



## Review Article

## Dental caries in Saudi Arabia: A systematic review

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## المخلص

**أهداف البحث:** هنالك العديد من الدراسات عن مستوى انتشار تسوس الأسنان في المملكة العربية السعودية، ولكن هذه النسب متفاوتة. ولذلك فإن هدف هذه المراجعة المنهجية هو تقييم مدى نسبة انتشار تسوس الأسنان بشكل أكثر دقة لدى البالغين والأطفال في المملكة العربية السعودية.

**طرق البحث:** تم البحث في قواعد البيانات على الإنترنت ومنها مكتبة "الكورين" و"مدالين" و"امبيز". بالإضافة إلى البحث اليدوي في مجلة طب الأسنان السعودية. وتم ضم الدراسات لهذه الدراسة إذا تم إجراؤها في المملكة العربية السعودية على أي مجموعة سكانية (البالغين والأطفال)، وجمعت خلالها بيانات تسوس الأسنان. واستخدم مقياس نيوكاسل-أوتاوا لتقييم جودة الدراسات.

**النتائج:** ضمت هذه الدراسة ٤٩ دراسة مقطعية. لكن أغلبها كان ضعيفا ومجالات الضعف كانت في تصميم الدراسات ومعدلات الاستجابة المنخفضة، وقياس النتائج الموثوق بها، وتحديد ومعالجة العوامل المربكة. لم يكن التجميع الإحصائي للبيانات مناسباً بسبب عدم التجانس الكبير، ويرجع ذلك جزئياً إلى التباين في الموقع الجغرافي والسكاني للمستهدفين في تلك الدراسات. قدمت ٢٩ دراسة بيانات عن الأسنان اللبنية. وتراوحت نسبة تسوس الأسنان بين الأسنان اللبنية من ٠.٢١ إلى ١. بينما قدمت ١٨ دراسة بيانات عن الأسنان الدائمة. تراوحت نسبة تسوس الأسنان بين الأسنان الدائمة من ٠.٠٥ إلى ٠.٩٩.

**الاستنتاجات:** جودة منهجية الدراسات المتضمنة في هذا البحث ضعيفة بشكل عام. بينما تراوحت نسبة تسوس الأسنان من ٠.٠٥ إلى ٠.٩٩ في الأسنان الدائمة، وفي الأسنان اللبنية تراوحت نسبه التسوس من ٠.٢١ إلى ١. لا تقدم البيانات المتوفرة حالياً تقييماً كاملاً لتسوس الأسنان في جميع أنحاء المملكة العربية السعودية. الدراسات الحالية محدودة من حيث السكان المشمولين.

## Abstract

**Objectives:** In KSA, numerous studies are conducted to measure the prevalence of dental caries. However, the prevalence of dental caries varies in KSA. This systematic review aims to improve the understanding of the prevalence of dental caries among adults and children residing in KSA.

**Methods:** Online databases of MEDLINE, EMBASE, and the Cochrane Library were searched. The Saudi Dental Journal was hand-searched. Study selection and data extraction were conducted in duplicate. The studies on dental caries in the Saudi population were included. The Newcastle–Ottawa Scale (NOS) was used to assess the quality of the selected studies. Finally, a narrative synthesis was conducted.

**Results:** Forty-nine cross-sectional studies were identified. Areas of weakness in study design/conduct were low response rates, reliable outcome measurement, and identification and handling of confounding factors. Statistical pooling of data was not appropriate due to substantial heterogeneity, also in part to a variation in geographical location and the target population. Twenty-nine studies presented data for primary dentition. The proportion of dental caries among primary teeth ranged from 0.21 to 1.00. Eighteen studies presented data for permanent dentition. The proportion of dental caries across permanent teeth ranged from 0.05 to 0.99.

**Conclusions:** In general, the methodological quality of the included studies was poor. Dental caries proportion level ranged from 0.05 to 0.99 in permanent teeth, and

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0.21 to 1.00 across primary teeth. The available data does not provide a complete assessment of dental caries across KSA. Existing studies are limited in terms of the populations studied for dental caries.

**Keywords:** Dental caries; Permanent teeth; Prevalence; Primary dentition; KSA

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## Introduction

Dental caries is one of the most common diseases in the world, making Dental caries a public health problem. A World Health Organization (2012) report on oral health stated that 60%–80% of children worldwide suffer from dental caries, and almost 100% of adults have them.<sup>1</sup> In KSA, several studies have been conducted to measure the prevalence of dental caries; most of them concluded that there is a high prevalence of caries among children and adults. Some of the studies were systematic reviews; for example, Al Agili et al. (2013) conducted a systematic review to measure the prevalence of dental caries in KSA between 1988 and 2010.<sup>2</sup> They concluded that 70% of children in primary schools had caries of their permanent dentition, while 80% of them had dental caries cavity in their primary dentition. Another review concluded that the amount of dental caries in permanent dentition is high, with a mean DMFT of 3.34; they also found that mean DMFT in primary dentition is 5.38.<sup>3</sup> Similarly, Al-Ansari et al. (2014) found that the mean DMFT in primary dentition is 7.34, while the mean DMFT in permanent dentition for adults is 7.35.<sup>4</sup> Other studies across KSA have reported different amounts of dental caries in different areas.<sup>5–11</sup> A systematic review was conducted to identify all relevant reports and risk factors due to the wide variation in reported dental caries prevalence across KSA. Each of these reports was critically appraised. This review will help to improve the understanding of caries prevalence in KSA. Furthermore, this study will attempt to identify reasons behind this variation of outcomes of studies on the prevalence of dental caries in KSA. This will be supported by an assessment of the risk of bias of identified studies to determine if methodological factors might have impacted the findings. DED

## Materials and Methods

The search strategy was designed to be as comprehensive as possible and followed the PRISMA statement. Three databases were used to identify articles published from 1999 to 2019: MEDLINE via OVID, EMBASE via OVID, and the Cochrane Library. Hand searching of the Saudi Dental Journal was also undertaken from 1999 to 2019. A mix of free-text and MeSH terms was utilised for both key concepts: dental caries and KSA. Given that the systematic review encompassed all study designs suitable for assessing caries

prevalence, no study design filter was applied to the search. There was no restriction regarding the geographical coverage of the study (i.e., local community setting, town, city, province, or country-wide).

### *Inclusion criteria*

Studies had to measure or report the dental caries experience in any area of KSA, using a valid measurement tool (for example DMFT, DMFS; ICDAS; proportion caries-free). Included studies could be conducted on adults and/or children as primary studies. They could also focus on specific demographics, such as employment status, systemic disease, or age. Studies had to be published after 1999 when the first national survey study was published.

### *Exclusion criteria*

Studies were excluded if they measured the incidence of other oral conditions and did not consider dental caries; were not conducted in KSA; were published in a language other than English or Arabic; were not primary studies; were published before 1999.

Identified studies were collected and checked for duplication in Endnote X9. A visual double-check was conducted to identify any duplication that could have been missed. Titles and abstracts of all the remaining articles were read to check for relevance according to the inclusion criteria. Irrelevant articles were excluded at this stage.

### *Selection of studies*

Three reviewers (FA, LOM, and AMG) independently reviewed all potential studies. Full copies of all potentially relevant articles were retrieved and reviewed until a final agreement was reached regarding inclusion.

### *Data extraction*

Once the included studies had been identified, relevant data from those papers were extracted and transferred from the paper source to a pre-specified data table (Table 3).

### *Assessment of risk of bias*

All included studies were assessed of potential risk of bias using a modification of the Newcastle–Ottawa Scale (NOS) appraisal tool; these findings were then tabulated.<sup>12</sup> The NOS items included sample methods, sample size, outcomes validity, outcomes reliability, confounders identified, and dealing with confounding factors. FA, LOM, and AMG assessed the studies.

### *Data analysis*

To interpret the findings from the included studies, caries data were plotted according to geographical location, separating data by primary and permanent dentition. Narrative synthesis analysis was applied.

## Results

### Search results

A total of 167 articles were found through the electronic search. These were imported into Endnote X9. Only one duplicate record was identified and deleted. Two additional records were identified through hand searching.

After screening of titles and abstracts, 71 records appeared to meet the inclusion criteria. However, on further assessment, 22 were excluded due to being multiple publications of the same study, not primary studies, or not providing data on dental caries experiences. The final number of studies included in the review was 49 (Figure 1). All studies were cross-sectional in design.

### Risk of bias

None of the identified studies scored 'Yes' for all domains assessed. However, nine studies were considered to be of

moderate quality, scoring 'Unclear' for one or two items, but 'Yes' for all others. All others studies scored 'No' for at least one item. The summary of the risk of bias assessment is presented in (Table 1).

### Sampling

Forty studies (82%) included information about sampling methods. Random sampling was used in 33 of the studies, of which three used random sampling based on the fluoride concentration zone.<sup>8,13,14</sup> Six studies included all their target populations. Finally, only one study used a convenience sampling approach.<sup>15</sup> Subsequently, seven studies did not indicate the sampling process used. The sampling method was not clear in two studies.

### Sample size

The sample sizes across the included studies ranged from 74 to 82,250 participants. Almost half of the studies (49%; 23 studies) justified their sample size. For 11 studies (23%), the justification of sample size was unclear. The remainder did not justify their sample size.

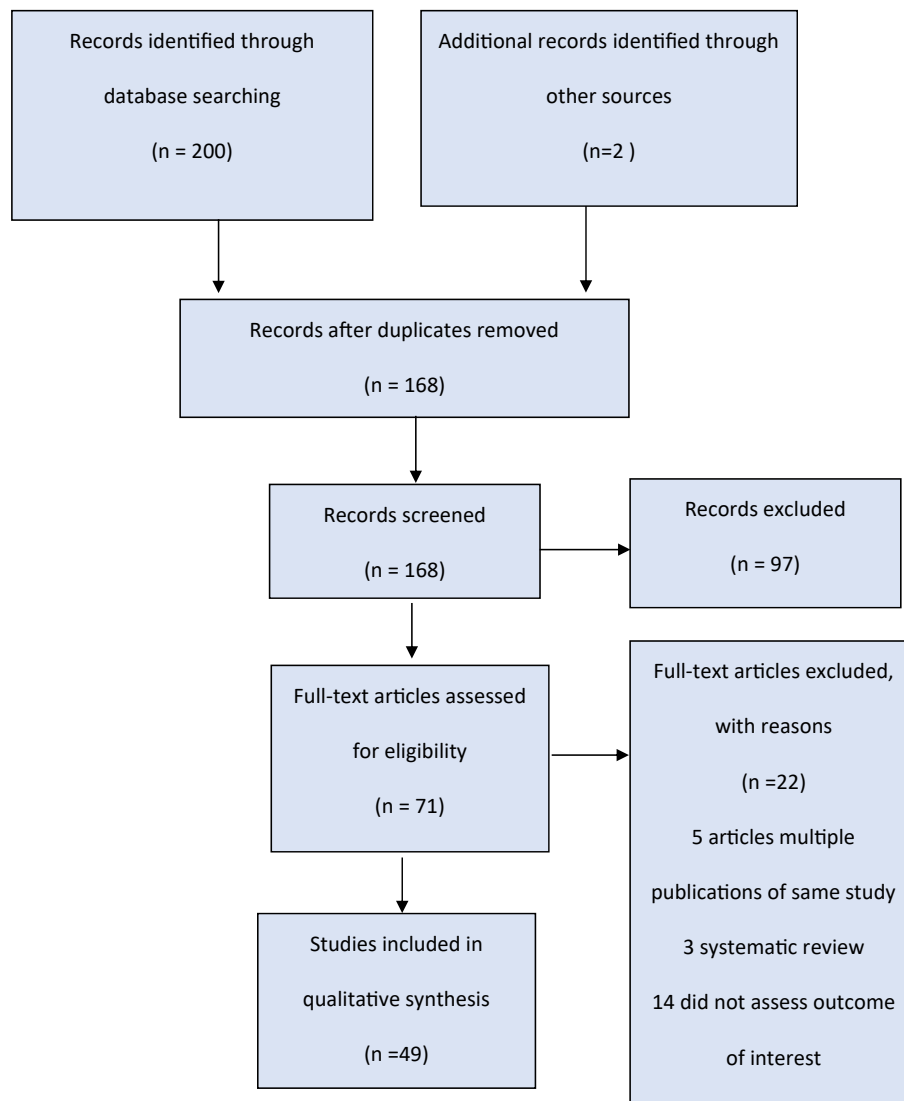


Figure 1: PRISMA Flow Chart.

**Table 1: Assessment of included studies using a modified Newcastle-Ottawa Scale (NOS).**

Study	Sampling strategy	Sample size	Responders/ non-responders	Valid outcome assessment	Reliable outcome assessment	Confounders identified	Confounders appropriately handled
(Bhayat & Ahmad, 2014)	Y	Y	?	Y	Y	N	N
(Al Agili & Alaki, 2014)	Y	Y	?	Y	?	Y	Y
(Al Agili & Park, 2012)	Y	Y	?	Y	Y	Y	?
(Alaki et al., 2013)	Y	N	N	Y	Y	Y	Y
(Alkarimi et al., 2014)	Y	?	?	Y	Y	Y	?
(Alamoudi et al., 2012)	N	N	N	Y	Y	Y	N
(AlDosari et al., 2004)	Y	Y	?	Y	?	Y	Y
(Al-Malik & Rehbin, 2006)	Y	Y	?	Y	Y	?	?
(Al-Shahrani et al., 2015)	?	N	?	Y	Y	?	?
(Al-hebshi et al., 2015)	?	N	?	Y	Y	N	N
(Al-Jobair et al., 2013)	Y	Y	N	Y	Y	?	?
(Al-Mobeeriek, 2012)	Y	N	N	?	N	Y	N
(Al-Banyan et al., 2001)	Y	N	?	Y	N	Y	Y
(Aldosari et al., 2010)	Y	?	N	Y	Y	Y	Y
(Alhammad & Wyne, 2010)	N	N	N	Y	N	Y	?
(Al-Malik et al., 2001)	Y	Y	?	Y	?	Y	Y
(Al-Qahtani & Wyne, 2004)	Y	Y	?	Y	Y	N	N
(Al-Shammery, 1999)	Y	Y	?	Y	Y	Y	Y
(Amin & Al-Abad, 2008)	Y	Y	?	Y	Y	?	?
(Atieh, 2008)	Y	Y	N	Y	N	Y	Y
(Brown, 2009)	Y	N	N	Y	Y	?	?
(Fadel et al., 2011)	Y	N	?	Y	Y	Y	N
(Farooqi et al., 2015)	Y	Y	?	Y	N	N	N
(Farsi, 2008)	Y	N	N	Y	Y	?	?
(Farsi, 2010)	Y	Y	?	Y	Y	N	N
(Gandeh & Milaat, 2000)	Y	Y	N	Y	N	Y	Y
(Khan, 2003)	Y	Y	N	Y	N	N	N
(Mannaa et al., 2013)	N	N	N	Y	Y	N	N
(Merdad et al., 2010)	Y	N	?	Y	Y	Y	N
(Paul, 2003)	Y	Y	N	Y	Y	N	N
(Quadri et al., 2015)	Y	Y	?	Y	N	Y	Y
(Wyne et al., 2002)	Y	Y	?	Y	Y	N	N
(Wyne, 2004)	Y	N	?	Y	N	N	N
(Wyne, 2008)	Y	Y	?	Y	Y	Y	Y
(Wyne et al., 2002)	Y	N	?	Y	N	Y	?
(Wyne et al., 2002)	Y	Y	?	Y	Y	N	N
(Wyne et al., 2001)	Y	N	?	Y	?	N	N
(Wyne et al., 2001)	N	N	N	Y	?	?	?
(Mansour, 2000)	Y	N	?	Y	N	N	N
(Al Zahidy, 2017)	N	N	N	Y	Y	N	N
(Alotaibi et al., 2017)	Y	Y	N	Y	Y	N	N
(Alosaimi et al., 2017)	Y	N	?	Y	Y	Y	?
(Aljanakh et al., 2016)	Y	?	N	Y	Y	N	N
(Alamri et al., 2017)	Y	?	N	Y	?	N	N
(Alghamdi & Almahdy, 2017)	N	N	N	Y	Y	Y	N
(Al-Meedani & Al-Dlaigan, 2016)	Y	Y	N	Y	Y	Y	N
(Alshahrani et al., 2018)	Y	Y	N	Y	Y	N	N
(Al-Otaibi et al., 2016)	N	N	N	Y	N	N	N
(Alhabdan et al., 2018)	Y	Y	?	Y	Y	Y	?

“Each of those items were marked either Y= Yes, N=No or? = Not clear. Each item that received a Yes was scored “1”; items were scored zero if they received a No and “0.5” if they were unclear. The total account of the scores for every study will help the reviewers to categorise the studies into three types to clarify their quality; the scores ranged from 0 to 6. Studies scoring 5 and above will be considered high quality, studies ranging from 4 to 5 will be considered moderate studies, and studies scoring lower than 4 will be considered low quality.”

#### Responders/Non-responders

All included studies either failed to include or had vague descriptions regarding the comparison of responders and non-responders.

#### Valid outcome assessment

In terms of the tools used to measure dental caries prevalence, all the included studies used a valid dental caries measurement. Forty-six studies used the DMFT index to

quantify the extent of dental caries, with 39 following the WHO diagnosis criteria. Of the remaining studies, two used the Basic Screening Survey (BSS). Finally, one study used the Arabic version of the Oral Health Questionnaire (GOHAI-Ar) and the DMFT index.

#### Reliable outcome assessment

More than half (63%,  $n = 31$ ) of the studies had an outcome reliability evaluation. However, 12 studies did not, and it was unclear if the outcome assessment was reliable or not for six studies.

#### Confounding factors – identified

Fewer than half of the studies (43%,  $n = 21$ ) listed potential confounding factors. These included socio-economic status (SES), oral hygiene practice, water fluoridation, smoking habits, and sugar consumption. Details of these factors are listed in (Table 2).

#### Confounding factors – adjusted for

Among the studies that identified risk factors, only 31% ( $n = 15$ ) adjusted for confounding factors, while 46% ( $n = 23$ ) of the studies did not. In almost a quarter (23%,  $n = 11$ ) of the studies, adjustment for confounding was unclear.

#### Study settings

The studies were divided into three main geographical settings:

- Two studies were national surveys covering the whole country
- Three studies were conducted across two provinces; Riyadh and two other cities (Jeddah and Qaseem).
- Forty-four studies were conducted in a single Saudi city (Almadinah Almunawwarah, Jeddah, Dammam, Riyadh, Jazan, Al Hassa, Al Kharj, Qaseem, Ha'il, and Asir).

#### Target population

##### National surveys

The two national surveys recruited children who attend either primary or intermediate schools with ages ranging from six to 18 years old.<sup>7,13</sup> One national survey recruited children based on SES and living place (urban or rural) to compare dental caries experience in urban and rural settings of all SES.<sup>7</sup> The second study, conducted by Aldosari et al. (2010),<sup>13</sup> recruited participants based on water fluoridation concentration to measure the prevalence of dental caries in each area and examine the effects of water fluoridation on dental caries prevalence.

##### Cross-province surveys

The three studies that made comparisons across provinces recruited the sample. Based either on oral health condition or water fluoridation zone. Fadel et al. (2011) evaluated the dental caries prevalence in adult periodontal patients with a mean age of 38 years old in Riyadh and Jeddah.<sup>16</sup> Aldosari et al. (2004) and Wyne (2004) recruited their samples from primary/intermediate schools in Riyadh and Qaseem

**Table 2: Studies indicated the risk factors.**

Study name	SES indicator(s) used
(Al Agili & Alaki, 2014)	Parents education and type of home
(Al Agili & Park, 2012)	Income and parents' education and smoking status
(Alaki et al., 2013)	Parents education, oral health practice and sugar consumption
(Alkarimi et al., 2014)	Family income and parents' education
(Al-Shahrani et al., 2015)	Family income, parents' education, sugar consumption and oral health practice
(Al-Malik et al., 2001)	Mother's education level and father's job
(Al-Malik & Rehbini, 2006)	School type (military school)
(Al-Shammery, 1999)	House size and type and sugar consumption
(Gandeh & Milaat, 2000)	House size
(Quadri et al., 2015)	Family income and parents' education level
(Wyne., 2008)	School type
(Wyne et al., 2002)	Parents' education level
(Alghamdi & Almahdy., 2017)	Parents' education level and house type
(Alhabdan et al., 2018)	School type, parents' education, type of school and Oral health practice
(Al-Banyan et al., 2001)	Oral health practice
(Alosaimi et al., 2017)	Oral health practice and sugar consumption
(Alamoudi et al., 2012)	Diet and sugar consumption
(Al-Mobeeriek, 2012)	smoking status
(Atieh, 2008)	smoking status
(Aldosari et al., 2010)	Water fluoridation
(Aldosari et al., 2004)	Water fluoridation

according to water fluoridation concentrations; the age ranged from six to 19 years in both studies.<sup>8,14</sup>

*Jeddah.* Fourteen studies were conducted in Jeddah to measure the prevalence of dental caries. The age range was from ten months to 40 years old. The youngest participants were aged from ten months to three years and were recruited alongside their mothers by Alamoudi et al. (2012).<sup>17</sup> This study recruited mothers who attended the dental hospital in Jeddah. Also, Mannaa et al. (2013) recruited mothers with their children as volunteers who visited the King Abdul-Aziz University (KAU) dental clinic.<sup>18</sup> In both studies, the mothers were aged above 25.

Two studies recruited children from nursery schools;<sup>19,20</sup> the age ranged from two to five years. Three studies recruited children aged six to 12 years from primary schools.<sup>6,10,21</sup> Al-Malik et al. (2006) and Alkarimi et al. (2014) recruited children from primary military schools.<sup>6,10</sup> Al Agili et al. (2014) recruited their sample of children from nine to 14 years old from both primary and intermediate schools.<sup>22</sup> Al Agili et al. (2012) evaluated the oral health status in adolescents, using smokeless tobacco among high-school students aged 16 to 20 years old.<sup>23</sup> Al Zahidy (2017) recruited the sample from high-school students aged 16 to 18 years old.<sup>24</sup> Alaki et al. (2013) evaluated





AlMobeeriek 2012	Riyadh	20_50 years	Male (59) Female (41) (Psychological)	Not recorded	Not recorded	DMFT: (13.81)	D=(2.95) (SD: 2.88)
			Male 59 Female (25) (Normal)	Not recorded	Not recorded	DMFT: (10.48)	D= (6.21) (SD: 4.87)
AL-BANYAN et al. (2000)	Riyadh	5_12 years	Male (154) Female (118)	99.3%	0.7%	dmft: (3.8) (SD:3.2) DMFT: (3.8) (SD: 3.2). (Notice there are sub)	Decayed primary teeth (70%) Decayed permanent teeth (41%)
Al Dosari et al. (2011)	Saudi	6–7 years old 12–13 years old 15–18 years old	Male (6100) Female (6100)	Not recorded	Not recorded	dmft: (2.68–7.07) DMFT: (1.81–4.70)	d primary teeth (86%) D permanent teeth (90%)
Alhammad et al., 2010	Riyadh	3 to 6 7 to 9 10 to 12 10 to 12	Male (82) Female (58)	(98.6%)	1.4%	DMFS: (18.8) (SD: 16.3). DMFS: (23.4) (SD:17.7). DMFS: 20.5 SD (14.0).	DS= (10.9) (SD: 7.5) DS = (15.4) (SD:12.1) DS= (12.4) (SD: 9.7)
Al Malik et al. (2001)	Jeddah	2 to 5 years old	Male (511) Female (476)	73%	27%	Over all dmft: (4.8) (SD:4.87) Over all dmfs: (12.67) (SD:15.46) Age 3: dmft: (3.59) (SD: 4.74) dmfs: (8.64) (SD: 13.59) Age 4: dmft: (4.82) (SD: 4.89) dmfs: (12.56) (SD: 15.33) Age 5: dmft (5.09) (SD: 4.85) Age (6_7): dmft: (7.58) (SD: 2.02)	
AL Qahtani and Wyne (2008)	Riyadh	6_7 years old 11_12 years old	Female (219)			Deaf: dmft: (7.35) (SD: 3.82) DMFT: (1.67) (SD: 1.67) Deaf DMFT: (0.87) (SD: 1.25) Age (11_12): dmft: (1.0) (SD: 1.9) DMFT: (5.12) (SD:3.45) Deaf dmft: (2.11) (SD: 2.53) Deaf DMFT: (5.81) (SD: 2.95) DMFT: (2.65) (SD: 2.62). DMFT: 2.69 SD (2.57).	(d) = (6.33) (SD: 2.74) (Deaf) (d)= (7.9) (SD: 3.55) (D)= (1.67) (SD:1.67) Deaf (D)= (0.87) (SD: 1.25)  (d)= (1.0) (SD: 1.9) (D)= (3.76) (SD (2.66) Deaf (d)= (1.0) (SD: 2.37) Deaf (D)= (5.16) (SD: 2.62)
Alshammary 1999	Saudi	12_13 Years old	Male (937) Female (937)	Rural: 64% Urban: 74%	36% 26%	DMFT: (2.65) (SD: 2.62). DMFT: 2.69 SD (2.57).	(D)= (2.38) (89.81%) (D)= (2.41) (89.59%)
Amin and Al- Abad 2008	AL_Hassa	10_14 Years old	Male (1115)	68.9%	31.1%	Not record	Not record
Atieh (2008)	Dammam	60 years old	Male (95) Female (65)	NS	NS	DMFT: (20.7) (SD: 5.3) GOHI-ar: (32.1) (SD:122)	Not record
Brown 2009	Riyadh	5 Years old	Male (203) Female (183)	Healthy: 84% Unhealthy: 91.9%	16% 8.9%	deft: (6.25) (SD: 4.71) deft: (9.91) (SD: 5.61)	d = 79.3% d = 79.5%
Fadel et al., 2010	Riyadh& Jeddah	Mean 38 years old (SD: 15)	Male (76) Female (36)	NS	NS	RDT: (0.6) (SD: 2)	D = (5) (SD: 4)
Farooqi et al., 2015	Dammam	6–9 years 10–12 years old	Male (406)	77.8% 68%.	22.2% 32%	dmft: (3.66) (SD: 3.17) DMFT: (1.94) (SD: 2.0)	(d)= (3.28) (SD: 2.92) (D)= (1.76) (SD:1.85)

(continued on next page)

Table 3 (continued)

Study name	Location	Age	Gender	% Caries	% Dental Free	Caries	Caries prevalence
Farsi 2008	Jeddah	6–11 years old 12–17 years old 18–40 years old	Male (179) Female (133)	99.04%	0.96%	DMFT: (2.93) (SD:2.29) DMFT: (6.83) (SD: 4.63) DMFT: (12.51) (SD: 5.45)	
Farsi 2010	Jeddah	4 years old 5 years old	Male (204) Female (306)			dmft: (3.73) dmft: (4.13)	
Gandeh and Milaat(2000)	Jeddah		Male (39,206) Female (43,044)	83%	17%	Not recorded	Not recorded
Mannaa et al. (2013)	Jeddah	4_6 years old 12_14 years old 37 years old (SD: 4.5)				dmft: (9.0) (SD: 5.0) DMFT: 5.8 SD (4.1) DMFT: 12.4 SD (5.3)	(d)= (8.0) (SD: 5.1) (D)= (4.5) (SD: 3.7) (D)= (5.5) (SD: 3.9)
Mardard 2009	Jeddah	>18 years old	Male (100) Female (100)			DMFS (Endo): (48.7) (SD: 21.8) DMFS (non-endo): (33.6) (SD: 22.5)	(D)= (5) (SD: 5.7) (D)= (7.5) (SD: 9.8)
Paul 2003	Al Kharj (Riyadh)	5 years old	Male (53) Female (50)	83.5%	16.5%	dmft: (7.1)	82% (d) = 5.8 (SD 5.0)
Quadri et al. (2015)	Jazan	6–15 years old	Male (520) Female (333)	91.3%	8.7%	Not recorded	Not recorded
Wyne et al., 2003	Riyadh	7–11 years old		94.4%	5.6%	dmft: (6.3) (SD: 3.5) DMFT: (1.6) (SD: 1.5)	(d)= (4.9) (SD: 3.1) (78%) (D) = (1.5) (SD: 1.4) (93%)
Wyne 2004	Central area	12–13 years old 15–19 years old	Male (723) Female (684)	90.5% 90.90%	9.50% 9.10%		
Wyne 2008	Riyadh	3–5 years old	Male (379) Female (410)	74.8%	25.2%	dmft: (6.1) (SD: 3.9)	(d)= (4.66)
Wyne et al., 2002	Riyadh	55 moths old (SD: 20.0)	Male (34) Female (40)	100%	0%		
Wyne et al., 2002	Al-Hassa	2–5 years old	Male (164) Female (158)	62.7%	37.3%	dmft: (2.92) (SD: 3.51)	(d)= (2.62) (SD:3.36)
Wyne et al., 2001	Riyadh	2–6 years old	Male (571) Female (445)	27.3%	72.7%	Overall: dmft (8.6) (SD: 3.4) Age 2: dmft (6.7) (SD: 4.7) Age 3: dmft:(6.9) (SD: 3.7) Age 4: dmft: (8.5) (SD: 3.3) Age 5: dmft: (9.2) (SD: 3.3) Age 6: dmft: (9.3) (SD: 2.3) DMFT: (0.91) (SD: 2.42)	For all (d) = (7.6) (SD: 3.5) 83.6%
Wyne et al., 2001	Qaseem	4–10 years old	Male (106) Female (47)	Mean aged 4.0 SD (1.4) 21.8% Mean aged (9.7 SD (2.9) 19.7%	79.2% 81.3%	DMFT: (0.74) (SD: 1.48)	
Mansour et al., 2000	Riyadh	6_7 years old	Female (200)	<i>Public school</i> 92.9% <i>Military schools</i> 97%	7.1% 3%	dmft: (6.0) (SD: 3.7) dmft: (8.1) (SD: 4.1)	(d)= (4.8) (SD: 3.6) (d)= (6.3) (SD: 4.2)
Al Janakh 2016	Hail	16 to 18 years old	Male	79%	21%	DMFT: (3.49) (SD: 2.78)	(D)= (2.68) (SD 2.27)
Al Otaibi et al., 2017 <sup>55</sup>	Riyadh	5–6 years old	Male (127) Female (97)	72.8%	27.2%	dmft: (3.96) (SD: 3.85)	(d)= (3.22) (SD 3.55)



Author(s)	Region	Age Group	Gender	Prevalence (%)	DMFT	DMFT (SD)	ID (SD)
Al Shahrani et al., 2018	Asir	15 to 17 years old	Male (3411)	72.9%	DMFT: (4.3)	(SD: 5.59)	(D)= (3.1) (SD 3.34)
Al-Meedani and Al-Dlaigan 2016	Riyadh	3 to 5 years old	Male (184) Female (204)	69%	dmft: (3.4)	(SD: 3.6)	
Alghamdi and Almahdy 2017	Riyadh	14 to 16 years old	Male (610)	54.1%	DMFT: (1.26)		(d)= (4.66)
Alhadban et al., 2018	Riyadh	6 to 8 years old	Male (578)	83%	dmft: (4.3)	(SD: 2.96)	
Al Amri et al., 2017	Riyadh	3 to 5 years old	Male (1571)	80%	dmft: (4.30)		(d) = (3.15)
Al Osaimi et al., 2017	Riyadh	3 to 5 years old	Male (255) Female (275)	85.5%	dmft: (5.54)	(SD: 3.49)	Not recorded
Al Zahidy 2017	Jeddah	12 to 14 years old	Male (1123) Female (990)	89.2%	Not recorded		Not recorded
AL-Otsibi et al., 2016	Qassem	6 to 12 years old	Male (121)	57%	Not recorded		Not recorded

the effects of asthma and asthma medication on dental caries in children aged five to 13 years old.<sup>25</sup> Farsi (2008) recruited from those who had attended the dental clinic at KAU, with participants ranging from six to 40 years old.<sup>26</sup> One study recruited adults only, focusing on adults with endodontically treated teeth; they were above 18 years old.<sup>27</sup>

*Riyadh.* Of the 17 studies conducted in Riyadh, 14 were conducted on children, with ages ranging from three to 12 years. Of these 14 studies, six focused on specific populations. Alhammad et al. (2010) evaluated dental caries in children with cerebral palsy (CP); Al-Qahtani et al. (2004) recruited their sample from blind, deaf, and mentally disordered children; Brown (2009) assessed the oral health status of children with metabolic disorders, heart diseases, and haematology diseases; Al-Jobair et al. (2013) evaluated dental caries in orphaned children; Al-Banyan et al. (2001) outlined the dental caries prevalence in national guard school children; Mansour (2000) investigated the oral health status of female children in military schools.<sup>28–33</sup> The remaining four studies of children recruited preschool/school children in general.<sup>9,34–40</sup>

Al-Meedani et al. (2016) and Alghamdi et al. (2017) conducted their studies on children in intermediate school aged 14 to 16 years old.<sup>41,42</sup> Furthermore, one study was conducted on adults aged between 20 and 50 with psychiatric problems.<sup>43</sup>

*Dammam.* Three studies were conducted in Dammam. Two of these studies recruited children and one recruited adults. In the two studies on children, the age ranged from six to 12 years. One study was performed on adults: Atieh (2008) outlined the oral health status of Saudis over 60 years old.<sup>44</sup>

*Al-Hassa.* There were two studies conducted in Al-Hassa; the ages ranged from three to 14 years old.<sup>11,45</sup>

*Jizan.* Two studies were conducted on public school children. Al-hebshi et al. (2015) focused on male primary school children aged six to 12 years.<sup>46</sup> However, Quadri et al. (2015) involved both male and female children from primary and intermediate schools with ages ranging from six to 15 years old.<sup>47</sup>

*Almadinah Almunawwarah.* One study was conducted in Almadinah Almunawwarah on male children aged 12 years from public primary schools.<sup>48</sup>

*Al-Kharj.* Paul (2003) conducted their study on preschool children aged five years.<sup>49</sup>

*Qaseem.* Two studies were conducted in the Qaseem area. The first study focused on children who lived either in the desert of Qaseem or around it; the age ranged from four to ten years.<sup>38</sup> The second study was conducted by Al-Otaibi et al. (2016), who recruited children with Down's Syndrome (DS) aged six to 12 years.<sup>50</sup>

*Ha'il.* One study was conducted in Ha'il city. Aljanakh et al. (2016) recruited their sample from high school students aged 16 to 18 years.<sup>51</sup>

Asir. A single study conducted by Alshahrani et al. (2018), targeted all the students in Asir who were aged from 15 to 17.<sup>52</sup>

All the study characteristics are presented in (Table 3).

Caries data

The caries data can be divided into two groups based on the type of teeth. Two studies by Manna et al. (2013) and Mardard et al. (2009) were excluded from the following analysis as they did not provide present the prevalence of caries as a percentage.<sup>18,27</sup>

Primary dentition

Twenty-nine studies across seven geographical locations (Al Hassa, Al-Kharj, Dammam, Jeddah, Jazan, Qassem, Riyadh, Riyadh, and Qassem) and one study across the whole of KSA presented data for primary dentition. There is substantial heterogeneity in the effect estimates ( $I^2 = 99%$ ), even when controlled for location of the study, which made it inappropriate to pool data across the studies. The proportion of caries prevalence within primary teeth ranged from 0.21 to 1.00 (Figure 2).

In Al Hassa, the proportion of dental caries among primary teeth ranged from 0.63 to 0.69; in Al- Kharj, 0.85; Dammam ranged from 0.66 to 0.78; Jeddah ranged from 0.45 to 0.96; Jazan, 0.91; Qassem ranged 0.21 to 0.57; Riyadh ranged 0.27 to 1.00; and in Riyadh and Qassem, 0.91.

Two studies were conducted simultaneously and targeted the same population in two cities of KSA. In Dammam, Farooqi et al. (2015), targeted children aged six to 12 who attended primary schools.<sup>53</sup> They recruited 711 children and found the prevalence of dental caries among them to be 0.78. Al-Shahrani et al. (2015) recruited 307 primary school children aged between nine and 11 years and found the proportion of dental caries among them to be 0.66.<sup>54</sup> The difference in the prevalence of dental caries can be explained by the difference in age group and sample size.

In Jeddah, Al Agili & Alaki (2014) recruited 1655 children aged nine to 14 years from public primary and intermediate schools; the dental caries proportion was 0.92.<sup>22</sup> Alkarimi et al. (2014) recruited 417 children aged six to eight who attended military schools, measuring the dental caries proportion as 0.87.<sup>10</sup> This difference can be explained by the variation in ages and sample size as well as the target population.

Moving to Riyadh, three studies were conducted in the same year and had different results regarding the prevalence of dental caries. Alotaibi et al. (2017) recruited 224 pre-school children aged three to four years from rural areas in Riyadh province (Aldwadmi) and recorded the dental caries proportion as 0.73.<sup>36</sup> The same age group was recruited by Alosaimi et al. (2017) but with a sample size of 530 children. The study recorded the dental caries proportion as 0.94.<sup>35</sup> Alamri et al. (2017) recruited 1844 primary school children aged six to nine and found the dental caries proportion to be 0.86.<sup>34</sup>

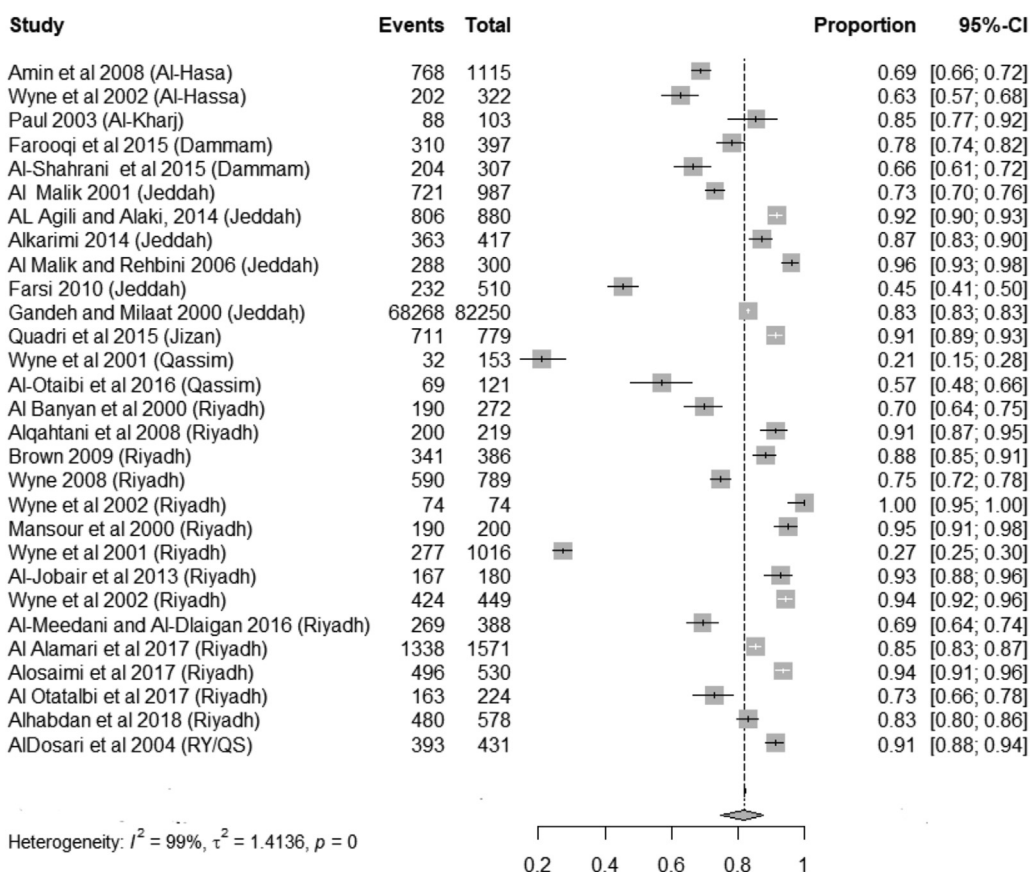
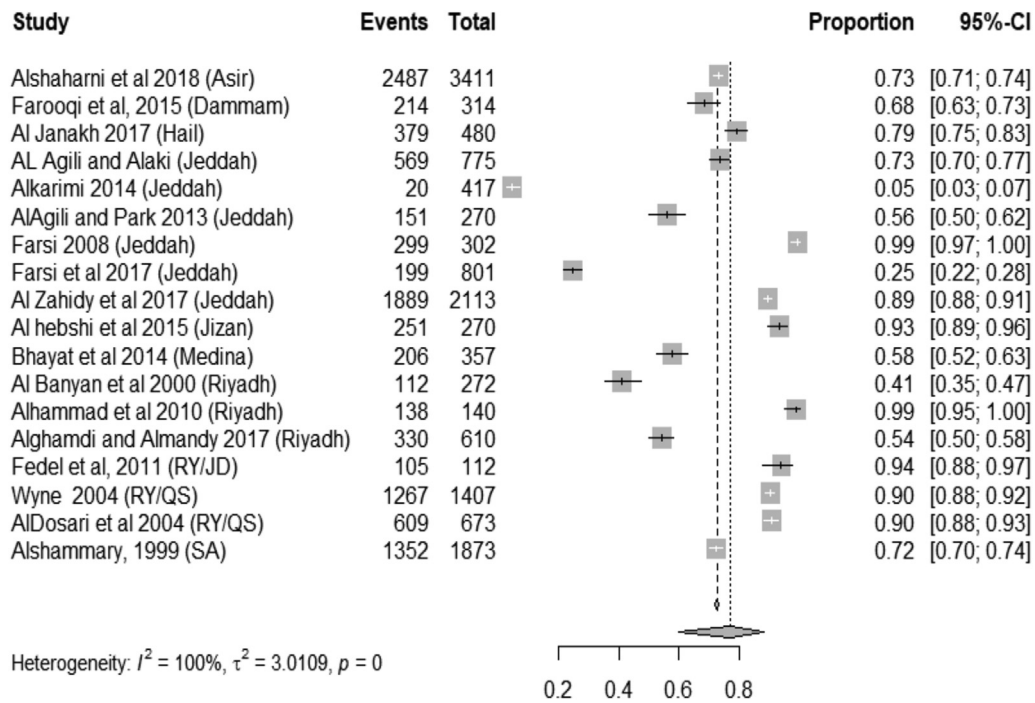


Figure 2: Effect estimates for caries prevalence in primary dentition.



**Figure 3:** Effect estimates for caries prevalence in permanent dentition.

This difference in dental caries can be explained due to the variation in the sample size and age group.

#### Permanent dentition

Eighteen studies presented data for permanent dentition across eight city locations (Asir, Dammam, Ha'il, Jeddah, Jazan, Almadinah Almunawwarah, Riyadh, Riyadh, and Qaseem) and one study examined the whole of KSA. There is substantial heterogeneity in the effect estimates ( $I^2 = 100\%$ ), even when considered by location of the study, which made it inappropriate to pool data across the studies. The proportion for caries prevalence among permanent teeth ranged from 0.05 to 0.99 (Figure 3).

In Asir, the proportion of dental caries prevalence among permanent teeth was 0.73; 0.68 in Dammam; 0.79 in Ha'il; 0.93 in Jazan; and 0.58 in Almadinah Almunawwarah. In Jeddah, caries prevalence ranged from 0.05 to 0.99; Riyadh ranged from 0.41 to 0.99. In Riyadh and Qaseem, caries ranged from 0.90 to 0.94; and in the whole of KSA, caries prevalence was 0.72.

#### Discussion

This study aimed to systematically review studies evaluating the prevalence of dental caries in KSA from 1999 to 2019. It identified 49 studies. The proportion of dental caries among primary teeth ranged from 0.21 to 1.00, and in permanent teeth, ranged from 0.05 to 0.99.

The included studies showed a substantial amount of heterogeneity ( $I^2 = 100$ ) regarding the prevalence of dental caries, both in primary and permanent dentition. This heterogeneity between studies came as a result of varying methodologies with different sample sizes, target populations, and geographical settings examined across the studies.

The sample sizes varied, ranging from 74 to 82,250 participants. Furthermore, only 49% of the included studies justified their sample size; the other studies either did not justify their sample size or had unclear justification. Another aspect is population variation, for example, targeting specific populations, such as those with specific medical conditions including cleft lip and palate, blind, deaf, mental disorders, children with cerebral palsy (CP), orphaned children, participants with asthma. Previous studies have shown such conditions are associated with a high risk of dental caries.<sup>56,57</sup> This is supported by the findings of the included studies. Alaki et al. (2013) reported DMFT of 8.96 with asthma and DMFT: 8.03 without asthma; DMFT: (2.16) with asthma; DMFT: (1.96) without asthma. Brown (2009) reported dental caries among children with cleft lip and palate as 0.92, while in healthy children dental caries prevalence was 0.86.<sup>30</sup>

The location of the studies also varied, with most of the studies conducted in two main cities: Riyadh (35%) and Jeddah (29%), leaving some parts of KSA with either a single or no studies at all.

A previous systematic review conducted to measure the prevalence of dental caries in KSA among school children concluded that 70% of children in primary school had caries of permanent dentition, while 80% of them had caries in their primary dentition.<sup>2</sup> However, this review did not assess the quality of the studies included in this review. Without exploring the quality of the studies, it is difficult to interpret differences in the identified rates of caries.

As a result, this present systematic review is limited by the quality of the studies included. This, alongside the significant heterogeneity, means that the findings can only be interpreted with caution. That makes the present study the first review of its kind to assess the quality of primary studies evaluating dental caries in KSA.

The prevalence of dental caries in countries bordering KSA were found to be lower. In Kuwait, Al-Mutawa et al. (2006) found the dental caries prevalence among children aged 12 to 14 years to be 0.18, and Ali (2016) found dental caries among children aged 12 to 16 years to be 0.52.<sup>58,59</sup> In Oman, Al-Ismaily et al. (1996) found the dental caries prevalence among children aged 12 years to be 0.58.<sup>60</sup> In Qatar, the dental caries prevalence among children aged five to 15 years old is reported as 0.73<sup>61</sup> and 0.85 among children aged 12 to 14 years.<sup>62</sup>

Regarding reporting outcomes other than dental caries, few studies reported clear data on issues such as diet and oral hygiene behaviours. Regarding oral health behaviours, none of the included studies reporting on this indicate high levels of oral health hygiene/oral health practice. Moreover, some studies report the consumption of foods high in sugar. There is clear, well-established evidence that brushing teeth with fluoride toothpaste is effective in preventing dental caries.<sup>63,64</sup> Similarly, the role of high sugar consumption in the development of dental caries is well established,<sup>65</sup> with the WHO recommending that sugar consumption be reduced, and strongly recommending that sugar should provide below 10% of the total energy provided by food.<sup>66</sup>

Despite public dental services being free in KSA, none of the included studies provided any information regarding access to dental services. Only a few studies gave some information about dental insurance, however, they did not indicate how this could help in improving oral health.

Due to the methodological weaknesses of the included studies, the clinical heterogeneity demonstrated and the gaps in the populations/geographical areas covered, the results of this study cannot be generalised to the general population of KSA. To truly develop a good understanding of dental caries, and to determine whether their levels are increasing or decreasing, it would be helpful to develop a national protocol to conduct regular surveys of both adults and children. Such methods exist in other countries; for example, in the UK there are regular epidemiological surveys, such as Public Health England (2012), which can be used to help inform the dental public health policy.<sup>67</sup> Having such survey systems in KSA will help the country run regular surveys to measure the prevalence of dental caries or other dental conditions. That will help provide accurate and up-to-date information on dental caries across KSA and give policymakers reliable indications of where dental services are needed.

## Conclusion

This study found that the methodology quality of the included studies is poor in general. Furthermore, the dental caries proportion level ranged from 0.05 to 0.99 and from 0.21 to 1.00 for permanent and primary teeth. This indicates that the prevalence of dental caries in KSA is high. However, the current data do not provide a complete assessment of dental caries across KSA.

## Recommendations

This study indicates the need to have criteria regarding future research to measure the prevalence of dental caries across KSA.

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## Conflict of interest

The authors have no conflict of interest to declare.

## Ethical approval

The authors confirm that this review had been prepared in accordance with COPE roles and regulations. Given the nature of the review, the IRB review was not required.

## Consent

As there were no participants in this study, consent was not required.

## Authors' contributions

FA, LOM, and AMG conceived and designed the study, conducted research, critiquing the included studies, and wrote the final manuscript. HA and FA analysed and interpreted data. MA and WS developed the methodology and counted the factor biases. AMG supervised the whole process. All authors have critically reviewed and approved the final draft and are responsible for the content and similarity index of the manuscript.

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