, or digital radiograph and use of protective aprons and thyroid collars for children (22,24).

Another important aspect to keep in mind is that taking dental radiographs depends on the child's cooperation. Taking dental X-rays might be a frightening experience for the children, therefore appropriate behavioral techniques should be used when indicated (22).

2.1.6 TREATMENT AND PREVENTION

In general, the treatment needs to be focused on two main aspects: controlling caries risk factors and managing the lesions. Furthermore, the treatment needs to be focused on the different tissues and surfaces in which the caries is located (9). Most common treatment mode of dental caries is cavity restoration with filling.

In case the caries is inactive and has not cavitated yet, no invasive treatment is indicated, while the treatment of active caries will differ according to different sites of lesions. Treatment options for dental caries are wide and may include minimal invasive dentistry, traditional or contemporary dentistry.

The aim of caries prevention is to preserve sound tooth structure, prevent demineralization and promote the healing process because caries is a disease process that needs be managed over a person's lifetime. Dental caries must be appraised as a non-communicable and behavioral disease, "[…] associated with a dysbiosis of the dental biofilm and caused by free sugar exposure, but strongly linked to deleterious lifestyles and behaviors, mainly related to inappropriate dietary patterns"(26).
Caries prevention can take place on the individual patient level and on the socioeconomic level.
Individual prevention focuses on the use of fluoridated toothpaste and mouthwash, dietary modifications, pit-and-fissure sealants, as well as fluoride varnish application.
Various socioeconomic programmes can implement various interventions to improve oral health, such as community fluoridation in schools, school mouth-rinse programmes, distribution of fluoride tablets in schools, and implementation of school dental sealant programmes (4).

2.2 OVERVIEW OF CHILDHOOD OBESITY

2.2.1 DEFINTION OF OBESITY AND CLINICAL ASSESSMENT

Obesity is one of the most severe public health problems and it has become a global epidemic and a serious public health challenge.
The World Health Organization (WHO) defines "[…] overweight and obesity as an abnormal or excessive fat accumulation that may impair health"(27). For epidemiological purposes and routine clinical practice, simple anthropometric measures, are generally used as screening tools, such as the body mass index (BMI), skinfold measurements, waist circumference and waist-to-hip ratio. Especially, for measuring abdominal obesity, waist circumference and waist-to-hip ratio is the first choice.
In children the standard ranges are adjusted by age and gender. Even so, those measuring options are rarely used and mostly used is the BMI.
The BMI is calculated as weight to height ratio (kg/m^2). Nevertheless, it does not take the type of tissue into account. Muscle tissue has a higher density than fat. Unlike in adults, Z-scores and percentiles are used to present the BMI in children. During research, there are mostly BMI Z-score cut off points of > 1.0, >2.0 and >3.0 used, which are recommend by the WHO and can be converted into percentile. BMI percentiles are used mostly during the clinical settings.
For children and teens of the same age and sex, normal weight is from 5^{th} to 85^{th} percentile. Underweight is less than fifth percentile. Overweight is at or above the 85^{th} percentile and obesity is at or above the 95^{th} percentile (28). The above-mentioned classification is used for children and adolescents between 2 and 20 years. For children younger than 2 years, weight for length is the accepted measure of overweight and obesity.

Nevertheless, BMI is the most frequently used measure of weight in relation to height, but there are others. These include Rohrer's Ponderal Index and Benn's Index, but such indexes are rarely used (29). The Rohrer's Ponderal Index is an indication of a person's weight relative to their height and is calculated as weight (kg) divided by cubed height (m^3) (29). Compared with BMI in respect of its ability to predict percentage body fat in children and adolescents, there is as long-term association with adult obesity. The index may perform as well or better in some respects than BMI, however, it is much least used, but remains popular in neonatologists.

Likewise, the Benn's Index can be used as well. Defined as weight divided by height^p, so the index is independent of height. However, p is never constant, therefore it is difficult to calculate (29).

Further, methods which have been adopted to measure fat in human subjects, are categorized as density-based methods (hydrodensitometry; air displacement plethysmography), scanning (computerized tomography; magnetic resonance imaging; dual-energy x-ray absorptiometry) and bioelectrical impedance methods (29).

Childhood obesity can be categorized in one of two ways syndromic and non-syndromic. Non-syndromic cases could be classified into monogenic obesity and polygenic obesity (28).

2.2.2 PREVALENCE OF PAEDIATRIC OBESITY

The prevalence of paediatric obesity has increased worldwide in the past five decades and it has plateaued at high levels; in most high-income countries and it is rising in many-low income and middle-income countries (27,30). The prevalence in the age group of 5 to 19 years is increased around eightfold to 5.6% in girls and 7.8% in boys, between 1975 and 2015. Furthermore, there are also significant changes in the age group 2 to 4 years; from 3.9% to 7.2% in boys and from 3.7% to 6.4% in girls observed between 1980 and 2015 (30).

According to the KiGGs baseline study in Germany in 2018, the prevalence of overweight (including obesity) in girls and boys aged 3 to 17 years is 15.4 % and the prevalence of obesity is 5.9% (31). More closer, there could be seen that the obesity prevalence among 3- to 6-year-old girls is 3.2% and 1.0% among boys. During aging, this proportions rises to 7.7% for girls and 9.2% for boys aged 14 to 17 years (31). In comparison to that, in Lithuania, the prevalence of overweight in girls and boys aged 7 to 17 years is 12.6% and the prevalence of obesity is 4.1% (32). The obesity prevalence among 14-to 17-year-old girls is 1.8% and 2.4 % among boys (32). Moreover, the prevalence of obesity among US children and adolescents, is still one of the highest with 18.5%. In the United States, "[…] the prevalence of obesity among adolescents (12-19 years; 20.6%) and school-aged children (6-11 years; 18.4%) was higher than among preschool-aged children (2-5 years; 13.9%)" (33).

Differences in prevalence are likely to reflect differences in the background level of the obesogenic environment. Furthermore, the sum total of the factors that promote obesity including factors that promote obesity could be of different origin and include physical, economic, policy, social and cultural factors (30). Further research will have to address the reasons of prevalence variation and differences according to different gender.

However, they may be related to cultural variations on parental feeding practices for boys and girls and societal ideals of body size.

Obese children tend to remain obese in adulthood, hence, early management of overweight and obesity must be considered crucial. The progression of obesity into adulthood is influenced by the age of the child, severity of obesity, and the presence of parental obesity.

In order to achieve early management, one must keep the risk factors in mind. The risk factors are multifactorial (27).

2.2.3 FACTORS CONTRIBUTING TO CHILDHOOD OBESITY AND PREVENTION

Over the past few decades, the extensive rise in obesity has been profoundly influenced by changes in the obesogenic environment and these changes could be on different levels at the level of the family, local community, or the broader sociopolitical environment (27).

Furthermore, dietary factors have been postulated as an important contributor to the development of obesity in children. These days the easy and cheap availability of high caloric fast food and the provided large proportions are most commonly the first choice of children. Subsequently there is an increased use of sugar sweetened beverages, sweet snacks, fast food containing excess fat, large portion sizes and high glycemic foods. Some studies which were published in the United States, showed that sweetened beverages provided an average of 270 kcal/d, representing 10 to 15% of the total caloric intake (34). Moreover, there are specific eating patterns which could lead to obesity.

In addition, there is an ever-expanding sedentary lifestyle, which is associated with the increased screen time, resulting in frequent snacking while watching screens. Other behavioral factors that influence child obesity risk include the frequent exposure to the ubiquitous food marketing and the lack of physical activity. Another growing problem is the short sleep duration, poor sleep quality and late bedtime (2,27).

Together these factors contribute to an excess in adipose tissue due to an imbalance in the equilibrium between energy uptake and utilization.

As well it is important to mention several early life factors that are considered to contribute to obesity in children. The role of parents against obesity in their children extends from the first years of life (27). Maternal obesity before pregnancy, excessive gestational weight gain, gestational diabetes and

maternal smoking during pregnancy, second-hand exposure to smoke are associated with increased birth weight (28).

Furthermore, feeding practices have variables influences on childhood obesity. Breastfeeding is suggested as one of the predictors which could be important in the protection to prevent early childhood obesity (35). Contrary, very early introduction of complementary foods and beverages have been shown to lead to overweight and obesity; especially this is observed in case of introduction to complementary foods before the age of 4 months or in formula-fed babies (35).

Additionally, parental feeding practices, particularly in the preschool age range, may affect the risk of developing obesity. For instance, it could be restriction of specific foods or the overall amount of food. A responsive feeding style is associated with healthy weight gain, whereas non-responsive feeding is linked with an increased child BMI or obesity (27).

Thus, parents have a high control factor of managing and modeling their children's eating behaviour and the family is inspired to play an important role in the educational process of building a healthy relationship towards food.

Furthermore, psychological environment, adverse childhood experiences, such as physical or mental abuse, family dysfunction and neglect are associated with the development of obesity (27).

Not only early life factors, but also medical conditions and genetic factors play an important role in the development and origin of childhood obesity. Medical conditions could range from different origin and include several endocrine disorders, central nervous system damage and post-malignancy (27).

Children, with genetic syndromes associated with obesity, typically have early-onset obesity and have characteristic features on physical examinations which occur secondary to the previously mentioned range of medical conditions (36). Typically, those children have a short stature, developmental delay, dysmorphic features, retinal changes, intellectual disability (mental retardation), or deafness.

As an illustration, there could be mentioned the Prader-Willi syndrome which is characterized by severe neonatal hypotonia and feeding difficulties during infancy. These conditions are followed by hyperphagia and subsequent development of obesity (2).

The next issue are several pharmacological agents which are associated with excessive weight gain, including glucocorticoids, anti-epileptics, insulin, and several atypical antipsychotics. Due to the fact that they cause excessive weight gain, anticipatory weight management strategies should be used when beginning such therapy (27).

Obesity is associated with clinical comorbidities which affect almost every system in the body including, but not limited to, the endocrine, gastrointestinal, cardiovascular, and musculoskeletal systems (2). Furthermore, it also includes social problems like bullying and depressions (28).
Firstly, it is important to mention that excessive weight gain in children can influence growth and pubertal development due to accelerated linear growth and advanced skeletal growth (2).
Appropriate nutrition is therefore essential for the typical timing and pace of pubertal onset. Otherwise, early onset puberty could happen due to altered hormonal parameters, which leads to premature adrenarche, thelarche, or precocious puberty. Additionally, adolescent girls with overweight are at higher risk of developing polycystic ovary syndrome and hyperandrogenism, as well manifestations can include menstrual irregularities, hirsutism, and acne (2).

Other clinical comorbidities could have a gastrointestinal origin. The most common cause of liver disease in children is Nonalcoholic fatty liver disease (NAFLD) which is strongly associated with obesity. The course of the disease can vary between simple steatosis, advanced steatohepatitis and cirrhosis. In most cases, the patients are asymptomatic; some patients have non-specific symptoms, including generalized abdominal discomfort and fatigue (31). Laboratory abnormalities include elevations in levels of liver transaminases, gamma-glutamyl transpeptidase and alkaline phosphatase, imaging may confirm the presence of fatty liver. Imaging for evaluating presence of fatty liver include the use of ultrasound, MR, CT and MRI.
Besides, there could be an impairment in mobility, increased prevalence of fractures, lower extremity joint pain and malalignment (2).
Other important points are the psychological and social problems which are common. This could be due to weight stigma. Weight stigma, which can lead to discriminatory actions against the target of the prejudice, refers to the negative beliefs attributed to an individual based on their weight (38). Weight-stigma could be seen in children or adolescence who are obese and do not fit the normal social norms for body weight, and negative misbeliefs that individuals are idle and that there is no motivation to improve their health are common (27).
Mostly, this action could be seen in the closer surroundings and the field the child normally interacts with, including parents, siblings, family members, teachers, and friends (38).
Actions involved weight-based victimization, bullying and differential treatment due to their weight. These actions result in poor self-esteem, anxiety, depression, social isolation, and decreased health-related quality of life, and can have severe implications for the general well-being of the child.
Additionally, there could be several other clinical comorbidities like dermatological and neurological problems.

The suitable treatment and intensity of it depends upon several factors: obesity severity, the age and developmental stage of the child, needs and preferences of the family. Nevertheless, the treatment is based on the target to reduce adiposity in general and to prevent the development of chronic diseases. Furthermore, the treatment aims to improve related physical and psychological complications.

The contemporary treatment needs to be based on multiple components including dietary interventions, physical activity increase , psychological therapy, pharmacotherapy, and surgical procedures (27).

3 POSSIBLE ASSOCIATION OF OVERWEIGHT/OBESITY AND DENTAL CARIES

Recent studies have identified an association between overweight/obesity and dental caries. The causes of overweight and/or obesity and dental caries are multifactorial, but they thought to share some common risk factors, which suggest that a relationship may exist between the two pathologies. Frequent risk factors include high sugar diet, lower socio-economic status (SES), and other social-environmental factors, as well as fathers' occupation, mothers' educational level and feeding methods during the first 6 months of life, however, this commonality remains under investigated (39). Furthermore, it has been believed that obesity can lead to changes in the oral microflora and salivary properties, which consecutively might predispose children to develop dental caries (40). However, this explanation necessitates that dental caries is a consequence of obesity. Gender is also thought to be an important consideration, as teeth erupt earlier in girls than in boys, so that girls have a longer exposure to cariogenic products in the oral cavity (41). Additionally, genetic variations associated with gender differences influence salivary flow and composition, enamel formation, dietary preferences and the composition of pathogenic bacteria (41). Even so, current literature is inconclusive and controversial if overweight and/or obesity may be a marker of dental caries.

Some studies (39,42) suggest that obese/overweight children are at greater risk of having caries than normal weight children, the finding is based on the fact that frequent intake of sugar-sweetened drinks and sugary foods, and frequent snacking between meals, can be risk factors both for dental caries and obesity.

For example, Hong et al (42) found that children who were at risk for being overweight or obese had higher dmft scores, compared to normal weight children between the ages of 60 -70 months.

Furthermore, the literature suggests that there is a correlation between obesity and caries that is more pronounced in older children than in younger ones (43). In other words, the association between obesity and caries is stronger and more consistent for permanent teeth. One factor influencing this relationship appears to be age. This is likely due to the fact that both conditions accumulate gradually over the course of one's life. Thus, future longitudinal studies should examine the relationship in

different age groups and explore possible mechanisms by which age might explain differences in outcomes.

Nevertheless, some other studies have shown that there may be a link between high caries and underweight. Children with dental caries experience pain and discomfort when eating, which contributes to weight loss and malnutrition. Yet malnutrition is associated with enamel hypoplasia and changes in saliva composition that contribute to tooth decay. This shows that malnourished children have more severe forms of caries than obese children (44). The hypothesis is supported by the study of Duijister et al (45). They showed that treatment of severely carious teeth in underweight Filipino children aged 48-68 months was associated with significant weight gain after treatment.

In addition, several studies suggest that the association between underweight and ECC is more pronounced in low-and middle-income countries. For example, Floyd et al (46) found that ECC is associated with lower socioeconomic status, whereas no statistically significant association was found in the high socioeconomic status area.

Other studies have suggested that there is no association between the prevalence of dental caries and weight status (42,47,48).

However, not many studies reported specifically in children aged under 6 years by ECC. Most studies searched the evidence relating to both children and adolescents (under 18 years of age), furthermore, the majority did not differentiate the results clearly for children under six years with primary dentition, which highlights a need to focus on evidence in early childhood, because ECC affects preschool children whose weight status can have a significant effect in their development and wide-ranging health outcomes later in life, especially in case of obesity. Further knowledge of this relationship could enable us to implement health promotion programs based on the common risk factor approach, and to reduce the prevalence of overweight and/or obesity and dental caries in young people.

4 AIMS OF THE STUDY

The aims of this review are 1) to identify the connection between overweight and dental caries in children, 2) to compare incidence of caries in two groups a) overweight and b) normal weight children. Furthermore, it aims 3) to identify risk factors.

5 METHODOLOGY

This review was conducted according to the PRISMA guidelines.

5.2 ELIGIBILITY CRITERIA

The eligibility criteria have been described according to the Population, Intervention/Exposure, Comparator, Outcome, and Study design (P(I/E)COS) criteria (Table 1).

5.2.2 POPULATION

Studies examining children under six years of age and with primary dentition. Furthermore, children with other medical conditions or dental abnormalities. Studies comparing children regardless of sex, country of origin, ethnicity or socioeconomic status. Studies that include children, adolescents, and adults, with mixed or permanent dentition will be excluded. If studies report only outcomes for children and adolescents older than 6 years, they will be excluded.

5.2.3 INTERVENTION/EXPOSURE

Studies examining overweight and obesity measured by validated measures like BMI, BMI z-score for age, BMI percentile for age, weight-for-height z-score. These have proved to be some of the most accurate measures of changes in adiposity in young children as they grow. Studies clearly categorized into normal BMI, overweight or obesity based on WHO, IOTF, and CDC.
Studies involving self-reported or nonvalidated measures for overweight and/or obesity are excluded. The adiposity status will be clearly categorized into normal weight, overweight and obesity.

5.2.4 OUTCOMES

The outcome of interest are studies which directly analyze the association between early childhood caries and overweight and/or obesity. Only validated measures for early childhood caries will be considered, if the dental caries is assessed by qualified professionals. Validates measures included: dmft, dmfs, as well as the ICDAS scoring method. Studies considering nonvalidated measures of early childhood caries and studies that mixed the outcomes of different dentition stages will be excluded, as well as studies that do not draw a direct comparison between overweight and /or obesity and dental caries outcome.

5.2.5 STUDY DESIGN

Studies published during the last five years until 31 December 2023 will be included. Studies design will include clinical research, case reports, human observational studies and birth cohort studies, but not limited to these study designs. Systemic reviews will be excluded and only used for reference mining. The studies must be in English language and accessible.

5.3 SEARCH STRATEGY

To formulate the research question and related search terms the Population Intervention/ Exposure Comparator Outcome (P(I/E)CO) was used. A combination of specified medical subject headings (MeSH) terms and keywords and Bool operators (AND and OR) were drafted, and three databases (PubMed, Wiley and Scopus) were searched for scientific and medical articles published between 2018 and 2023. The search was conducted with the following
MeSH terms: (((“Obesity” [MeSH]) OR “Overweight” [MeSH]) OR “Body Mass Index” [MeSH] AND “Dental Caries“ [MeSH].

5.4 STUDY SELECTION

The studies identified through the electronic databases, was uploaded into reference manager software, Mendeley, and duplicates were removed.
Reference mining was performed in titles, abstracts, and full-text papers for additional references. A total of 347 records were identified through the database search and 32 duplicates were removed.
A two-phase strategy was used for the search. During the first phase, articles and abstracts were screened to identify those that were potentially relevant based on the electronic search.

5.5 DATA EXTRACTION

During the initial phase, a total of 347 articles were identified across the three databases and reference mining, after abstract screening a total of 20 studies were identified for full-text reading. The full text was assessed and afterwards it was decided whether these meet the eligibility criteria, finally seven studies (44,49–54) were included. A PRISMA flow diagram (Figure 1) was constructed showing the identification, screening, eligibility and included studies.

TABLE 1 Eligibility criteria according to the (P(I/E)COS) criteria

	Inclusion Criteria	Exclusion Criteria
Population	• Children < 6-years of age with primary dentition • Any gender • Children with other medical conditions or dental abnormalities	• Children, adolescents, and adults, with mixed or permanent dentition
Intervention/Exposure	• Overweight/obesity measured by validated measures (BMI,BMI z-score, BMI z-score for age, BMI percentile for age, weight-for-height z-score, etc.) • Children clearly categorized into normal BMI, overweight or obesity based on validated standards such as WHO, IOTF, and CDC	• Self-reported or nonvalidated measures for overweight and/or obesity
Outcomes	• Studies which directly analyze association between early childhood caries and overweight and/or obesity (<6-y of age) • Early childhood caries measured by validated measures (e.g., dmft, dmfs,deft,dft,dfs, etc.)	• Nonvalidated measures of early childhood caries • Studies that mixed the outcomes of different dentition stages • Studies that do not draw a direct comparison between overweight and/or obesity and dental caries outcome
Study design	• Not older than 5 years • Studies published until 31 December 2023 • Clinical research • Case reports • Human observational studies • Birth cohort studies • Must be in English and accessible	• Older than 5 years

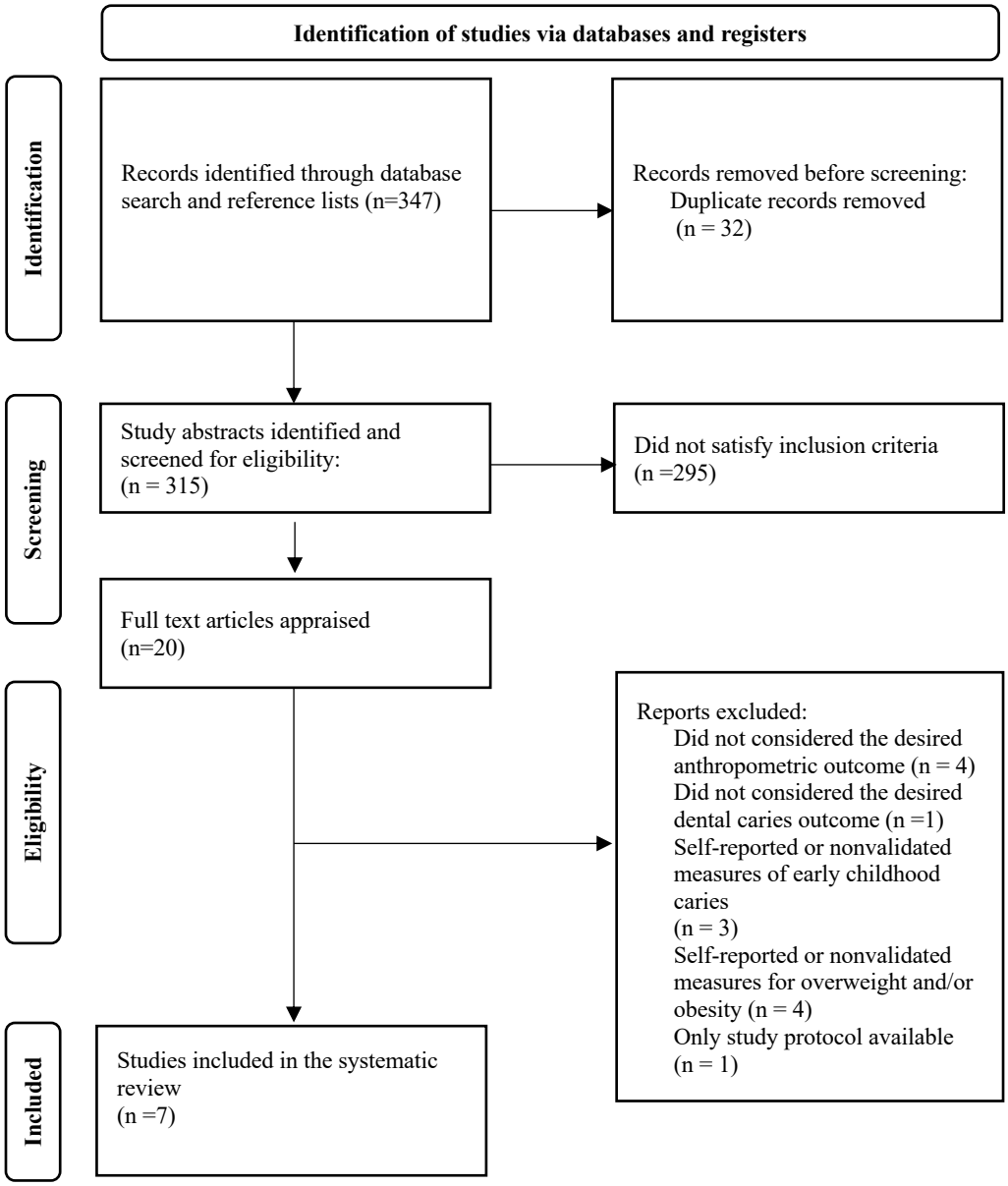

FIGURE 1 Flowchart according to the PRISMA checklist showing the flow of articles arising from the main search

6 RESULTS

6.2 TYPE OF STUDY, SAMPLE POPULATION AND QUALITY ASSESSMENT

As shown in Table 2, there were two types of studies among the shortlisted articles.
Out of the 7 studies, there were six cross-sectional studies (44,49,50,52–54), and one study was a retrospective study (51).
These were published between 2018 and 2022. All studies were in the English language and accessible. Out of the previously mentioned studies, four studies were conducted in developed countries (49–51,53) and three in developing countries (44,52,54).
Included studies assessing association of overweight/ obesity and dental caries were conducted on children whose age ranged from birth to 6 years, the mean age in the study population was 4.2 ± 0.5(SD) years. There was a great variation in respect to sample population used in the studies ranging from as low as 150 children to as high as 27,333 children. The median sample size of the included studies was 4505 children, and most studies had a sample size of 200-500 children. One study had a sample of 150 children, and two studies had more than 1000 children included in the study.
The total number of participants in all studies included was 31,538. All studies included children of both genders; 50.30% of the participants were boys and 49.30% of them were girls.

6.3 STUDY CHARACTERISTICS

Four studies (50–52,54) used the "dmft" (number of decayed, missing due to decay, and filled primary teeth) index, while one study (52) employed the additional "dmfs" (number of decayed, missing due to decay, and filled primary tooth surfaces) index. Another study (53) assessed using the "dt" (decayed teeth) score and the "dft" (decayed filled teeth) score, while an additional study (44) employed the "ICADS" (International Caries Detection and Assessment System) scoring method. The last study used only the "dmfs" (number of decayed, missing due to decay, and filled primary tooth surfaces) index (49).
Five studies (44,49,51,53,54) examined overweight/obesity using the BMI *z*-scores recommended by the WHO, where a z-score > + 1 standard deviation (SD) is classified as overweight, and obesity is classified as a z-score > + 2 standard deviation (SD). Two studies (49,53) used the BMI-for-age centiles based on CDC clinical growth charts. One study (53) used the age-and gender-appropriate international classification system for childhood obesity (BMI[kg/m^2]) recommended by the International Obesity Task Force (IOTF), and one study (50) assesses overweight/obesity using BMI scores based on the UK90 growth charts.

6.4 ASSOCIATION OF OVERWEIGHT/OBESITY WITH EARLY CHILDHOOD CARIES EXPERIENCE

Conclusively, the majority of the included studies revealed analogous associations. Four studies, comprising three cross-sectional studies (49,52,53) and one retrospective study (51), outlined those children classified as overweight and/or obese exhibited a higher prevalence of ECC compared to children with normal body weight.

Among these four studies, three (two cross-sectional and one retrospective) yielded statistically significant positive results. Hung et al (52) as well reported that ECC was associated with higher BMI children, however, the difference was not statistically significant with $p \geq 0.05$.

One study conducted by Paisi et al (50) found no association between any measure of overweight and/or obesity and ECC (Table 3).

Different results are derived dependent on the measure used to assess child weight status. A significant relationship between dental caries and obesity is noted in the studies using validated measures for assessing child obesity such as BMI-for-age centiles.

6.5 RELATIONSHIP BETWEEN BMI AND EARLY CHILDHOOD CARIES

Furthermore, two studies which examined correlations between nutrition status with different factors and dental caries of preschool children, reported an association between ECC and underweight. Olatosi et al (54) identified that the dmft score distribution was highest among children within the severely wasted or wasted groups, lowest among children with normal *z* scores, and intermediate in the overweight or obese groups. A similar trend was observed among children aged 2-5 years in Vietnam (44). Despite the general trend observed in the study by Coung et al (44) which indicated a higher association between being underweight and ECC, it is noteworthy that 58.3% of children classified as overweight or obese also exhibited caries incidence.

TABLE 2 Basic information of the included 7 studies

Authors	Country	Year	Study design	Participants (n)	Boys (n)	Girls(n)	Age	Caries measurement	Weight assessment
Kennedy et al.	Canada (developed country)	2020	Cross-sectional study	150	78	72	3.95±1.18 (SD)	dmft index	BMI z-scores
Paisi et al.	England (developed country)	2018	Cross-sectional study	349	175	174	5.1±0.31 (SD)	dmft index	BMI z-scores
Aung et al.	New Zealand (deveoped country)	2021	Retrospective study	27333	13869	13464	5.0±0 (SD)	dmft index	BMI-for-age
Hung et al.	Vietnam (developing country)	2021	Cross-sectional study	468	265	203	4.46±0 (SD)	dmft and dmfs index	BMI z-scores
Piovesan et al.	United States (developed country)	2022	Cross-sectional study	2275	1117	1158	3.4±1.1 (SD)	dt and dft index	BMI-for-sex-and-age
Olatosi et al.	Nigeria (developing country)	2022	Cross-sectional study	273	130	143	4.19±0.96 (SD)	dmft index	Weight-for-age z-score Height-for-age z-score Weight-for-height z-score BMI-for-age z-score
Cuong et al.	Vietnam (developing country)	2022	Cross-sectional study	690	356	334	3.5±0 (SD)	ICDAS standards	BMI- for -age

TABLE 3 General outcomes of the included studies

Authors	Study setting	Outcome	Outome direction	Result
Kennedy et al.	Winnipeg, Canada	significant	positive	ECC is associated with higher BMI
Paisi et al.	Plymouth, England	not-signficant	negative	No asssociation between ECC and BMI
Aung et al.	Northland/Auckland, New Zealand	significant	positive	ECC is associated with higher BMI in children with European ethnicity
Hung et al.	Hanoi, Vietnam	not-signficant	positive	ECC is associated with higher BMI
Piovesan et al.	United States	significant	positive	The relationship between obesity and ECC varied based on the definition of obesity
Olatosi et al.	Lagos State, Nigeria	significant	negative	ECC is associated with underweight
Cuong et al.	Van Xuan, Vietnam	significant	negative	ECC is associated with underweight

6.6 RELATIONSHIP BETWEEN BMI AND DENTAL CARIES BY COUNTRY

The subgroup analyses indicated that compared with normal weight children, obese children from developed countries had a significant relationship between overweight and/or obesity and caries (49,51,53) (Table 2).

Nonetheless, the study conducted by Hung et al (52) in a developing country (Vietnam) found a non-significant association between obesity and dental caries.

Furthermore, the subgroup analyses, indicated that ECC is often associated with underweight issues in developing countries such as Nigeria and Vietnam (44,54).

6.7 COMMON RISK FACTORS FOR CHILDHOOD OVERWEIGHT AND/OR OBESITY AND DENTAL CARIES

All studies were screened for potential confounding variables, encompassing demographic factors such as age, gender and ethnicity, alongside familial characteristics including family type and sociodemographic status. Additional considerations extended to children's oral health practices, community water fluoridation, feeding modalities during the first six months, and factors related to nutrition status (ANNEX A).

Particularly, two studies (49,53) identified that a low family socioeconomic status (SES) is associated with both overweight/obesity and dental caries amongst the study population. Both studies used the BMI z-scores to assess the weight status, however they used different criteria to assess ECC. Kennedy et al., (53) used the dmfs index, whereas Piovesan et al., (53) used the dt and dft score.

A detailed examination of these studies revealed poverty, delineated by diminished income levels, as a potential confounding variable influencing the association between BMI z-scores and heightened caries prevalence (ANNEX A).

Furthermore, two studies (52,53) identified that the diet plays an important role in the obesity and caries relationship. Hung et al (52) found that related factors such as using soft drinks, drinking milk at night and eating sweet marshmallows were associated with ECC in obese children with $p<0.001$. A similar trend was identified by Piovesan et al (53) which shows that greater intake of added sugar influence the caries and obesity relationship (ANNEX A).

In addition, Aung et al (51) pointed out that ethnicity is the main confounding variable. In the study, ethnicity, including Asian, European, Māori, Pacific, and other ethnic backgrounds, was systematically assessed to investigate its potential influence on the observed outcomes.

In the analysis, European ethnicity emerged as a significant factor associated with the relationship between ECC and obesity, suggesting a potential link between this ethnic group and the observed health outcomes.

One study (54) that identified a positive relationship between being underweight and ECC elucidated bottle-feeding or mixed feeding method during the first six months of life as a confounding variable, whereas the other study found no relation between any confounding variable.

7 DISCUSSION

The aim of the study was to identify whether there is a connection of overweight children with increased ECC and to compare incidence of caries in overweight children with a normal body weight children. Three out of seven included studies reported a significantly higher caries experience amongst children with overweight and/or obesity (49,51,53), one study reported a higher caries experience, but it was not statistically significant (52); whereas one study found no association between ECC and obesity (50). Two additional studies (44,54) have identified an association between being underweight and early childhood caries; however, as these findings do not align with the primary aim of the current study, they will not be extensively discussed.

The outcomes of the current review are consistent with the findings of the previous conducted systematic review by Manohar et al (39), which reported that six studies identified, consisting of four cohort studies and two case-control studies, children with overweight and/or obesity exhibited a higher prevalence of dental caries. Additionally, one cohort study found an association, but it was not statistically significant; while two studies found no difference in the caries experience within the children with high BMI scores. Conversely, the systematic review by Hayden et al (43) found no association between obesity and dental caries in the primary dentition: however, the principal findings indicate an association between obesity and level of caries in the permanent dentition.

An explanation for this observed age-dependent correlation could be due to the progressively sedentary lifestyles, particularly among older age groups. This sedentary behaviour is associated with increased television viewing habits and increasingly self-moderated and an unhealthy diet, and increased meal frequency, particularly snack consumption, which is often highly processed and high in sugar. This sedentary behaviour correlates with increased television viewing habits and a trend toward self-regulated and unhealthy diet. Thus, results in an imbalance in the equilibrium between energy uptake and utilization, which can increase the risk of weight gain and obesity, additionally it also promotes the development of dental caries.

On the other hand, the positive association between obesity and caries in children aged 6 years and under may reflect the fact that children rely on their parents for appropriate health behaviours, such

as diet, in their early years (39). Sedentary lifestyle could be observed in young children too, this could be presented with excessive usage of TV, phone or other screens.

However, it is essential to acknowledge that obesity and dental caries are complex, multifactorial diseases: thus, the concept of a direct cause-effect relationship should be regarded critically.

Another potential explanation could be due to the alterations in various organs, including the salivary glands. Due to the fact that salivary glands and saliva plays a significant role in maintaining oral health, an increase in the salivary flow rate, may exacerbate health problems such as dental caries and oral infections. Especially, in children with obesity and overweight, there could be figured out that the salivary function is reduced, which could affect the course of dental caries, because the decrease in flow and salivary quality in obese children will cause some disturbances in the process of remineralization, which plays an important role in the progression of dental caries (40).

Another medical explanation could be that children with overweight and/or obesity tend to consume large amounts of obesogenic and cariogenic in same time food, which can cause protein – energy malnutrition (PEM). It occurs when there is a deficiency in protein, energy, or both, relative to the body's needs. Such a state of malnutrition in the body during its development can have an effect on the oral structures. Dental caries are caused by organic acids produced by bacteria in dental plaque, which demineralize the enamel and dentine. These acids are formed through the anaerobic metabolism of dietary sugars. The biological factors of caries are cariogenic bacteria (plaque), fermentable carbohydrates, and host factors.

More relevant to PEM, however, are the host factors associated with caries, particularly tooth defects and the salivary system. Especially, external structural defects, such as hypoplasia, can provide a more cariogenic environment and less protective enamel as well as defects that include hypomineralization which might increase the susceptibility to demineralization (55). As mentioned earlier, salivary flow rates are directly related to caries through oral clearance, as well as in relation to buffering capacity and antimicrobial components (55). Anyway, this review did not explore the mechanisms behind the identified association. These hypotheses require further investigation.

Despite that, it has been thought that children with overweight/obesity have higher caries experience, because they share common risk factors such as high-sugar diet, low SES, and low health literacy. However, the relationship between overweight/obesity and dental caries cannot be explained by the consumption of high-sugar diet alone and includes other significant underlying factors.

The present review identified poverty and a low family SES as common underlying causes associated with overweight and/or obesity and dental caries in two studies (49,53). These findings coincide with the previously conducted study by Manohar et al (39) in which two studies identified low parental income and educational level as a common risk factor for both conditions: caries and overweight.

The socioeconomic status of the family would predict parental health beliefs; this, in turn, could affect the health behaviours and practices of the parents, as well as their coping skills. Furthermore, poverty influences children's health; this impact is indirect, manifesting through adverse effects on their physical environment and psychosocial experiences (56). For example, low family income can result in limited access to dental hygiene products as well as preventive measures such as dental sealants. Besides, it could also affect access to appropriate medical and health services, which is hindered by the high volume of patients and the limited number of facilities.

Not to mention dietary and lifestyle choices. Similarly, a higher income tends to be associated with a higher level of education, which in turn is associated with greater awareness of and knowledge about health issues.

Furthermore, higher incomes are associated with better dietary habits, housing conditions and medical and healthcare services, etc. (57).

Especially, dietary choices play an important role in manifesting dental caries and overweight and/or obesity. This could be due to high sugar diet, which is the leading cause for caries and obesity, as well as lifestyle choices, which could be, for example, that children and adolescents of low socioeconomic status have been found to participate in fewer leisure activities (56).

There is evidence that taking part in physical activity during leisure time improves health and reduces the levels of depression and anxiety (56).

Another important aspect to mention is that parental education levels directly relate to parent's health literacy (56). This could be for example, the attitude towards oral health behaviours. Likewise, it is well known that a childs routine health behaviours are shaped by their parents.

Noteworthy, a study by Ponthiere et al (58), figured out that if a mother of a 0-3 years old child has a healthy lifestyle, the child is 27% more likely to adopt the healthy lifestyle and to be healthy. One's lifestyle mirrors their personal habits, which can be classified as either positive or negative.

Therefore, it is thought that children from highly privileged families have better ability to adopt good oral health habits, along with overall lifestyle preferences, because it is thought that the influence of SES on health is closely related to the lifestyle.

It is noteworthy to mention that lifestyle involves both health risk behaviors and health promoting behaviors. For instance, it is thought that people who have higher SES are more motivated and have better resources to maintain a healthy and balanced lifestyle which leads to better health outcomes (57).

Thus, a strategy embedding interventions against dental caries and obesity into public health promotion programs could enhance the general health, development and overall well-being of the child. Furthermore, both conditions can progress into adulthood, leading to additional complications later in life; highlighting the importance of preventing these. Due to the growing evidence of an

association, it was thought that dental care professionals are well-positioned to play an essential role in preventing and treating dental diseases and childhood obesity (59).

Explicit dietary targets such as minimizing sugary foods and drinks, increasing intake of fruit, vegetables and high-quality protein, and limiting prolonged consumption of refined foods are emphasized strategies to meet dietary guidelines while targeting obesity prevention and reducing the risk of dental caries (59).

Another important aspect is to implement educational programs in schools and in communities to teach children and their families about the importance of oral hygiene, healthy eating habits, and regular physical activities. Furthermore, it could be useful to strive for collaboration with healthcare providers, including pediatricians , dentists, and nutritionists, to provide comprehensive care for children. In fact, it is recommended that targeted oral health screening and awareness programmes to be implemented for children with abnormal BMI and those living in deprived areas are recommended, but not limited to these areas. In addition, the effectiveness of such programmes should be regularly monitored using universal oral health indicators. For example, expanding access to oral health service through mobile and virtual dental clinics is recommended. In terms, public health policies that mandate regular dental check-ups for children at an early age are warranted to detect and treat dental caries.

Moreover, it is important to recognize the critical role of other health professionals, such as primary care physicians, pediatricians, social workers, community health workers, registered dietitians and nursers, in addressing the childhood dental caries and obesity epidemics. Interprofessional collaboration can support multidisciplinary approaches to comprehensive care. This is particularly relevant for paediatric primary care providers, who see children on a regular basis throughout their early years and are therefore a logical collaborator in these efforts. Furthermore, discussing the dietary association between obesity and dental caries in the practice setting and providing dietary advice will improve children’s and parents understanding of the link and may help them to adopt healthy eating habits. In addition, training should address weight-related bias and stigma in the delivery of care.

7.2 LIMITATIONS

However, although most of the studies in this review showed a positive association between overweight/obesity and dental caries in children aged 6 years and younger, there were several discrepancies that could affect the outcome of the current review. Firstly, potential confounding variables were assessed in all the studies, although the factors that were considered as confounding variables varied between the studies. In addition, the statistical methods used to adjust for confounders varied. These confounding variables have the potential to change the strength of an observed association and may even to reverse the association altogether. Another aspect was that

some studies were conducted in developed countries and some studies in developing countries, and that country, ethnicity and SES varied. This may affect the children's living environment, diet, health and access to health care and education. As well, regional variation in incidence of dental caries could be due to sociodemographic differences that influence dietary habits, family income, parental education, access to dental services, and fluoride levels due to variations in water sources.

In addition, all the studies used different assessment measures to assess overweight/obesity and dental caries. The categories used for BMI also varied: five studies (44,49,51,53,54) used the WHO criterion; two studies (49,53) used the CDC criterion, one study (53) used the IOTF criterion, and one study (50) used the UK90 criterion. Caries status was assessed by dmft, dmfs, dt, dft score and ICDAS standards.

Four studies (50–52,54) used the dmft index, while one study (52) employed the additional dmfs index. Another study (53) assessed using the dt score and the dft scores, while another study (44) used the "ICADS" scoring method. The last study used only the dmfs index(49).

This variation may have biased the effect size of the relationship between BMI and dental caries in some studies.

In summary, the review was able to identify the factors that influence the association between overweight/obesity and dental caries; which may help in the development of health promotion interventions and educational programmes based on a common risk factor approach to prevent the burden of obesity and dental caries. Opportunities to understand the impact of demographic, economic and behavioral risk factors on dental caries and BMI could include prospective longitudinal approaches.

Thus, the main limitations of the review are that the studies used different definitions and indices of dental caries, such as dmft, dmfs, dt score and ICDAS standards, and that the criteria for BMI classification were inconsistent between studies.

Furthermore, the limited number of included studies (less than 10) may have overlooked trials studies with results that are inconsistent with the current findings, which could change the significance of the current results. Similarly, if more studies were conducted, the subgroup analysis could be affected.

7.3 RECOMMENDATIONS FOR FUTURE RESEARCH

Therefore, in future, it will be necessary to conduct a more comprehensive electronic database search, including grey literature, and possibly extend the time range to find more studies that analyze the association between overweight and/or obesity and dental caries in children aged six years and younger. In addition, it would be useful to address the limitations of the current review in further research. First, it may be advisable to ensure equal confounder and use consistent statistical adjustment methods. Additionally, it would be helpful to use uniform assessment measures for both

overweight/obesity and dental caries. It is also recommended to use standardized criteria for BMI categorization and dental caries index assessment.

In addition, it might be useful to investigate further the hypothesis that another biological mechanism that might link obesity and caries is the reduced stimulated salivary flow that has been found in obese children compared to their healthy peers. Reduced salivary flow affects the development of caries, so obese children could be at higher risk of caries due to reduced salivary flow.

8 CONCLUSIONS

The relationship between children who are overweight or obese and higher incidence of dental caries is widely acknowledged. However, the current literature is inconclusive and controversial regarding whether overweight and/or obesity may be a marker for dental caries.

1) Identification of connection between overweight children with increased ECC

This review suggests that children aged six years or younger who are overweight or obese have a higher experience of dental caries compared to children with normal weight.

2) Comparison of caries in two groups: overweight children and normal weight children

Therefore, four out of seven studies found a positive correlation between early childhood caries and higher BMI. However, there was also a positive correlation found between underweight and early childhood caries, albeit the incidence was reported to be very low.

3) Identification of risk factors related with overweight and/or obesity and dental caries

Furthermore, several risk factors were commonly associated with both overweight/obesity and dental caries in young children. Poverty and low parental income, which are associated with low socioeconomic status, are linked to both conditions in young children, as well as ethnicity. Specifically, European ethnicity was associated with early childhood caries and being overweight and/or obese.

This is not limited to dietary habits, which may include a higher intake of added sugar. Bottle-feeding or mixed feeding may also play an important role in the relationship between obesity and early childhood caries.

However, the results showed a positive association in regard to the review aim. Whether there is an association between overweight/obesity and dental caries in children aged 6 years and younger or not, there were several discrepancies and limitations that could have affected the overall outcome. Therefore, the limitations need to be focused on further research on this topic.

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ANNEX A Summary of the extracted information from included studies

Author	Sample population	Dental Assessment/ Dental Outcome	Weight Assessment/ Weight Outcome	Confounders	Outcomes	General Outcome
Kennedy et al.	Mean age of 47.7 ± 14.2 (SD) months n(total)=150 52% girls (n=78) 48% boys (n=72)	dmfs index Median dmft: 40 Range: 5-84 Mode: 40	BMI z-scores Mean BMIz of 0.9 ± 1.3 42% at "risk for obesity" (18.7%), "overweight" (16.7%), "obese" (5.3%) or "severe obesity" (1.3%)	Age Sex Family type Place of residence Annual household income Receipt of social assistance Parents level of education Dental coverage Physical activity Registered First Nation Status (RFNS)	Poverty is associated with ECC and obesity	Analysis with simple linear regression demonstrated a statistically significant positive association between dmfs score and BMIz (ß=.01;P=.04) Analysis with multiple regression was relatively weak and was not significant (ß=.004; P=.47)
Paisi et al.	Mean age of 5.10±0.31 (SD) years n(total)= 349 49.9% girls (n=174) 50.1% boys (n=175	dmft index Mean dmft: 1.01±2.07 (0.79-1.23) Mean dmft in case of caries:3.18±2.57 (2.70-3.67)	BMI z-scores underweight 0.6% (n=2) healthy weight 79.9% (n=279) overweight 10.9% (n=38) obese 8.6% (n=30) No difference between boys and girls in any of the BMI categories (p= 0.726) or in terms of caries presence (p=0.818)	Children's demographic and socioeconomic characteristics Children's oral health habits Frequency of snacking of certain sugary foods/ beverages in between meals	Income is associated with ECC and obesity	No associations between any measure of obesity and ECC were found

Aung et al.	Mean age of 5.0± 0(SD) years n(total)= 27 333 49.3 % girls (n= 13 464) 50.7% boys (n= 13 869)	dmft index Mean dmft: 1.85 ± 0	BMI for age Reference group 52% (n=14 320) At risk for overweight 22% (n=6101) Overweight 14% (n= 3948) Obese 11% (n=2964)	Sociodemographic information Community water fluoridation status Degree of neighborhood deprivation Ethnicity	Ethnicity is associated with ECC and obesity	ECC is associated with higher BMI in children of European ethnicity Adjusted odds ratio for overweight children compared to normal weight children: 1.16; 95%CI: 1.02,1.32 and adjusted odds ratio for obese children: 1.20; 95% CI : 1.00, 1.45)
Hung et al.	Mean age of 4.46 ±0 (SD) years n(total)=468 45.5% girls (n=203) 54.5% boys (n=265)	dmft index and dmfs index: Obese group: Mean dmft: 6.84±4.92 Mean dmfs: 9.10±7.48 Normal group: Mean dmft: 6.11±4.16 Mean dmfs: 8.49±6.68	Group classification was based on BMI	Dietary habits Oral health habits Frequency of dental visits	Dietary habits is associated with ECC and obesity	ECC was associated with higher BMI children. However, the difference was not statistically significant with $p \geq 0.05$
Piovesan et al.	Mean age of 3.4±1.1(SD) years n(total)=2275 50.9% girls (n=1158) 49.1% boys (n=1117)	dt and dft index Mean dt: 0.32 ±1.46 Mean dft: 1.01 ± 2.89	BMI for sex and age z-score >+2 SD (WHO standards) BMI-for-sex-and-age > 95th percentile (CDC standards) BMI ≥ those age-specific BMI cut-offs corresponding to BMI = 30 at age 18 years (IOTF Standards) Prevalence of obesity based on the standards used: 9.5% (WHO), 11.5%(CDC),5.9% (IOTF)	Family Socioeconomic Status Child's demographic factor Intake of added sugar	Demographic factors, low family SES and greater intake of added sugar are associated with ECC and obesity	The relationship between obesity and ECC varied based on the definition of obesity and dental caries used. Associations were observed when obesity was defined using the IOTF standards and dental caries was defined using lifetime indicators

Olatosi et al.	Mean age of 4.19±0.96 (SD) years n(total)=273 52.4% girls (n=143) 47.6% boys (n=130)	dmft index Mean dmft: 3.044±2.28 Mean dmft based on BMI-for-age Z score and WFH z-score, respectively Overweight: 2.6±1.3 Obese: 2.4±1.1 Overweight: 3.7±2.3 Obese: 2.2±1.0	BMI-for-age z scores Overweight (n=8) Obese (n=10) WFH z score Overweight (n=12) Obese (n=15)	Sociodemographic status Socioeconomic status Feeding methods during the first 6 months of life	Bottle feeding or mixed feeding methods are associated with ECC and obesity	The dmft score distribution was highest among children within the severely wasted or wasted groups, lowest among children with normal z scores, ad intermediate in the overweight or obese groups
Coung et al.	Mean age of 3.5±0 (SD) years n(total) = 690 48.4% girls (n=334) 51.6% boys (n=356)	ICDAS standards Mean of the dental caries rate: 71.3% Dental caries n and % respectively: Stunting n=80; 63.5% Underweight n=38; 61.3% Wasted n=14; 58.3% Overweight/obesity n=28; 58.3%	BMI for age Wasted (n=24) Normal (n=558) Overweight risk (n=60) Overweight (n=38) Obese (n=10)	Dietary habits Parents occupation Educational level of parents Number of children in the family Using water resources	None	The children with malnutrition have a higher ratio (63.5%) of ECC (statistically significant is the difference in the stunting group, $p<0.05$). However, 58.3% of children with overweight/obesity had caries incidence.