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Oral Health Status of Children with Attention Deficit Hyperactivity Disorder: A Systematic Review

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Review Article

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ABSTRACT

Background: Attention-deficit hyperactivity disorder is one of the most common neurobiological disturbances that develop in children. Its characteristics can directly affect the individual's ability to maintain good oral hygiene; however there is no clear evidence whether it is a risk factor for poor oral health.

Objectives: To assess the oral health status of children with attention-deficit hyperactivity disorder and to determine if this condition influences the oral health status of the affected children.

Methods: A systematic search was conducted using multiple search engines. Only English publications between the years 2000 and 2014 that assess the oral health status including the caries experience and/or oral hygiene and/or gingival health and that included healthy controls were included. The target population was children with Attention-deficit hyperactivity disorder that are free from any other medical condition, with ages ranging from 0-18 years.

Results: Database search retrieved a total of 207 records using the keywords. According to title screening and after removing the duplicates 38 records were found to be relevant to our specifications and their abstracts were reviewed. Finally 10 articles were found to be suitable for inclusion in the systematic review. Children with attention-deficit hyperactivity disorder tend to have significantly higher caries in the primary dentition compared to controls. Enamel caries were also found more significantly among this group of children. They also have higher plaque index scores when compared to healthy children. Gingival enlargement and gingival bleeding were significantly higher in children with attention-deficit hyperactivity disorder who were taking Amphetamine.

Registration number: CDR42015015661 with the International Prospective Register of Systematic Reviews.

INTRODUCTION

Attention-deficit hyperactivity disorder (ADHD) is one of the most common neurobiological disturbances that develop in childhood. It is a disorder, which can be manifested in the preschool and early school years [1,2]. The main characteristics of ADHD include: impetuous, hyperactivity, behavioural and emotional deficits and inattention [3]. There are subtypes of ADHD, which include: the inattentive, the hyperactive/impulsive, and the combined type [4].

The data from genetic and environmental clearly stated that the etiology of this disorder is dopamine related gene (DRD4 AND DAT) and support its association with the ADHD. They documented the presence of structural and functionally abnormality in the brain [5]. Other researchers suggested that, traumatic injuries to the brain might also be accompanied with behaviors characteristic of ADHD [6]. In the same way, prenatal exposure to alcohol, exposure to any source of infections such as meningitis and birth trauma also has been linked to the development of ADHD [7]. Food components, especially, food additives/artificial colors, food allergies, and refined sugar, are considered to be a causal link to ADHD [8]. Overall, scientific evidence has not supported these hypotheses.

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National Survey of Children's Health (NSCH) 2003 established that boys are 2.5 times usually diagnosed with ADHD than girls [9]. It has been concluded that it affects between 5% and 12% of the school-aged population worldwide [10]. While, one can be affected in every 25 (4%) in adults making it one of the most frequent mental health problems in adulthood as well as in childhood. The most widespread subtypes are; the combined and the predominantly inattentive subtypes [11].

ADHD characteristics can instantly affect individual's ability to maintain good oral hygiene. The parents' motivation and awareness is poor, they usually give their children cariogenic treats to control the behaviors [12]. On the other hand, evidence supports that severe and atypical caries patterns were predominated in children who were medicated with retalin (methylphenidate hydrochloride) or dexadrine (dexamphetamine) [13,14]. These drugs cause dry mouth that is a potential side effect and it might be the cause of dental caries in ADHD children. However, Hidas et al. concluded that caries rates were similar in medicated or non-medicated ADHD children to control healthy children. Dental caries is a multifactorial disease; still there are no clear studies that show whether ADHD is a liable factor for oral health status [15].

The aim of this systematic review was to assess the oral health status of children with ADHD in comparison with that of healthy children, and to determine whether having ADHD influences the oral health status of the affected children.

METHODS

The protocol for this systematic review was registered with the International Prospective Register of Systematic Reviews, and allocated with the registration number CDR42015015661. The Preferred Reporting Items for Systematic Reviews (PRISMA) guidelines for conducting a systematic review were used to ensure transparent and complete reporting [1].

Eligibility Criteria

Case-control studies, cohort studies and cross-sectional studies assessing at least one of the following aspects of oral health in children with ADHD; dental caries, oral hygiene and gingival health. Publication dates were restricted between the years 2000 and 2014, to ensure having recent data. Only publications in the English language were considered.

Studies in which participants of interest were children between the age of 1 to 18 years who were diagnosed with ADHD and were free from any other physical, medical or psychological conditions to avoid any confounding effect were included in this review. Both medicated and non-medicated children with ADHD were included. Studies with participants who are older than 18 years, or have other medical, physical or psychological conditions, or the ones who did not incorporate a healthy comparison group were excluded from this review.

This review was limited to studies evaluating the oral health status of children with ADHD and comparing it with the oral health status of healthy controls. The primary outcomes considered was the oral health status including dental caries assessment using the Decayed, Missing, Filled Teeth/Surfaces index for permanent dentition (DMFT/DMFS) and for primary dentition (dmft/dmfs) and/or oral hygiene assessment using any index, and/or gingival health using any index for scoring. Studies that did not provide any form of oral health assessment and the ones that did not include a control group of healthy children were not included in the review.

Search Strategy

Studies were identified by searching electronic databases and scanning reference lists of articles. The search was restricted to English publications and publication dates between 2000 and 2014.

A literature web search for eligible journal articles was conducted by the three authors on the 11th of May 2014, using the following data bases: Cochrane Library, ProQuest, Springer Link, EBSCO, Medline, Web of Science, Wiley, PubMed, Elsevier, Science Direct and the Google scholar. The last record was obtained on the 20th of May 2014 and no more records were acquired after that. The databases were divided among the three authors and each one was responsible for searching in the databases to which they were assigned.

The following search terms were used to search all registers and databases: ADHD; oral health; children; special needs; gingival health; gingival index; caries; dental caries; DMFT; ADHD and children; ADHD and oral health; ADHD and DMFT; ADHD and caries; ADHD and dental caries; ADHD and gingival health; ADHD and gingival index; children with special needs.

The author allocated for each one of the databases scanned the titles retrieved from the search, and excluded duplicates and titles that were completely irrelevant to the aim of the current systematic review. Then two reviewers evaluated the abstracts of the titles that were found relevant. An abstract review sheet was developed to ensure standardized and complete assessment. In that sheet, information regarding the language used in the article, the title, the authors, the date of publication, the journal's name, the key words that are included, and the type of the study were recorded. Information regarding the sample used were recorded as well, and those included the age of the sample, the gender, the number of children diagnosed with ADHD, the control group, and the setting in which the study was conducted. In addition, information regarding the methods used was recorded, and those included the assessment of caries and type of index used the assessment of periodontal health and the type of index used, and assessment of the oral hygiene and type of index used. Finally, a statement on the results was recorded as well.

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For abstracts that did not fulfil the information required in the abstract review sheet, the full text was retrieved and reviewed to complete the required items. Abstracts that did not meet the inclusion criteria were not included. Full texts were obtained for the remaining reports. At this stage, full texts that could not be obtained using the databases that were used, were requested from the authors, however when full text was not provided, the articles were excluded from the review.

Eligibility assessment of the full texts was performed by two authors independently in an un-blinded standardized manner where the authors were free to discuss their findings with each other after reviewing their allocated articles independently. The articles were reviewed using a standardized reviewing method. The Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) [16] was used for evaluation of the articles and for assessment of the risk of bias in individual articles. Disagreements between authors were resolved by consulting the opinion of a third author. The authors were also responsible for hand searching through the references in the articles they were assigned to.

Data Collection Process

The articles to be included were reviewed by two authors; the data was extracted when available independently using a self-designed data extraction sheet based on STROBE [16]. After reviewing the full text, articles that did not meet the inclusion criteria of the current review were excluded.

One reviewer extracted the data from the full text and a second reviewer evaluated the extracted data. In case of disagreement the opinion of the third reviewer was consulted.

Data Items

The information extracted from each included article was divided into:

1. Characteristics of the study including: the title, the authors, the date of publication, and the objective of the study.
2. The participants including the number of children diagnosed with ADHD (number of medicated children and non-medicated if specified by the study), the age and gender of children in the study group, and the type of the control group.
3. The methods including the study design, the setting of the study i.e., whether an examination was conducted to evaluate the oral health status of the children or an evaluation of dental records was performed, the variables assessed, that is the aspect of oral health assessed in the study whether it was assessment of dental caries and/or the assessment of gingival health and/or the assessment of oral hygiene, and the index used for the assessment, and the risk of bias.
4. Summary of the main results including the outcome data and any additional analyses.
5. The discussion including the limitations and generalizability.

The oral health status (including the dental caries and/or the oral hygiene and/or the gingival health) of children with ADHD was the primary measured outcome. The preferred index for assessing the dental caries was the DMFT/DMFS and dmft/dmfs and for assessing the oral hygiene and gingival health any index was acceptable. The mean scores of the indexes for the dental caries, the oral hygiene and/or the gingival health were used for the assessment and for comparison between children in the ADHD group and the healthy controls.

Studies with similar outcomes were assessed together and were described in a narrative manner. The results of the studies that performed assessment of dental caries were reviewed together and significant differences between children in the ADHD and in the control groups were noted. Results on primary and permanent dentitions were discussed separately. Similarly, in studies assessing the oral hygiene and gingival health. Assessments of other aspects of the oral health were considered as secondary outcomes and were assessed separately.

RESULTS

Study Selection

A total of 10 studies were identified for inclusion in the review. The database search using the selected keywords retrieved a total of 207 records; 13 from ProQuest, 11 from Springer Link, 20 from EBSCO, 39 from Medline, 41 from Web of Science, 6 from Wiley, 28 from PubMed and finally 49 were located when the keywords were entered in the Google scholar search engine. However, Elsevier, Science Direct and the Cochrane databases did not provide any records when the selected keywords were used.

The 207 records were screened and the duplicates were removed resulting in a total of 122 record. After evaluation the titles of the 122 records, 84 were discarded because they were clearly irrelevant, only 38 were found to be relevant to the aim of the current review and were considered for abstract screening. **Figure 1** demonstrates the article screening process.

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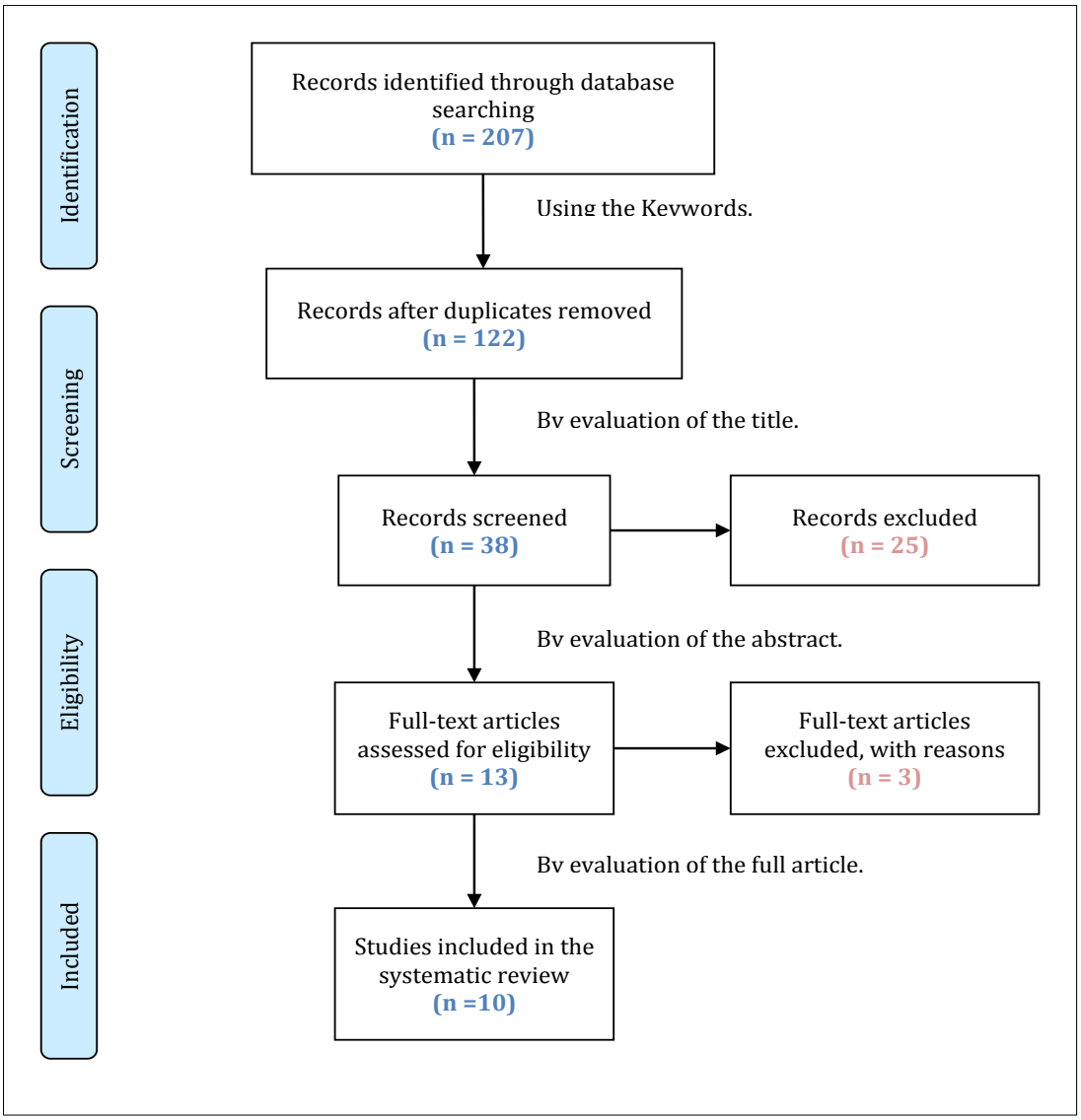

Figure 1. PRISMA flow diagram demonstrating the record selection process [1].

The evaluation of the abstracts of the 38 papers resulted in exclusion of 25 articles that. Among the excluded articles, 13 were rejected because the study sample did not include children diagnosed specifically with ADHD. One additional study had a single participant diagnosed with ADHD among a group of children with other disabilities; it was not included in the review.

The age group of participants was outside the range of this review in 2 reports, and thus they were rejected. One report was found to be a poster when attempting to obtain the full text, and thus could not be included in the study. Five reports were rejected because they were not original researches (2 analysis and evaluation articles; 1 letter to the editor; and 2 reviews of literature).

When trying to retrieve full texts of the reports available, the full texts of two abstracts could not be obtained from any database, and were requested from the authors by e-mail. However, no reply was received and thus they were excluded. Finally, one abstract was rejected because it could not be found at all in any database. The reasons for the rejection in the abstract review phase **(Table 1)**.

The full texts of the 13 remaining reports that met the inclusion criteria-were obtained and reviewed. Finally 10 articles were found to be relevant according to STROBE.

The articles that were excluded after full text review were the ones conducted by Williamson et al. [41] and it was rejected because the sample was divided according to the caries experience to a “caries active” and “caries free” groups rather than a children with ADHD group and healthy controls, in addition, there was no statement indicating that the children were not diagnosed with ADHD. They assessed the behavior of the children using the child behavior checklist (CBC) only, which was not acceptable for inclusion in this review.

The second study by Stankova et al. [42] was excluded because children with ADHD were incorporated in both the cases and the controls, and no specific results were provided for children with ADHD.

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The last one to be excluded was by Broadbent et al. [12] and it was rejected because the study sample included children with ADHD and other medical problems, which would affect the accuracy of the results of the current review.

Table 1. List of reports according to reason of exclusion.

Reason for exclusion	Studies that were excluded
No children diagnosed with ADHD in the sample	Padilla and Ritter [17]
	Altun et al. [18]
	Ivancic Jokie et al. [19]
	Ajami et al. [20]
	Chen et al. [21]
	Desai et al. [22]
	Sagheri et al. [23]
	De Jongh et al. [24]
	Jain et al. [25]
	Nqcobo et al. [26]
	Shanbhong et al. [27]
	Lewis [28]
	Schultz et al. [29]
Only one child with ADHD	Oredugba and Akindayomi [30]
Different age group	Shah et al. [31]
	Dellavia et al. [32]
Poster	Burns [33]
Not original research articles	Maupome [34]
	Broadbent and Thomson [35]
	Maupome [36]
	Nowzari and Rich [37]
	Charles [38]
Could not obtain full text	Nemutandani et al. [39]
	Shyama et al. [40]
Could not be found in any database	Smith et al.

Characteristics of the Included Studies

Table 2 provides an overview on the characteristics of the included studies.

Study type

All of the studies included in the review were cross-sectional studies except for the one conducted by Kohlboeck et al. [43], which was a cohort study. And the one conducted by Bimstien [44], which is considered a retrospective study since it utilized dental records. The three Blomqvist et al. studies are cross- sectional studies that are a part of large cohort study [45-47].

Participants

In the included studies participants were diagnosed with ADHD whether medicated or not, except for children in the control groups. Hidas et al. [15,48] divided the study group into medicated and non-medicated sub-groups. Kohlboeck's [43] cohort study divided the sample according to the Strength and Difficulties Questionnaire [49] into children with borderline or abnormal hyperactivity/inattention values and children with normal hyperactivity/inattention values.

The control groups were healthy children in 9 of the included studies [15,44-49,50-52]. However in Kohlboeck's study [43] the control group was determined using the strength and difficulties questionnaire [49], and it consisted of children who scored normal values in that questionnaire.

Age of the study population

In the present systematic review, the age of the children in the selected articles was in the range from birth till 18 years. In the studies that were included the youngest age was 5 years and it was found in the studies conducted by Hidas et al. [15,48]. The oldest age was found in the same studies as well and it was 18 years old

The three Blomqvist et al. studies [45-47] were part of a cohort study and the same children were examined at the ages 11, 13

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Table 2. An overview of the selected articles.

Author	Study Design	Country, Setting	Age	Sample Size	Study tool	Mean values	Outcomes
Hasan and Ciancio [52]	Cross-sectional	Buffalo, NY, USA Dental Department at the Children Hospital of Buffalo	6-14 years	20 (group 1) taking Adderall (18 Male, 2 Female) 20 (group2) controls (17 Male, 3 Female)	Examination and history Modified gingival index (MGI) Silness and Loe Plaque Index (PI) Gingival Enlargement Index (GE) Visual comparison of photos	Group1: GI=0.86 (± 0.11) PI=1.05 (± 0.06) GE=1.15 (± 0.17) Group2 (controls): GI=0.59 (± 0.08) PI=0.94 (± 0.07) GE=0.55 (± 0.14)	Significant difference between the 2 groups in GE (p=0.008) and GI (p=0.0483). Significant association between GE and amphetamine (p=0.0467). Significant association between GE and GI in group 1 (p=0.0022). Significant increase in medication dose and GI in patients with GE in group 1 (p<0.05). There was no statistically significant association (P>.05) between the GI and PI.
Grooms et al. [51]	Cross-sectional	NC, USA Duke university Medical Center Pediatrics and Pediatric Dentistry Clinics	6y 10m -10y 11m	Convenience Sample 38 ADHD (31 Male, 7 Female) 38 non-ADHD (31 Male, 7 Female)	Oral health questionnaire Medical history Dental examination Timed, Quantitative un-stimulated saliva sample.	ADHD: D(1)MFS=5.76 (± 8.81) d(1)mfs=0.89 (± 2.03) Saliva Produced= 0.94 g Non-ADHD: D (1) MFS=5.81 (± 10.76) d(1)mfs= 0.58 (±1.48) Saliva Produced= 0.82 g	No significant difference in DMFS and dmfs between the 2 groups. ADHD pts had significantly more enamel caries in primary and permanent teeth than controls (p=0.04, p=0.01). No significant difference in amount of saliva produced when taking medication (z=0.00, p=1.0).
Bimstein et al. [44]	Cross-sectional	Florida, USA College of Dentistry at an urban university campus. Community-based healthcare facility in an urban area. Community-based health care facility in a rural area	Mean age 88.6 m (± 42.9)	25 were medicated for ADHD (15 Male, 10 Female) 127 had no systemic or mental disability (55 Male, 72 Female)	Record evaluation: Demographics Dental history PI. GI. CI. Decayed and filled surfaces for permanent and primary teeth (DFS/dfs).	ADHD: DS=8.1 (± 12.1) FS=1.3 (± 3) Unmet treatment needs=76.9 (± 36.9) Controls: DS=6.5 (± 7.1) FS=1.6 (± 3.8) Unmet treatment needs=81.6 (± 30.8)	In ADHD group, significantly more parents reported previous toothache, bruxism, bleeding gums, and oral trauma. The 2 groups didn't differ in recorded oral hygiene or DFS/dfs.

Chandra et al. [50]	Cross-sectional	Bangalore, India ADHD from out-pt department of Child and Adolescent Psychiatry, National Institute of Mental Health and Neuro Sciences Non-ADHD from various schools	6-14 years	40 ADHD (32 Male, 8 Female) 40 non-ADHD (32 Male, 8 Female)	Dental examination for caries and oral hygiene (O'Leary Index) Conner's 10-item behavior assessment questionnaire. Dental history questionnaire.	ADHD: DMFS=1.05 (± 1.24) dmfs=8.9 (4.87) Non-ADHD: DMFS=0.68 (± 1.02) Dmfs=2.85 (2.76)	A significant difference in the mean defs scores between ADHD and non-ADHD (p=0.002). No difference in DMFS. A higher significant difference in the mean PI scores between ADHD and non-ADHD (p=0.02).
Hidas et al. [48]	Cross-sectional	Hebrew University, Hadassah School of dental medicine, Jerusalem, Israel	5-18 years Mean ADHD1: 10.3 y (± 2.8) Mean ADHD 2: 11.8 y (± 3.5) Mean Controls: 10.7 y (± 2.9)	31 ADHD 1 (non-medicated) 30 ADHD 2 (Medicated) 30 Controls	Examination Decayed, missed and filled surfaces (DMFS) Questionnaire (oral health behavior)	ADHD 1: DMFS=2.55 (± 2.29) ADHD 2: DMFS=4.30 (± 3.80) Controls: DMFS=4.10 (± 3.59)	No differences in DMFT/dmft, MS, and oral health behavior between 3 groups.
Hidas et al. [15]	Cross-sectional	Hebrew University,Hadassah School of dental medicine,Jerusalem, Israel	5-18 years Mean ADHD 1: 10.3 y (± 2.8) Mean ADHD 2: 11.8 y (± 3.5) Mean Controls: 10.7 y (± 2.9)	31 ADHD 1 (non-medicated) 30 ADHD 2 (Medicated) 30 Controls	Examination: USF (unstimulated salivary flow) PI (Silness and Loe) Questionnaire (oral health behavior)	ADHD 1: USF=0.72 (± 0.33) ADHD 2: USF=0.85 (± 0.53) Controls: USF=1.13 (± 0.70)	The PI was significantly higher in the two ADHD groups combined than in the control group (p=0.024). No significant correlation between PI and DMFT.
Kohlboeck et al. [43]	Cohort	Munich, Germany (Combination of the GINIplus and LISAplus cohorts)	Mean age at time of examination10 years (± 10.2)	1,126 children (577 Male, 549 Female) 161 with borderline or abnormal hyperactivity/ inattention values 965 with normal hyperactivity/ inattention values	Dental examination: Plaque Gingivitis DMFT/S Parent-reported strength and difficulties questionnaire (SDQ)	Borderline or abnormal hyperactivity/inattention values: DMFT=0.27 (± 0.72) DMFS=0.37 (± 1.01) Normal hyperactivity/ inattention values: DMFT=0.30 (± 0.80) DMFS=0.39 (± 1.24)	Logistic regressions showed that non-cavitated caries lesions were positively related with the presence of hyperactivity/inattention (OR=1.51 CI=1.08-2.11). An association found between hyperactivity/ inattention symptoms and Molar - Incisor Hypomineralization that include one permanent molar (MIH/1A) but did not reach statistical significance (OR=1.59 CI=1.00-2.53)
Blomqvist et al. [46]	Cross-sectional	Children born in 1991 Attending mainstream and special schools in the municipality of Sigtuna in Stockholm County.	11 years	25 ADHD 58 Controls	Dental examination Bite-wing radiograph Dental Subscale of Children's Fear Survey Schedule (CFSS-DS) was completed by parents	ADHD: DMFS=2.0 (± 3.0) DS=1.7 (± 3.6) GBI=4.3 (± 4.5) Controls: DMFS=1.0 (± 1.5) DS=0.5 (± 0.9) GBI=4.1 (± 4.5)	Children with ADHD had significantly higher decayed, missing or filled surfaces (DMFS). ADHD group had significantly higher decayed surfaces (DS). Differences between the groups regarding CFSS-DS scores were non-significant. In the ADHD group, the prevalence of behavior management problem (BMP) increased when the children were between 7 and 9 years of age.

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Blomqvist et al. [47]	Cross-sectional	Children born in 1991 Attending mainstream and special schools in the municipality of Sigtuna in Stockholm County	13 years	21 ADHD 79 Controls	Dental examination. Questionnaire on dietary habits. Questionnaire on dental hygiene habits	ADHD: DMFS=2.8 (± 4.0) DS=1.0 (± 2.2) GBI=7.0 (± 5.4) Controls: DMFS=2.2 (± 3.2) DS=0.7 (± 1.5) GBI=8.1 (± 6.3)	Differences between the groups regarding decayed, missed, or filled surfaces, decayed surfaces, initial caries lesions, and gingival inflammation were non-significant.
Blomqvist et al. [45]	Cross-sectional	Children born in 1991 Attending mainstream and special schools in the municipality of Sigtuna in Stockholm County	17 years	32 ADHD 55 Controls	Dental examination Radiograph	ADHD: DMFS=6.1 (± 4.3) DS=2.0 (± 2.2) Controls: DMFS=4.4 (± 4.9) DS=0.9 (± 1.4)	Adolescents with ADHD exhibited a statistically significantly higher prevalence of caries (DS) compared to controls (p=0.003). There was no significant difference in the DMFS between the groups.

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and 17 years respectively. The Kohlboeck et al. [43] study was also a cohort and provided the range (9.8-11.8 years) and the mean age (10 years) of the children in the sample at the time of the examination. The Bimstein study [44] evaluated the dental records of the children and provided a mean age of 88.6 (± 42.9) months, which is almost equal to 7 years. It also provided the mean age of the ADHD children 90.4 (± 39.6) months and of the controls 88.2 (± 43.6) months. In the two Hidas et al. [15,48] studies an age range of 5-18 years was determined, and the mean ages in each groups were determined (ADHD 1 non-medicated group 10.3 (± 2.8) years; ADHD 2 medicated group 11.8 (± 3.5) years; control group: 10.7 (± 2.9) years). The rest of the studies provided an age range according to which the sample was selected. Grooms et al. from 6 years 10 months to 10 years 11 months [51]; Chandra et al. from 6 years to 14 years [50]; Hasan and Ciancio from 6 to 14 years [52].

Year of publication

The studies that were included in the systemic review were the ones published between the years 2000 and 2014. The oldest one retrieved was the one conducted by Hasan and Ciancio and it was conducted in 2004 [52], and the most recent ones retrieved were conducted in 2013 by Kohlboeck et al. and by Hidas et al. [43,48]. The Study conducted by Blomqvist et al. in 2006 was repeated again in 2007 and 2011 [45-47]. Hidas et al. published another study in 2011. There was one study published in the year 2008 [44] and one published in the year 2009 [50].

Country and setting

Regarding the country where each study was conducted, 3 were done in the United States, Grooms et al. in North Carolina [51] Bemstein et al. in Florida [44], and Hasan and Ciancio in Buffalo, New York [52]. Three studies were conducted in Sweden [45-47] two in Jerusalem [15,48], one in Germany [43], and one study was conducted in India [50].

Regarding the setting, five of the studies included oral examinations that were conducted in the dental department of a medical center or hospital [15,43,48,51,52] and one [44] provided examinations in three different settings including the clinics at the college of dentistry in an urban university campus, a community based health care facility in an urban area, and community based health care facility in an rural area. In one of the studies [50] the examinations for the ADHD children were conducted in a psychiatry center where the children were enrolled and the controls were examined in their regular schools. In Blomqvist et al. studies the examinations were conducted in the schools of the children with special needs [45-47].

Odds ratios (OR) of hyperactivity/inattention categories on presence of oral health characteristics (defined as 0 0 no, 1 0 yes) are estimated by logistic regression. GI=gingival index, PI=plaque index, GE=gingival enlargement.

Caries Experience

The findings of the eight studies that assessed caries experience are summarized in **Table 3.**

From the studies included in the systematic review there were eight studies discussed the relation between DMFT and ADHD [43-48,50,51]. No significant difference was found between ADHD and control groups regarding decayed, missed and filled teeth in primary (dmft) or permanent (DMFT) in the study of Grooms et al. [51], however enamel caries in both primary and permanent dentitions were found more significantly in children with ADHD (p=0.04, p=0.01 respectively). Also no significant difference was found with Bemstein et al. [44] regarding decayed and filled surfaces in permanent (DFS) and primary teeth (dfs). While Chandra et al. [50] revealed a significant difference in the primary dentition (p=0.002) where the decayed, indicated for extraction and filled tooth index (defs) scores in children with ADHD were higher than those in the control group, but not the decayed, missed and filled surface index of permanent teeth (DMFS). Other studies done by Hidas et al. in 2011 and 2013 [15,48] found a non-significant difference between the groups. Additionally, Kohlboeck et al. [43] found an association between hyperactivity/inattention symptoms and Molar-Incisor-Hypomineralization that include one permanent molar (MIH/1A) but did not reach statistical significance.

Blomqvist et al. studied the association between the ADHD and the caries experience longitudinally in three stages. First examination done when the children were 11 years old and they found a significant difference between ADHD group and control group regarding DMFS and DS [46]. Then they repeated the test two years later but at that time they didn't find any significant result [47]. Lastly they did the examination again when the children were 17 years old and they found significantly higher caries experience (DS) (p=0.003) in children with ADHD compared to the controls. On the other hand there was not statistically significant difference between the groups with regard to the DMFS [45].

Moreover, as a secondary outcome Blomqvist et al. found in 2006 that there was no significant difference in the prevalence of dental anxiety measured by Dental Subscale of Children's Fear Survey Schedule (CFSS-DS). While an increase in BMP was seen in the ADHD group of children between 7 and 9 years of age, with a significant difference compared with the control group indicating that children with ADHD find it increasingly difficult to cope with the dental treatment situation at an age when they are expected to do so [46].

Three studies focused on the relationship between caries experience and type of medications used. Hidas et al. reported a non-significant difference in DMFT/dmft between the groups whether medicated ADHD, non-medicated ADHD, and controls. They suggested that it could be as a risk factor because the medication used by ADHD specifically the methylphenidate can

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Table 3. Summary of the studies that assessed the caries experience.

Author	Age	Mean values	Outcomes
Kohlboeck et al. [43]	Mean age at time of examination 10 years (± 10.2)	Borderline or abnormal hyperactivity/inattention values:	Logistic regressions showed that non-cavitated caries lesions were positively related with the presence of hyperactivity/inattention (OR=1.51 CI=1.08-2.11). An association showed between hyperactivity/ inattention symptoms and MIH/1A but did not reach statistical significance (OR=1.59 CI=1.00-2.53).
		DMFT=0.27 (± 0.72)	
		DMFS=0.37 (± 1.01)	
		Normal hyperactivity/inattention values:	
		DMFT=0.30 (± 0.80)	
		DMFS=0.39 (± 1.24)	
Hidas et al. [48]	5-18 years	ADHD 1:DMFS=2.55 (± 2.29)	No significant differences were found in the DMFT/dmft scores between the three groups.
	Mean ADHD1: 10.3 y (± 2.8)		
	Mean ADHD 2: 11.8 y (± 3.5)	ADHD 2:DMFS=4.30 (± 3.80)	
	Mean Controls: 10.7 y (± 2.9)		
		Controls: DMFS=4.10 (± 3.59)	
Blomqvist et al. [45]	17 years	ADHD:DMFS=DS=2.0 (± 2.2)	Adolescents with ADHD exhibited a statistically significantly higher caries (DS) compared to controls (p=0.003). There was no significant difference in the DMFS between the groups.
		DMFS=DS=0.9 (± 1.4)	
Chandra et al. [50]	6-14 years	ADHD:	A significant difference was found in the mean defs scores between ADHD and non-ADHD groups (p=0.002). No significant difference in DMFS was found.
		DMFS=1.05(±1.24)	
		defs=8.9(±4.87)	
		Non-ADHD:	
		DMFS=0.68(±1.02)	
		Defs=2.85(±2.76)	
Grooms et al. [51]	6 y 10 m-10 y 11 m	ADHD:	No significant difference in DMFS and dmfs between the groups. ADHD children had significantly more enamel caries in primary and permanent teeth than controls (p=0.04, p=0.01 respectively).
		D(1) MFS=5.76(± 8.81)	
		d(1) mfs=0.89(± 2.03)	
		Non-ADHD: D(1)MFS=5.81(± 10.76)	
		d(1) mfs=0.58(± 1.48)	
Bimstein et al. [44]	Mean age 88.6 m (± 42.9)	ADHD:	The 2 groups didn't differ significantly in recorded DFS/ dfs.
		DS=8.1(± 12.1)	
		FS=1.3(± 3)	
		Controls:	
		DS=6.5(± 7.1)	
		FS=1.6 (± 3.8)	
Blomqvist et al. [47]	13 years	ADHD:	Differences between the groups regarding DMFS, DS, and initial caries lesions were non-significant.
		DMFS=2.8 (± 4.0)	
		DS=1.0 (± 2.2)	
		Controls:	
		DMFS=2.2 (± 3.2)	
		DS=0.7 (± 1.5)	
Blomqvist et al. [46]	11 years	ADHD:	Children with ADHD had significantly higher DMFS. ADHD group had significantly higher DS.
		DMFS=2.0 (± 3.0)	
		DS=1.7 (± 3.6)	
		Controls:	
		DMFS=1.0 (± 1.5)	
		DS=0.5 (± 0.9)	

cause xerostomia [48]. Grooms et al. were studying 2 groups of ADHAD'S medications (methyphenidate and dextroamphitamine) with the control taking non-stimulant medication on the DMFS/dmfs. They found that methylphenidate group experienced more carious lesions in primary dentition and low salivary rate, on the other hand the dextoamphitamine and the non-stimulant group showed less carious experience in the primary teeth and more saliva production. However, there were no significant relations with the type of medication taken by ADHD children and the DMFS/dmfs score [51]. On the other hand, Bimestein et al. didn't find any significance between the medicated ADHD and healthy children [44].

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Oral Hygiene

Oral hygiene was investigated in four of the studies that were included in this review [15,44,50,52]. Plaque Index (PI) was the measure used in three of them [15,44,52]. Hidas et al. found that the PI scores were significantly higher (p=0.024) in children with ADHD (ADHD1 + ADHD2). However, no significant correlation was found between the PI scores and DMFT scores [15].

Chandra et al. found a significant difference in the mean PI scores was found between ADHD and non-ADHD (p=0.02). However in this study, the mean scores were not mentioned in the results. They only mentioned in the methodology that the O'Leary index was used to assess the oral hygiene [50].

In the study conducted by Bimstein et al. no significant difference was found in the number of children who had plaque in the ADHD and control groups. Although in the methodology they mentioned using the PI for scoring, no mean score values were presented in the results [44].

Hasan and Ciancio did not find a significant difference in the PI scores between children with ADHD and the controls as well. They also found that the plaque index, medication duration and dosage, and the patient's age have no significant association with gingival enlargement [52]. The studies that assessed the oral hygiene are summarized in **Table 4.**

Table 4. Summary of the studies that assessed the oral hygiene.

Author	Age	Values	Outcomes
Hidas et al. [15]	5-18 years Mean ADHD1: 10.3 y (± 2.8) Mean ADHD 2: 11.8 y (± 3.5) Mean Controls: 10.7 y (± 2.9)	ADHD 1: PI score 1=11 (35.5%) PI score 2=16 (51.6%) PI score 3=4 (12.9%)	Significantly higher levels of plaque were found in children with ADHD (ADHD1+ ADHD2) compared with the controls (p=0.024). No significant correlation was found between the PI and DMFT scores.
		ADHD 2: PI score 1=9 (30.0%) PI score 2=14 (46.7%) PI score 3=7 (23.3%) PI score 1=9 (30.0%) PI score 2=14 (46.7%) PI score 3=7 (23.3%)	
		Controls: PI score 1=18 (60.0%) PI score 2=11 (36.7%) PI score 3=1 (3.3%)	
Chandra et al. [50]	6-14 years	Values were not mentioned in the study	A significant difference in the mean PI scores was found between ADHD and non-ADHD (p=0.02).
Bimstein et al. [44]	Mean age 88.6 m (± 42.9)	ADHD: 10 (83%) children had plaque	There was no significant difference between the two groups.
		Controls: 76 (86%) children had plaque	
Hasan and Ciancio [52]	6-14 years	Group 1:PI=1.05 (± 0.06)	There was no statistically significant difference between the two groups in the PI scores.
		Group2 (controls):PI=0.94 (± 0.07)	There was no statistically significant association (P>0.05) between the GI and PI.

PI: Plaque Index
GI: Gingival Index

Gingival Health

The four studies that assessed the gingival health are summarized in **Table 5.**

Blomqvist et al. studied the gingival bleeding index in ADHD children and compared it with healthy controls first in 2006 when the children were at the age of 11 years, and they found a higher gingival bleeding index (GBI) in ADHD group when compared to the control group [46]. However when they examined the children at the age of 13 years, no statistically significant difference between the two groups was found [47]. Finally, they repeated the assessment when the children were 17 years old, and they found a higher statistically significant difference toward the ADHD group [45].

Hasan and Ciancio in their study assessed the gingival index (GI) as well as gingival enlargement (GE). A significant difference between children with ADHD and the controls was found in GE (p=0.008) and in GI (p=0.0483). They also found a statistically significant increase in the prevalence of gingival enlargement in patients taking amphetamine (Adderall). This study showed that gingival enlargement is significantly associated with the gingival index in patients taking amphetamine [52].

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Table 5. Summary of the studies that assessed the gingival health.

Author	Age	Values	Outcomes
Blomqvist et al. [45]	17 years	ADHD: GBI%=35 (± 39%)	The mean number of gingival sites that exhibited bleeding on probing (GBI%) was significantly higher in the ADHD group (than in the control group (p=0.022).
		Controls: GBI%=16 (± 24%)	In adolescents with ADHD, 56% had a GBI% of ≥ 25 compared with 27% of adolescents in the control group (p=0.031).
Blomqvist et al. [47]	13 years	ADHD: GBI=7.0 (± 5.4)	The GBI was not significantly higher in the ADHD group compared with the control group.
		Controls: GBI=8.1 (± 6.3)	
Blomqvist et al. [46]	11 years	ADHD: GBI=4.3 (± 4.5%)	There was no significant difference between the two groups.
		Controls: GBI=4.1 (± 4.5%)	
Hasan and Ciancio [52]	6-14 years	Group1: GI=0.86 (± 0.11)	A significant difference between the groups was found in GE (p=0.008) and in GI (p=0.0483).
		Group2 (controls): GI=0.59 (± 0.08)	A significant association was found between GE and amphetamine (p=0.0467).
			A significant association between GE and GI in children with ADHD was found (p=0.0022).
			A significant increase (p<0.05) in the medication dosage and the GI in patients who had gingival enlargement (mild and moderate) compared to the controls.

GBI: Gingival Bleeding Index
GI: Gingival Index
GE: Gingival Enlargement

DISCUSSION

Attention-deficit hyperactivity disorder (ADHD) is a common, chronic childhood disorder. The oral health status had been reviewed by many studies. In our systematic review we reviewed certain oral health status outcomes including caries experience, oral hygiene, and gingival health.

Caries experience was assessed using DMFT/dmft scores. Children with ADHD medicated/not medicated when compared with healthy children showed to have more carious lesion starting early as an enamel lesion than the control whether primary or permanent [51,53]. This means that the children with ADHD will have at least one carious lesion starting at the enamel than the non-ADHD children, which could be a key for early preventive program for those children. These results were in accordance with Broadbent et al, where they stated that the ADHD have 10 times more odd in being high-risk group for dental caries [12].

The type of the medication (methylphenidate/dextroamphetamine and non- stimulant medication) taken by ADHD children didn't differ significantly in the carious experience DMFT/dmfs between the ADHD children [51]. This finding did not match with the study that concluded that the patients with hyposalivation as a side effect from their drugs are in high risk to develop caries [54].

Chandra et al. revealed a significant difference in caries in the primary dentition only and this finding was explained by the fact that by the time the parents realized that their child had ADHD the oral hygiene measures were neglected by both parents and child leading to this severe damage [50]. While Blomqvist et al. reported the association between the ADHD and the caries experience longitudinally At 11 years old and 17 years old; they found a significant difference between ADHD group and control group regarding DMFS and DS [45,46]. These results were in accordance with the study done by Mejare et al. where they reported that the caries progression is highest among adolescence [55]. The same was also reported by Abernathey et al, they showed that the caries rate is highest at first post pre-eruptive period i.e., first and second permanent molar which makes oral health behavior crucial during this period of time [56].

On the other hand, at 13 years old Blomqvist et al. Chandra et al. and Bemesein et al. didn't find any significant results although there were poor oral hygiene practices and poor dietary habits [44,45,47,50] Additionally, Kohlboeck et al. found an association between hyperactivity/inattention symptoms and Molar-Incisor-Hypomineralization that include one permanent molar (MIH/1A) but did not reach statistical significance, in that study they attributed the limitation of their results to the small sample size, and they couldn't address the exact cause of the hypomenaralization whether it is from the medication, or from the socioeconomic level of the parents [43].

Other oral health status outcome has been reviewed was the oral hygiene. It was assessed using the plaque index and it was reported in 4 papers [15,44,50,52]. Hidas et al. Chandra et al. Hasan and Ciano reported that there are significantly higher levels of plaque in children with ADHD than the control. These results were in accordance with Chae et al. who reported that the

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poor neurobiological disturbance, which is one of the most common characteristics in children with ADHD, could affect the daily tooth brushing practice resulting in plaque accumulation [3]. Others reported that, the children with ADHD have a deficit in their decision-making behaviors, which affect their planning and motivation and can make difficulties in individual's adherent to dental preventive measures [53].

The last oral health status that has been reviewed was the gingival health. It was reported in form of gingival bleeding and gingival enlargement. Gingival enlargement was found to be significantly higher in children at 17 years old with ADHD than the 11 and 13 years old children with ADHD [46,47]. These results were in accordance with studies that stated that gingival enlargement prevalence was higher in late adolescence and among young adult [57,58].

RECOMMENDATIONS

Further studies are needed to clarify the biological role of the ADHD condition on the oral health status. Better methodologies are still required to evaluate the effect of different doses and different types of medications used in ADHD and correlate them with the oral health status, and the oral hygiene practices of this group of children. Dentists should emphasize the importance of prevention strategies (such as fluoride supplementation, pit and fissure sealants, and dietary improvement) for ADHD children. Children with ADHD are considered to be at high risk for dental caries, thus short dental recall time is essential for early diagnosis of problems. Dentists should express love and care toward children with ADHD, and they need to understand their behavioral management needs. Communications between dentists and the physicians regarding the use of alternative medications should be considered. Increasing parental awareness regarding their children's oral health is the dentist's key for the improvement of the oral health status of children with ADHD.

LIMITATIONS

The present systematic review had a few limitations, these include: limiting the studies to be included to the ones published during or after the year 2000 and rejecting any publications prior to that year. Not including studies published in languages other than English because translating the articles written in other languages was not feasible. In addition, in this review only three aspects of the oral health that are the caries, oral hygiene, and gingival health were assessed. The inability to obtain the full texts of two articles, even after contacting the authors.

CONCLUSION

Reviewing and analyzing the literature revealed that the oral health status of children with ADHD is not very satisfactory. They tend to have significantly higher caries levels in the primary dentition compared to healthy, normally developing children. Enamel caries were also found more significantly among children with ADHD. It was also found that children with ADHD showed higher plaque index scores when compared to healthy controls. Studies also revealed that the use of medication did not affect the DMFT/DMFS and PI scores significantly. Gingival enlargement and gingival bleeding were reported to be significantly higher in children with ADHD who were taking medication (Amphetamine).

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