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A SYSTEMATIC REVIEW OF POPULATION- BASED DENTAL CARIES STUDIES AMONG CHILDREN IN GULF COOPERATION COUNCIL STATES:

A META-ANALYSIS

By

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ABSTRACT

A SYSTEMATIC REVIEW OF POPULATION- BASED DENTAL CARIES STUDIES AMONG CHILDREN IN GULF COOPERATION COUNCIL STATES: A META-ANALYSIS

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Aim:

The aim of this systematic review is to evaluate the prevalence and severity of dental caries in the Gulf Cooperation Council (GCC) area in order to help the development of systematic approaches for preventive oral care programs in the Gulf States and to provide sound information for oral health promotion and public health care.

Materials and Methods:

A comprehensive search to identify both published and unpublished articles concerning relevant studies of dental caries published during the period from 1992 to 2016 in children aged 2 to 16 years, with no language and time limit was performed. The search strategies employed electronic databases and incorporated both dental subject headings and free-text terms.

Results:

The overall mean *dmft* in the primary teeth was 5.136 and prevalence was 80.9% in the GCC area. The permanent teeth DMFT and the prevalence of caries were 2.577and 64.7%, respectively.

Conclusion:

The overall prevalence and severity of dental caries were high, especially in primary dentitions in the GCC area. This study did not provide a comprehensive picture of caries prevalence and severity in the GCC area because in many of these countries only a few studies had been performed. Therefore, additional studies are needed to better evaluate the prevalence and severity of caries in children and adolescence in GCC countries.

DEDICATION

This thesis is dedicated to my mother, my husband Ali and my angle Alreem

For their endless love, support and encouragement

DECLARATION

I declare that all the content of the thesis is my own work. There is no conflict of interest with any other entity or organization.

Name: Wafa Al Ayyan

Signature:

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LIST OF ABBREVIATIONS

AAP = American Academy of Pediatrics

AAPD = American Academy of Pediatric Dentistry

AAPHD = American Association of Public Health Dentistry

ADA = American Dental Association

AGD = Academy of General Dentistry

CI = Confident interval

CMA = Comprehensive Meta-Analysis

DIFOTI = Digital Imaging Fiber-Optic Trans-Illumination

dmft= Decayed-Missing-Filled primary tooth

DMFT = Decayed-Missing-Filled permanent tooth

ECC = Early Childhood Caries

GCC = Gulf Cooperation Council

GDP = Gross Domestic Product

HBMCDM = Hamdan Bin Mohammad College of Dental Medicine

ICDAS = International Caries Detection and Assessment System

MBRU = Mohammed Bin Rashid University of Medicine and Health Sciences

PHE = Public Health England

RRs = Rate Ratios

SD = Standard deviation

S-ECC= Severe Early Childhood Caries

SMD = Standardized Mean Difference

SSC = Stainless Steel Crown

MS = Streptococcus Mutans

TPI = Terahertz Pulse Imaging

WHO = World Health Organization

LIST OF APPENDICES

1.00 INTRODUCTION

Dental Caries is a microbial disease affecting the hard parts of the teeth. This progressive disease cannot be reversed and is more prevalent than any other condition affecting the human species. Besides being painful and financially expensive to treat, it can have negative effects on nutrition and overall health[(1)]. Once it has occurred, its manifestations persist throughout life even after the lesion has been treated. It affects both genders, all races, all ages and all socio-economic groups[(2)]. Caries can cause pain, which varies in severity, but has the potential to compromise the quality of life of affected children. Caries may not only result in disfigurement but also have deleterious effects on future dentition [(3)].It is a widely established fact that dental caries is an infectious disease induced by diet. The main etiological factors causing this disease are; cariogenic bacteria, fermentable carbohydrates, a susceptible tooth (host) and time[(4)]. In children, dental caries is particularly critical because even following repair, the affected tooth structure exhibits increased vulnerability to damage [(1)].

The mechanism of the caries process leads eventually to cavitation of the tooth structure. As a result of the fermentation of carbohydrates, organic acids are produced by oral bacteria, including lactic formic, acetic and propionic acids. These acids are able to penetrate dental tissues, here, they dissolve the enamel forming the outer layer of the tooth, together with the underlying dentin and the cementum which forms the root of the tooth. The erosion of substance can led, in time, to cavitation. Before cavitation has occurred, it is possible to reverse the demineralization by treatment using calcium and phosphate, in conjunction with fluoride, resulting in new deposits on the remnants of the surviving crystalline structure (tooth enamel). This renewed mineral crystalline surface resists acid more strongly in comparison with the

original hydroxyapatite (tooth enamel). The processes of de-and re-mineralization are a daily occurrence, leading either to cavitation, repair, reversal or maintenance of the status quo [5].

Usually the examination for dental caries is performed after teeth have been air-dried, under artificial light and with the aid of a dental mirror and an explorer which is used for the removal of plaque. The number of teeth with caries is recorded for each patient. All erupted teeth are evaluated according to the criteria recommended by the World Health Organization (WHO) using the **De**cayed, **M**issing, **F**illed(DMFT) index for permanent teeth[6].

The DMF index has been in use for over 70 years and is generally recognized as the standard measure of caries experience in terms of dental epidemiology[7]. The DMF Index refers to the permanent dentition and represents the total number of teeth or surfaces suffering from decay (D), missing (M), or filled (F) for any particular individual[8]. When the index is used to assess teeth specifically, it is referred to as the DMFT index, with the scores per individual ranging from 0 to 28 or 32, the latter being when the third molars are included in the scoring. When only tooth surfaces are evaluated (five for a posterior tooth, four for an anterior tooth), it becomes the DMFS index, and scores per subject can now range from 0 to 128 or 148, again, with the latter being when the third molars are part of the scoring [8]. When primary teeth are being scored, *dmft* and *dmfs* refer to teeth and surfaces respectively. Here, the scores can range from 0 to 20 for *dmft* and 0 to 88 for the *dmfs* index in children whose primary dentition is complete.

According to the WHO Oral Health Data Bank in 1980, DMFT values were available for 107 of 173 countries. Of these, 51% had a score of 3 DMFT or less, while the remaining 49% had higher values. In the year 2000, data were available for 184 countries as recorded in the WHO Oral Health Country/Area Profile Programme4, of these, 68% had a DMFT score of less than 3 (WHO, Oral health)[9]. DMFT index is a routine indicator used to evaluate dental health status in many studies for over 50 years [10]. The DMFT index has been widely utilized in epidemiological

surveys of oral health. It is recommended by WHO for measuring and comparing the experience of dental caries in populations.

There are a limited numbers of studies done in the Gulf Cooperation Council (GCC) states regarding the prevalence of dental caries. More studies are needed to more clearly understand the status of caries in the GCC region. The format of a systematic review is very effective in collecting a large amount of data and analyzing it simultaneously.

Examples of GCC states caries status can be seen in studies that have assessed the national prevalence of dental caries and its severity in children in the Kingdom of Saudi Arabia (KSA) and the United Arab Emirates (UAE). In the KSA, it was estimated to be approximately 80% for primary dentition and 70 % for permanent teeth in children[(1)]. While in the UAE, the prevalence of dental caries was very high in preschool children 36% to 47% at age 2 years, 71% to 86% at age 4 years and 82% to 94% at age 5 years according to Al-Hosani *et al.* [(11)]. According to a UAE survey done in 2006, the proportion of 5-year-olds who had caries experience in their primary dentition was 83% overall; this varied from 71% in Ajman to 93% in the Western Region[(12)].

Therefore the main objective of this systematic review is to identify the prevalence and severity of dental caries in the GCC area, in order to assist in the development of systematic approaches for preventive oral care programs in the GGC states and provide sound information for oral health promotion and public health care.

2.00 LITERATURE REVIEW

2.10 Background

Dental caries is among commonest chronic diseases affecting children with severe forms of untreated dental caries being very prevalent in pre-school children worldwide [13]. This disease is caused by a combination of many factors including host, food substrate, and bacteria. Other factors, such as mother's educational level, socioeconomic status, underlying medical conditions have been shown to play a role in the presence and severity of dental caries in children[14, 15]. Dental caries has many negative consequences for the child. The growth and well-being of the young children can be affected when the child's ability to eat properly is affected by the pain[16, 17]. In general, the quality of life, including the psychological and social aspects of the child's life, can be affected [13]. The first and foremost management strategy of dental caries should be prevention, to stop the disease from progressing and recurring, before the treatment of any symptoms[18].

In this chapter the literature is reviewed regarding dental caries in Gulf Cooperation Council (GCC) states. The review included: Geographic background of the GCC states; their socioeconomic and health services background; dental caries prevalence and management strategies; evidence based dentistry, with particular emphasis on systematic review and meta-analysis and the importance of carrying out a systematic review and meta-analysis in the GCC area regarding the prevalence of dental caries.

2.20 Geographic background of GCC

The Gulf Cooperation Council (GCC) was established in 25th May 1981, gathering together the Kingdom of Bahrain, State of Kuwait, Sultanate of Oman, State of Qatar, Kingdom of Saudi Arabia and the United Arab Emirates into one cooperative political entity. These countries shared special relations, geographic proximity and similar political systems based on Islam, the Arabian heritage, joint destiny and common objectives. At present it encompasses a total area of 2,672,700 sq. km. The official language of countries in the GCC is Arabic[(19)]. The GCC countries are famous for their desert climate; the general climate in the region has high temperatures during the day with cooler nights, especially the inner desert areas. The region is also famous for its oil reserves, multi-culturalism, tourism and business endeavors. During the winter months, some of the GCC countries experience colder climes than the others, such as KSA and Oman where the temperatures can drop to as low as 2°C, whereas in other areas the temperature varies between 16-28°C at the peak of the day. During the summer months, many of the GCC countries suffer high temperatures and humidity levels that can reach 90% [(20)].

2.30 Socioeconomic background

The socioeconomic status is a well-known term used to measure the combination of education, income and occupation [(21)]. According to the Bank of America-Merrill Lynch database, the Gross Domestic Product (GDP) per capita income in the GCC dropped from $114,000 in 2014 to $51,235 in 2015.The drop was blamed on the oil crisis and the economic circumstances that followed this crisis. The GDP per capita in GCC as a whole is still higher than many other countries. As an example the international ratings agency sees per capita income of residents of the UAE capital, Abu Dhabi, as $74,405[(22)]. From an educational perspective; building high quality schools and universities is considered a top priority for GCC governments, with more

than $90 billion spent on education-related construction projects in 2014[23]. Education is becoming an attractive business proposition and the GCC education market is experiencing an increased level of activity with private firms being interested in participating in this sector [24]. However, at present the quality

of education differs from country to country as explained in Table 1[24].

Table 1:Quality of education system in GCC area by Al Masah Capital Management Limited 2013[24]

Country	Quality of educational system		Quality of primary education		Higher education and training		Quality of scientific research institutions	
	Rank	Score	Rank	Score	Rank	Score	Rank	Score
Qatar	4	5.7	10	5.6	33	4.9	5	5.8
United Arab Emirates	17	5.0	18	5.2	37	4.9	35	4.6
Saudi Arabia	32	4.4	45	4.4	40	4.8	37	4.5
Bahrain	35	4.4	51	4.2	34	4.9	107	3.1
Oman	60	3.9	59	4.1	61	4.3	74	3.5
Kuwait	104	3.1	89	3.4	82	4.0	103	3.2

On the other hand, the total number of students in the GCC area was expected to rise to 11.6 million by 2016 according to recent statistics [25].In 2015, the new job opportunities, as reported by Bayt.com, shows 4,307 jobs listed in UAE, KSA came second with 2,936 jobs followed by Qatar (1,355), Kuwait (906), Oman (224) and Bahrain (151 jobs) [26].

2.40 Socioeconomic health

There is an established link between the socioeconomic status of individuals and the oral health status of the people as a whole in a society. As a rite of passage, the GCC countries hold world oral health celebrations to raise awareness about the issue and offer free dental examinations to patients from GCC countries. Poor oral health has been known to lead to poor health as well as being a contributing factor in many other diseases like cardiovascular diseases and diabetes[27].

The GCC countries possess some of the most elaborate health systems in the world while simultaneously having some of the direst needs for dental health care personnel[28]. The region hosts many state of the art hospitals, polyclinics, dental centers and clinics [28].

Many studies have confirmed a clear link between the oral health and socioeconomic status of individuals. The lower the social status of an individual, the more likely they are to have poor oral health. There is also converse evidence indicating that when people have bad oral health, there is a greater probability of them being undernourished or are have a low socioeconomic status in society[29].

2.41 socioeconomic health in the GCC

Having poor oral health is a possible indicator that an individual is starving or suffers some form of social deprivation in the society where they live[30]. There is, for instance, a higher risk of developing oral cancer among people with low economic standing than among people of a higher economic status[31]. The current research focuses on the dental health of the people in the GCC without bias as to whether they come from the high economic classes of the society or not. Chronic illnesses are another example of conditions more commonly afflicting members of the lower economic class of the Arab League (an entity of 23 Arabian countries that includes the GCC states). A disadvantaged individual's social status is a direct, and the easiest, indicator of other problems of oral health[32]and the same correlation holds true across various spheres of society even with regards to other areas of health..

It is clear, that in the UAE, one of the GCC countries, and especially in Abu Dhabi- that children exhibit relatively high levels of dental caries, although the average family income of the population is high and dental health services are free. Given the arguments expressed above, it

seems , therefore that the caries prevalence is one of the highest in the world, with higher caries scores coming from higher income families[33]. It has been argued that the underlying cause of this anomaly is the fact that high sugar foods and drinks are readily available in shops and are given freely to children by relatively affluent parents, and extended family members[33].

2.50 Dental caries

2.51 Definition of dental caries:

Caries is one of the commonest chronic diseases affecting the oral cavity. Dental caries is a multifactorial complex infectious disease[34] caused by a combination of different factors. The primary factor being the presence of bacteria in the mouth, mainly Streptococcus mutans (MS), which has been repeatedly implicated as a major etiological agent of dental caries[35]. The other factors are frequent snacking, sugary foods and drinks, poor oral hygiene and elevated host susceptibility. Caries is an interaction between a biofilm (dental plaque) and the tooth surface and subsurface across the time. The bacteria present in biofilm, like MS, are metabolically active and metabolize the free carbohydrates in the oral environment causing a significant drop in plaque pH. The fluctuations in pH may cause loss of mineral content from the tooth when the pH level is lower, a gain in minerals when the pH level rises. Progression of this disease occurs when there is an imbalance in the equilibrium between demineralization and remineralization; which leads to mineral loss[36].

Thus, dental caries is a dieto-microbial, site-specific disease caused by a shift from protective factors favoring tooth remineralization to destructive factors leading to demineralization[37]. Although caries is an infectious oral disease, it can be arrested in its early stages. Caries can be prevented and managed in many ways. There are two kinds of prevention available: the first is

primary prevention which is aimed at averting the onset of caries, while secondary prevention is designed to stop the progression of early caries to cavitation[36].

Dental caries in infants and young children is known as Early Childhood Caries (ECC). It is defined as "the presence of one or more decayed (non-cavitated or cavitated lesions), missing (due to caries), or filled tooth surfaces in any primary tooth in a child 71 months of age or younger" [38]. In children aged 3 or younger, any sign of smooth-surface caries indicates severe early childhood caries (S-ECC). From ages three to five, one 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 (age three), ≥ 5 (age four), or ≥ 6 (age five) surfaces scores as S-ECC[39]. The etiology here parallels that in adults, but the cariogenic challenge is severe and frequently greater than the protection available from saliva. ECC results from a combination of frequent consumption of fermentable carbohydrates as drinks, especially when a baby is sleeping, with on-demand breast or bottle feeding, oral colonization by cariogenic bacteria, poor oral hygiene and poor parenting[40].

2.52 Prevalence of caries worldwide

Worldwide, the prevalence of caries is high. Recent studies in all European countries have revealed a decrease in the prevalence of caries for children and adolescents. However, in several countries where levels were already low in primary teeth, no further decrease has been observed. Looking at the permanent dentition, the levels in 12 year olds fell further, with the improvement being greater still at the ages of 15–19 years. However, some Central and Eastern European countries continue to exhibit high levels of caries in children and adolescents[41].

In the United States of America (USA) in 2011 and 2012, data collected from the National Health and Nutrition Examination Survey showed 23% of the children from 2 to5 years had caries in their primary teeth. While for the age group 2 to 8 years old, 37% of them had caries in their primary teeth. The prevalence of dental caries in the permanent teeth of children aged 6–11 years old was 21%[42].

A study conducted on children in Queensland, in Australia, collected data from 2,214 children age group (5- to 8-year-olds) and 3,186 (9- to 14-year-olds) from 207 schools in 16 areas. The prevalence of dental caries in the primary and the permanent dentitions was found to be 47.1% for the age 5 to 8 years and 38.8% for the 9 to 14 years[43].

A survey conducted in the United Kingdom (UK) in 2005/2006, for 239,389 children from the age group 5 and 6 years old from England, Wales, Scotland and the Isle of Man. The results showed a wide variation in disease prevalence. The mean *dmft* across England was 1.47, across Wales the corresponding value was 2.38, and in Scotland 2.16. Overall, 39.4% of children in Great Britain had evidence of caries experience in dentine[44]. More recently in the UK, a national survey published by Public Health England (PHE) in 2013 reported the prevalence of dental caries varied from 2% to 34% across the country. In addition, 3 year old children had an average of 3 decayed teeth; however, 88% of children in this age group presented with no decay in their teeth. This shows a significant improvements in dental health since the introduction of fluoride toothpaste in 1976[45]. According to the Child Dental Survey there was an obvious decrease in the severity and extent of tooth decay present in the permanent teeth for the age group 12 and 15 year olds overall in England, Wales and Northern Ireland between 2003 and 2013. The prevalence of dental caries was around 46% for 15 years old, while for 12 year olds it was 34% in their permanent teeth this showed a decline in caries prevalence from 2003, when the corresponding figures were 56% and 43%respectively. However, for the aged group 5 years

the prevalence was 31% in the primary teeth and for the age group 8 years the prevalence was 46%[46].

In 2005, an Oral Health Survey of preschool Children in Malaysia found that more than half (55.8%) of the 5-year-old children had three or more deciduous teeth affected by caries and more than a quarter (25.3%) had a *dmft* greater than 10 (*dmft*>10). While in Nepal the prevalence of dental caries in 5- to 6-year-olds was 52%, with a mean of *dmft* of 1.59[33]. In the Peoples Republic of China (PRoC) in 2002, a national survey by National Committee for Oral Health examining 5 year old children found that 76.6% were affected by dental caries and the mean *dmft* was 4.5. Mean DMFT varied from 1.0 in 12-year-olds, 1.4 in 15-year-olds, 1.6 in 18-year-olds[47]. While in Indian children, a total of 813 randomly selected children aged 2-6 years were screened. The prevalence of nursing caries was 19.2% in the Davangere preschool population[48]. In comparison, in the Mueang Nan district, Northern Thailand, a prospective cohort study for 3 year old Thai children with a sample size ($N = 597$) concluded that 44.1 % of the 3 year old children had S-ECC[49].

GCC area studies of caries in children showed a very high prevalence in all countries. In 2016 a study in the KSA of a random sample of 388 preschool children aged 3 to 5 years reported a prevalence of 69%. There was no statistically significant difference between boys and girls [50]. A higher prevalence (91.3%) was reported in another KSA cross sectional study of 853 children aged 6-5 years conducted in 2015 [14].

Farooqi *et al.* in 2015 examined 711 KSA children aged 6 to 9 and 10 to 12 years and reported prevalence rates of 78% and 68 % respectively[51]. In 2014, Bhayat *et al.* studied the prevalence of dental caries and mean DMFT in 360 12-year-old male children in Medina City, KSA. The mean DMFT score was 1.53, while the prevalence of dental caries was 57.2%[52].

Al Agili *et al.* in Jeddah, KSA reported a prevalence of 83.13% in 1,655 children aged 9 and 14 years [53]. Another study was conducted in Jeddah by Alkarimi *et al.* in 436 children. The prevalence of caries was 87.1% and the mean *dmft* index was 5.7 in 6 to 8 years old children [54].

Wyne *et al.* in 2007 studied the prevalence of dental caries in preschool children of Riyadh, KSA. The sample size consisted of 789 randomly selected preschool children; 379 (48%) male and 410 (52%) female with a mean age of 4.7 (SD = 0.5) years were examined. The overall caries prevalence was 74.8%[55].

Malik *et al.* in 2006 reported a study of a random sample of 300 children aged 6 to 7 years with mean (SD) of 0.41 (0.86)[56]. Another study by Aldosari et al (2004), in Riyadh and Qaseem, (KSA) reported an overall prevalence of 91.2% in 1,044 children aged 6 to 7 while, in 12 to 13 year-olds, the prevalence was 92.3 % in Riyadh and 87.9% in Qaseem[57].

In 2003 Al-Malik *et al* .studied the prevalence of dental caries in preschool children in Jeddah, Saudi Arabia using a random sample of 987 children. Caries was found in 73% of the children with a mean *dmft* of 4.80 (±4.87)[58]. However, in the same year (2003), Paul *et al.* reported a higher prevalence (83.5%) and *dmft* of 7.1 in a sample of 103 5-year-old children in Al-Kharj[59].

In 2002, Wyne *et al.* reported a prevalence of 62.7% in 322 randomly selected preschool children in the kindergartens of Al-Ahsa, KSA. The mean *dmft* was 2.92 (±3.51) [60]. Wyne *et al.* carried out another study in 2001, in the Al-Qasseem region of Saudi Arabia in 153 children. The primary dentition group consisted of 77 children, with a mean age of 4.0 (±1.4) years, while the mixed dentition group consisted of 76 children with a mean age of 9.7 (±2.9) years. The prevalence of dental caries in the primary dentition group was (20.8%) and mean *dmft* was 0.91

(±2.42). While the prevalence of dental caries in the mixed dentition group was (19.7%) [61]. Wyne *et al*. in 2001, also examined the dental caries in 1,016 randomly selected children of one kindergarten from every area of Riyadh. The prevalence of ECC was (27·3%) and the mean *dmft* was 8·6 (± 3·4) [62].

Another study reported by Al-Malik *et al.* in 2000, measured the prevalence of caries, rampant caries and erosion in a group of 4–5-year-old children living in Jeddah in Saudi Arabia. The prevalence was 30%, and the mean *dmft* was 0.95 (±2.03)[63].

In 2000, Abolfotouh *et al.* examined 959 school boys selected randomly in Abha with ages 6 to 13 years and reported a high prevalence rate of 85.4% for dental caries. The mean dft values at ages 6, 9 and 12 years were 6.53, 3.97 and 1.07, respectively, while the mean DMFT values were 0.16, 0.83 and 1.23, respectively[64]. Gandeh *et al*. in 2000, reported the epidemiology and prevalence rates of dental caries among children in primary-school children in Jeddah in a large sample of 82,250. The prevalence rate of detected dental caries was 83%[65]. Another study in 2000 by Al-Banyan *et al*. in 272 children aged 5–12 in Riyadh area. A high prevalence of dental caries of 99.3% was reported. While the mean *dmft* was 3·8 (± 3·2) and mean DMFT was 2·0 (± 1·9) [66].

In 1999 Al-Shammery *et al*. studied the prevalence of dental caries of 1,873 schoolchildren aged 12–13 years. Children from the urban and adjoining rural areas were screened. The prevalence of caries was 89% [67].

Alamoudi *et al*. performed a study in 1996 to examine caries prevalence in children. The number of the children examined was 1,522 aged 6–9 years in Jeddah, Saudi Arabia. The mean *dmft* and

DFT were 4.23 and 1.85, respectively. The study reported that 73.9 %of the children had caries [68].

Akpata *et al*. in 1992, reported prevalences of dental caries ranging between 69% and 84% in a randomly selected 363 Riyadh schoolchildren aged 12–13 years[69].

Oman has been the subject of limited published studies about the prevalence and severity of dental caries in children. Al-Ismaily *et al*. in 2004 carried out a survey of 2,860 15 year old students. The caries prevalence was found to be 73.2%[70]. Another study conducted in 1997 in Oman in 3,114 6-years old children reported the prevalence of dental caries to be 84.5%[71]. Al-Ismaily *et al*. in 1996 found that the prevalence of dental caries for 12 years old children was 58.1% in a sample of 3,435 children[72].

In the UAE, in 2015, Kowash *et al.* in a convenient sample of 176 preschool children aged 2 to 5years old, the prevalence rate of dental caries was 99.4% [73]. Hashim *et al*. examined 1,297 children aged 5 and 6 years in Ajman emirate and reported a prevalence rate of 72.9% and 80%, respectively [74]. El Nadeef *et al*. in 2010, examined 1,340 5-year-old children as part of the first national survey of oral health of children in the UAE and the prevalence rate was found to be 83%[12]. In older age groups, the prevalence rate was 54% for 12 years and 75% for 15 year olds, in a sample size of 2,651[75]. In 1998 Al-Hosani *et al*. reported the prevalence of dental caries to be 41.5%, 78.5%, 88% for the age groups 2 , 4 and 5 years old, respectively in the Emirate of Abu Dhabi, UAE[11].

In Qatar there have been few studies about the prevalence of caries in children. In 2016, the prevalence of dental caries was found to be 89.2% in 4 to 5 years old[76]. In 2014, Al-Darwish *et*

al. examined 2,113 children aged 12 to 14 years and reported a prevalence of 85%[77]. In 2013, Bener *et al*. reported that the prevalence of caries was 73%[78].

Similarly, in Kuwait few studies have been conducted about the prevalence of dental caries. Ali *et al*.in 2016, reported a prevalence rate of 52% among 12 to 16 year-old children[79]. In a 2006 national epidemiologic survey among 2,290 12 to 14 year old children, Al-Mutawa *et al*. found that the prevalence of dental caries was 18.825%[80].

Finally, no published studies exist about the prevalence of caries in children in Bahrain. Nevertheless, according to unpublished school health reports by a Nasseb *et al.*, the prevalence of dental caries in school attendees was 85% for the children less than 16 years old.

2.53 Etiology of dental caries

Many factors are involved in the etiology of dental caries and it is clear that the disease has a complex multifactorial etiology. There are three main factors, namely: bacteria, environment and host. The effect of bacteria depends on: types, adhesion, acid production capacity, amount, and plaque formation. Environmental factors such as diet and host susceptibility, buffer capacity, resistance to caries, saliva secretion and others factors are also involved[81]. The underlying cause of dental caries is physiological imbalance between fluid and mineral dental biofilm (microbial cells in a matrix, this is predisposed to utilizing nutritional resources available in the oral cavity and was termed plaque in the past)[82].

Children with ECC have been shown in bacteriologic studies to in excess of 30% of MS in their normal cultivable plaque flora. Such a concentrated level of dental infection was, not unexpectedly, associated with carious lesions, white spot lesions and sound tooth surfaces near

the lesions. These results add substance to the idea of ECC being an infectious disease and support the theory that the most likely infectious agent is MS[83]. The earlier the MS colonies invade the oral cavity, the higher the resulting caries experience[84]. There is, in addition, a direct relationship between adult caregiver MS levels and dental caries prevalence in their children[85].

Dental decay in infants and young children also seems attributable to on-demand bottle feeding and high consumption of sweets in combination with poor oral hygiene, lack of fluoride and lack of regular dental health visits[73]. In addition, the consumption of carbonated drinks and fruit syrups has also been shown to be related to caries. Other significant factors include socio-economic and demographic factors which play a significant role in causing tooth decay [86].

The susceptibility of the host plays an important role in causing dental caries; with this believed to be related to the structure of dental enamel, immunologic response to cariogenic bacteria, or the composition of saliva. Genetic variation of the host factors may also contribute to increased risks of dental caries[87].

2.54 Types of dental caries

There are many ways to classify dental caries according to the nature of tissue involvement, either initial or incipient, or deep. The International Caries Detection and Assessment System (ICDAS) classified caries according to the progression and severity of the lesion into initial (ICDAS 1-2), moderate (ICDAS 3-4) and extensive (ICDAS 5-6) stages. Counts of tooth surfaces with progression, by baseline caries severity level, were used to compute rate ratios (RRs) relative to sound stages [88]. Wyne in 1999 classified ECC into three types. These types are:

Type I (mild to moderate) ECC: isolated carious lesion(s) involving molars and/or incisors usually caused by the combination of cariogenic semi-solid or solid food and with poor oral hygiene. The number of affected teeth increases as the cariogenic challenge persists. It is commonly seen in 2 to 5 years old children [89].

Type II (moderate to severe) ECC: Labiolingual carious lesions affecting maxillary incisors, the presence of molar caries being dependent on the age of the child and stage of the disease, with mandibular incisors not usually affected. The commonest cause is either mistaken use of a feeding bottle, or breast-feeding on demand, or a combination of both, with or without poor oral hygiene which almost certainly aggravates the cariogenic challenge. It is possible to detect this type of ECC shortly after the eruption of the first teeth. Failure to control the situation will inevitably lead to type III [89].

Type III (severe) ECC: In this type most of the teeth are affected by caries including the lower incisors. The causes are the combination of cariogenic diets with poor oral hygiene. This type is usually found between age 3 and 5 years. The condition is aggressive and involves tooth surfaces which are usually unaffected by caries[89].

According to the AAPD guidelines, the classification of ECC depend on age, any sign of smooth- surface caries for the children less than three years of age is termed severe early childhood caries (S-ECC)[90]. One or more cavitated or missing teeth due to caries, or filled smooth surfaces from ages three through five, in primary maxillary anterior teeth or a decayed, missing, or filled score of greater than or equal to four (age 3), greater than or equal to five (age 4), or greater than or equal to six (age 5) surfaces also constitutes S-ECC[90].

2.55 Consequences of dental caries

Dental caries carries with it significant morbidity, and has a considerable impact on the wellbeing of children[91]. Of the many risks inherent in dental caries, examples are physical, biological, environmental, and behavioral problems [92]. In addition, there is also high risk of the children developing dental decay in their permanent teeth if they had caries in primary teeth[93]. Dental caries can affect a child's eating habits and nutritional intake, potentially influencing growth, early childhood development and school readiness. In addition, untreated caries can lead to pain and infection, with this leading to poor school attendance and problems in speaking, and learning. Dental caries and its complications may affect the quality of life, both physically and physiologically; for example, pre-mature loss of primary teeth can result in a variety of adverse medical problem, such as gastro-intestinal disorders and psychological problems[94]. Premature loss of primary dentition also may predispose to malocclusion and aesthetic problems of the permanent dentition.

Rapid caries progression usually causes complications such as pulpitis and apical periodontitis which require extensive dental treatment, often including pulp therapy and extractions, making treatment even more difficult. Severe forms of ECC may require high cost treatment under general anesthesia[93].

In California (USA) half a million school children missed at least one day of school in 2007 due to dental problems and this resulted in a loss to the school district of $29.7 million Dollars. In the National Survey of Children's Health, California, Arizona and Texas were ranked bottom in the scale of children's oral health[85].

2.56 Diagnosis of dental caries

The first dental visit should coincide with the first tooth eruption in the mouth and no later than 12 months of age[95]. However, the developing dentition and occlusion should be monitored in the child's mouth throughout eruption and this should be checked during regular clinical examinations. It is important to detect and manage oral conditions in the early stages. This can improve a child's oral health, general health and well-being, and school readiness. While delayed diagnosis of dental disease might lead to complications which require more extensive and costly dental care [96].

There are many methods of diagnosing dental caries. Generally, most carious lesions can be diagnosed by visual inspection or clinical examination. However, bite-wing radiographs play an important role in detecting dental caries especially proximal caries lesions. These significantly improved the accuracy of the diagnosis of fissure and proximal caries[97]. Clinicians are able to detect lesions, predict their activity and severity and define a logical management of occlusal caries on the basis of a single examination[98]. Additionally, radiographic assessment of coronal and proximal carious lesions is important in the diagnosis of cavitation. Once there is cavity in the enamel, the possibility of arresting the progression of the caries lesion or of remineralizing the enamel is extremely remote. Studies have demonstrated no precise radiographic cut off, or the unequivocal detection or prediction of enamel cavitation[97]. However, there are several tools that are considered effective in diagnosing dental caries; an example of these is Digital Imaging Fiber-Optic Trans-Illumination (DIFOTI™). DIFOTI has been reported to have superior sensitivity in detecting proximal, occlusal and smooth-surface caries[99]. A new imaging technique called Terahertz pulse imaging (TPI) has been developed for both biological and non-biological applications. However this technique needs more research and is expensive [100]. In addition, Electrical Impedance/conductance

measurements are sometimes used to diagnose caries [101]. Another recently developed method to diagnosis caries is laser-induced fluorescence[102]. Other methods that can be used in detection of the caries are the DIAGNOdent, pen which must be employed with caution, and the CarieScan PRO, which, however, is unsuitable for use in the primary dentition[103].

2.57 Prevention of dental caries

A number of strategies have been devised to halt the onset of childhood dental caries. These are based on the concept of such preventive action being more cost effective than having to treat advanced caries at a later stage. A comprehensive program of oral care for preschoolers costs significantly less than treating emergency situations, and extensive restorations can require sedation or treatment under general anesthesia. In seeking to avoid of reduce progressive caries the early identification of risk indicators and implementing oral health preventive practices when the child is at a young age are effective strategies. The American Dental Association (ADA), the American Academy of Pediatric Dentistry (AAPD), the American Academy of Pediatrics (AAP), the American Association of Public Health Dentistry (AAPHD), and the Academy of General Dentistry (AGD), all promote the idea of a child seeing a dentist to establish a *dental home* before their first birthday or within six months of the eruption of the first primary tooth. A 'dental home' is conceived of as a continuing relationship between a dentist and the child patient to enable all aspects of oral health care to be delivered in a comprehensive, continuously accessible, coordinated, and family centered way. This establishing of a dental home must include the possibility of referral to more specialized dental practitioners when this is appropriate[85]. Naturally, the child and its parents should be made aware of how important the daily use of a tooth brush in conjunction with fluoridated toothpastes is for preventing dental caries [104].

2.57.1 Tooth brushing with fluoride toothpaste

There is strong evidence that daily use of fluoride toothpaste has a significant caries-preventive effect in children compared with a placebo. The effect was boosted by supervised tooth brushing, increased brushing frequency to twice daily, and use of a toothpaste concentration of 1,500 ppm fluoride [105]. It is important for parents to know what the exact amount , and concentrations to be used for their children depend on their age[106]. For the children less than three years a proper amount of the fluoridated tooth-paste should be 'smear' or 'rice-size' which is around 0.1 mg. However for the children from three to six years old a 'pea-size' amount of fluoridated toothpaste approximately 0.25 mg fluoride is the appropriate amount. Parents should dispense the toothpaste onto a soft, age-appropriate sized toothbrush and help their children when they are using tooth brush especially for preschool-aged children. Finally, rinsing should be avoided after brushing to maximize the benefit of the tooth paste[18].

2.57.2 Prophylaxis and topical fluoride treatment

Professional fluoride application, especially employing fluoride varnish, is a very important preventive measure particularly for at risk children. The recommended frequency of fluoride varnish application is two to four times a year depending on the caries risk[107]. It is advisable to first use prophylaxis to remove bacterial deposits and plaque from the tooth surfaces. However, plaque and pellicle do not constitute a barrier to fluoride uptake in enamel. Consequently, there is no evidence of a difference in caries rates or fluoride uptake in patients who receive prophylaxis before application of fluoride. For the high caries risk group fluoride should be applied every three to six months while moderate group should receive a professional fluoride treatment every six months[96].

2.57.3 Fluoride supplementation

Fluoride helps to prevent and inhibit dental caries. The AAPD advise that every child should be treated with optimal fluoride dosages; the importance of recognizing that the presence or addition of fluoride in community drinking water constitutes the most beneficial and cost-effective preventive intervention must be emphasized. However, supplementary fluoride should be restricted to children at moderate to high caries risk where other fluoride intake is less than the optimal level; it must be stressed that any such fluoride supplementation should conform with the guidelines issued by the AAPD and the ADA[96]. If infants are older than six months and their exposure to fluoride is less than 0.3 ppm in terms of drinking water, they should have dietary fluoride supplements of 0.25 mg fluoride per day[108].

2.57.4 Sealants

Sealants are another important method for preventing dental caries. A sealant is a flowable material that reduces the risk of pit and fissure caries in susceptible teeth and comprises a cost-effective treatment when maintained. It is indicated for both primary and permanent teeth with deep pits and fissures that are predisposed to plaque retention. Teeth with high risk pits and fissures should be sealed as soon as possible; with the efficacy of the sealants being reassessed at periodic preventive care appointments[96].

2.57.5 Diet counseling

Diet counseling is an integral part of anticipatory guidance during the infant oral health visit. In addition, dietary instructions are very important for children of all ages. The primary emphasis

should be on sugar intake frequency. There are, however, other infant-specific dietary issues that must also be addressed during the infant oral health visit. Breast-feeding is important especially for the first year of the child's life and it should be encourage and supported. Although *ad libitum* nocturnal breast-feeding should be discouraged after the first primary tooth erupts. Weaning from the breast or the bottle should be encouraged by 12 to 14 months of age [108].

2.57.6 Xylitol

Xylitol use can be helpful with moderate or high caries-risk patients. However, in recommending xylitol the practitioner should familiarize themselves thoroughly with the product labeling and take care to recommend age-appropriate products. According to the frequency guidelines, a minimum of two doses should be given in the course of a day; with doses of from three to eight grams of xylitol being required to produce a beneficial clinical effect. The available methods are syrup, chewing gum, and lozenges[109]. Chewing gum has been the most popular form of usage regarding xylitol delivery in most clinical studies. However, xylitol-containing mints and hard candies have also been demonstrated as effective options to xylitol-containing chewing gum[109].

2.58 Treatment of dental caries

The treatment costs of ECC in general is high in terms of money and time, and in most cases it requires full dental rehabilitation under general anesthesia by a pediatric dentist or using some form of conscious or deep sedation as an aid to the management of behavior [73]. Evidence suggests that the intervention to treat the ECC will be more effective if it occurs in the first

two years of a child's life. However, it is rare for parents to take their children to see the dentist and ask for a checkup before the age of two years unless they are in pain[110].

The primary method used in treating caries is the traditional or conventional way which entails surgical removal of the infected dental tissues, followed by restoration with a suitable filling material[75] [111]. Failure of restorations is commonly seen in primary teeth in younger age groups and can be due to several factors such as the anatomy of the primary teeth, small mouths and the limited cooperation of the patient which make the placement of restorations challenging. Preformed stainless steel crowns (SSCs) are another popular method of treating caries in primary teeth, especially multi surface caries and pulp-treated primary molar. SSCs are recommended by the British Society for Paediatric Dentistry (BSPD) as the treatment of choice for primary molar teeth with caries involving two or more surfaces[111]. Additionally, the AAPD recommends their use for "extensive decay, large lesions, or multiple-surface lesions"[111]. Recently, there has been renewed interest in the use of SSCs "Hall Technique" for treating the dental caries[111]. The Hall technique was developed by Dr. Hall a general dental practitioner from Scotland[112]. It is a method for managing carious in primary molars, sealing the decay under the preformed metal crowns without any caries removal, tooth preparation, or local anesthesia[113]. It is a popular technique with high evidence of longevity and success rate[112]. It is of paramount importance that following restoration of decayed teeth, a strict preventive program and recall appointment should be agreed upon between dentist and child/parent or caregiver to prevent and treat any recurrence of decay and its complications [73].

2.60 Evidence based dentistry

2.61 Hierarchy of evidence-based dentistry

Evidence-based dentistry is the way that dentists use research-based information to carry out the practice of dental health and treatment of patients[32]. The diagram below (Figure 1) represents the pyramid that can be used to understand the hierarchy of evidence-based dentistry.

There are five steps in evidence-based dentistry. The researcher ought, first of all, to develop clear and distinct questions that are clinically focused. The researcher then goes on to identify, summarize and to synthesize the questions that are concerned with the study and that serve to answer the questions asked. Evidence appraisal regarding applicability and relevance is then carried out. The clinical evidence is combined with the clinician's expertise and the characteristics of the patient. Finally, the successful implementation of previously considered steps is performed.

The evidence is extrapolated using the highest level of evidence as the starting point for the dental information. In the absence of a **Meta-analysis,** the next piece of evidence that is sought is a systematic review[27]. The definition of a meta-analysis is: a field of small but related studies put together and identified and then combined via the use of systematic review into a common pool of data for a single large analysis of the population[114]. **Systematic reviews** are a summary and a synthesis of the evidence available, and that is related to the diagnosis. It entails the prognosis of the therapy and the harm that might affect the clinicians, decision makers and the patients. These kinds of reviews form some of the most powerful tools for transforming knowledge into action[32].

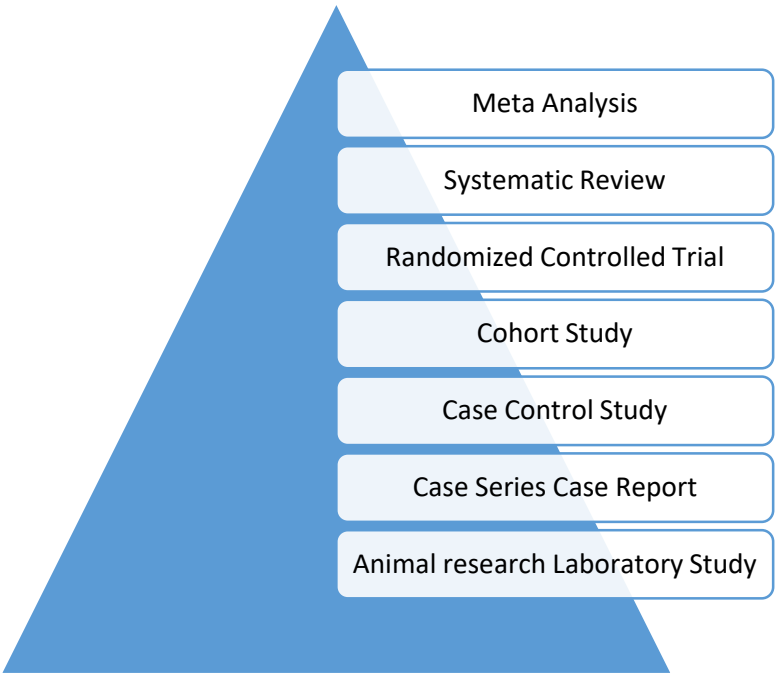


Figure 1 Diagram showing Hierarchy of Evidence-Based Dentistry

A randomized controlled trial is simply an assessment of the treatment in the medical field for the patients. In randomized controlled treatment, the participants are placed into two or more groups at random for comparison of the results[(115)]. The treatment is designed to check for the consistency and the reliability of the procedure. **A cohort study** is a format in which a particular sample that represents the entire population is selected and studied over a period of time to check for the consistency and the reliability of the outcomes and to test the procedures.

The ADA describes the practice of evidence-based dentistry as something that is open in its approach to bettering oral health of the patients by the use of theoretical evidence that is universally approved by the dental association[(27)]. It is the assessment of the clinically relevant evidence in the practice of dentistry. The practice must relate to the oral and medical conditions of the patient and also take into account the history of the patient[(114)]. The use of evidence-based dentistry is meant to bridge the gap between dentistry and research in the field of dental

medicine. **A case report is a** report that describes one patient. **A case series**, on the other hand, describes patients whose cases relate to similar cases**. Cross-sectional** studies try to associate a risk factor that could affect the patient and a particular condition[116].

2.62 Evolution of the evidence-based dentistry; systematic reviews about dental caries in GCC countries

The medical practice of clinical dentistry is increasingly becoming more sophisticated and patients interested in becoming better informed[30]. Care based on evidence is now looked upon as the standard by which the practice of dentistry is evaluated. Health care based on evidence is opening up the field of healthcare in the entire world and is influencing the way that medical practitioners practice as well as deliver the healthcare and medicine[29]. Published health research projects comprise the standards upon which the research in medicine is based.

Evidence-based dentistry is the form of dentistry that is lifelong and self-directed, and that is aimed at giving the patients the power to decide and participate in the health care process[117]. The provision of healthcare is critical for the diagnosis, prognosis and effective treatment of dental disease. Evidence-based provision of medicine is the best way to provide information that is current, precise and practical for the provision of medicine[118]. Evidence-based dentistry integrates research based on evidence and scientific findings with the expertise of the clinician and the treatment preferences of the patient. Evidence-based treatment is practical and proactive in dealing with the matters of oral health of the patient[30].

2.70 Meta-analysis

2.71 Definition of meta-analysis

Meta-analysis is the source of authoritative information that assists in the delivery of evidence-based healthcare practice[116]. More and more information continues to be provided to elucidate the field and hopefully make it an area of better practice for the specialty. On a daily basis, the practice of dentistry presents tremendous challenges to the practitioners[119].As health care providers, it is important that dental and medical practitioners provide the best possible dental health for their patients.

Meta-analysis is essentially the process of systematically reviewing and putting together pertinent qualitative and quantitative data from several different studies that are selectively chosen using common criteria[120]. Meta-analysis is used to arrive at conclusions that contain greater statistical power. Meta- analysis combines the research and the findings of several different, but similar, research materials to guide other research and reach conclusions that have the authority of all the combined data gathered in the assembled research[30]. It is a quantitative type of analysis that is used in the study of subjects[27]. A mechanism for data synchronization across the studies is required to carry out the research and ensure that the research is authentic and accurate[121]. In the past, narrative reviews were used for research, but they have been discounted on the grounds of being subjective[120]. It is subjective because different researchers produce different findings and recommendations. The examination of heterogeneity in the research is significant in the study of meta-analysis procedures. Results that accrue from a meta-analysis include more accurate estimates of the results and the outcomes of the research[32]. The effects of treatment are an essential component in implementing the results of the research.

2.72 Advantages of meta-analysis

Research in medicine is assembled and correlated in a meta-analysis, and the results are used to understand the resultant conditions for health better. The data resources are analyzed so that the researchers can arrive at clinical solutions that are based on verifiable evidence[120]. There has been an increase in activities relevant to evidence-based dentistry in the 21st century. More and more health practitioners are adopting the concept in offering dentistry expertise that is based on evidence[120]. A great deal of information is being produced in the form of meta-analyses that provide guidance for better dental health care practices.

There are various benefits in carrying out meta-analyses. They provide greater statistical power and the use of research-based information to support findings that are appropriate for the practice of research[120]. With regards to dental health, meta-analysis assists the dental practitioner to make accurate judgments that assist in improving dental practice[115]. Meta-analysis possesses more statistical power than other forms of statistics and research. Meta-analysis is also beneficial in the sense that it provides the ability to confirm the data analysis used for research[29].

There is the provision for cross checking facts that allows researchers to make more accurate decisions regarding dental procedures and arrive at better treatment procedures[122]. Decisions concerning how valid a hypothesis is, or the utility of an invention are not something that can be decided by the use of research material from a single study. There have to be several similar sets of research materials that can be combined to give the research more authenticity[114]. It is probable that there are certain variations in material and procedures from one research finding to another; no to research studies can produce data that are identical, regardless of how closely the research methodologies resembled each other [27].

Every researcher subscribes to a particular school of thought. Because different researchers arrive at different findings, it becomes difficult to discern the correct result when more than one

research and result are involved[120]. Meta-analysis uses various types of objective means of finding the most accurate result and this process assists in the general research process that is ultimately beneficial to clinical practice[120]. This creates the possibility of applying the different forms of research findings to find the optimum result at the conclusion of the analysis.

The above section, which I have extensively amended, needs checking for accuracy by your supervisor.

2.73 Software used for meta-analysis

Computer software is available to carry out the process of meta-analysis. Comprehensive Meta-Analysis (CMA) is a software developed in the USA and used in Meta-analysis. It is an essential software for meta-analysis. Complex analyses can be conducted easily using this intuitive software. CMA 2.0 is perhaps the most user-friendly statistical software and it makes the complicated process of conducting a meta-analysis much easier[123].

The Meta-analysis calculator is a device that takes data and converts it into meta-analysis data for computing and analysis[122]. In computer software like the Microsoft office Excel 2013, there is a tool for the input of the meta-analysis function, like the MIX 2.0, which functions by keying in the data, with the software then performing the fundamental processes of the meta-data calculation[120]. The application is used in more than forty countries around the world, and it is one of the most efficient means of generating a meta-data analysis[120]. It is one of the most popular software in the meta-analysis. Various steps are involved in performing the meta-analysis.

2.80 Why it is important to do systematic review and meta-analysis in GCC about the prevalence of dental caries:

As mentioned above, dental caries prevalence and severity were high in GCC countries according to published studies. A meta-analysis comprises a procedure to combine the results from the individual studies to result in an appropriate analysis with greater validity. The general purpose of a meta-analysis is to arrive at a more powerful estimate of the true size effect in contrast to the less accurate size effect produced by a single study carried out under a given single set of assumptions and conditions. Therefore, it seems appropriate to collect studies from all GCC countries and conduct a meta-analysis to evaluate the overall prevalence and severity of dental caries in order to help the development of systematic approaches for preventive oral care programs in the GCC states and to provide sound information for oral health promotion and public health care.

3.00 MATERIAL AND METHODS

3.10 Protocol Development

The main objective of this systematic review and meta-analysis was to identify the prevalence and severity of dental caries in the GCC countries. It was based on a specific protocol developed following the guidelines outlined in the PRISMA statement[124] (Appendix 1). The protocol was approved by the research and ethics committee at Hamdan Bin Mohammad College of Dental Medicine (HBMCDM) at, Mohammed Bin Rashid University of Medicine and Health Sciences (MBRU) (Approval letter reference (EC0915-002) October 8, 2015) Appendix 2.

3.20 Sources of Data

The body of this review was mostly limited to the studies identified by database searches including PubMed, Google search, and hand searching of journals and gathering of unpublished reports. Conference proceedings were outside the scope of the review. The PubMed database and Google search were conducted using the search by key words: *dental caries, child, prevalence, DMFT, dmft* and *GCC countries (Bahrain, Oman, Kuwait, KSA, Qatar and UAE)*. The search included all literature published in English and Arabic from January 1st 1992 to June 30th 2016. The titles, authors and abstracts from all studies identified were printed and reviewed independently on the basis of keywords, title and abstract by two reviewers to determine whether these meet the inclusion criteria.

3.30 Selection criteria

The selection criteria applied to the following: study design, study population, and study outcomes which were the prevalence and severity of dental caries identified by *dmft* and DMFT.

3.31 Types of study design:

All studies on the prevalence and severity of dental caries conducted in GCC countries, including sectional, cohort and case-control studies were included. There was no language restriction and papers in English and Arabic languages were included.

3.32 Study Population

All included studies on prevalence and severity of dental caries involved healthy children aged 16 years and below in the GCC countries.

3.33 Inclusion criteria

- Studies conducted in one of the six GCC countries
- Prevalence of the caries in children aged 2 to 16 years
- Studies including prevalence and/or DMFT/*dmft* data
- Healthy participants without systemic diseases or syndromes

3.34 Exclusion criteria

- Studies in children with systemic diseases or syndromes

- Studies with participants below 2years or older than 16 years
- Studies on prevalence and or severity of caries in specific teeth
- Any study published before January 1992
- Studies with duplicated data

The flow of studies through the reviewing process is shown in (Figure 2). The search initially identified 193 studies and subsequently 120 were excluded due to being non GCC studies. From the 73 studies that remained and which were assessed in full-text, 16 were excluded for various reasons (five studies duplicates, five studies due to the mixed dentition, two studies on unfit children, one study due to the specific tooth and three studies due to the age limits, above 16 or below 2 years.

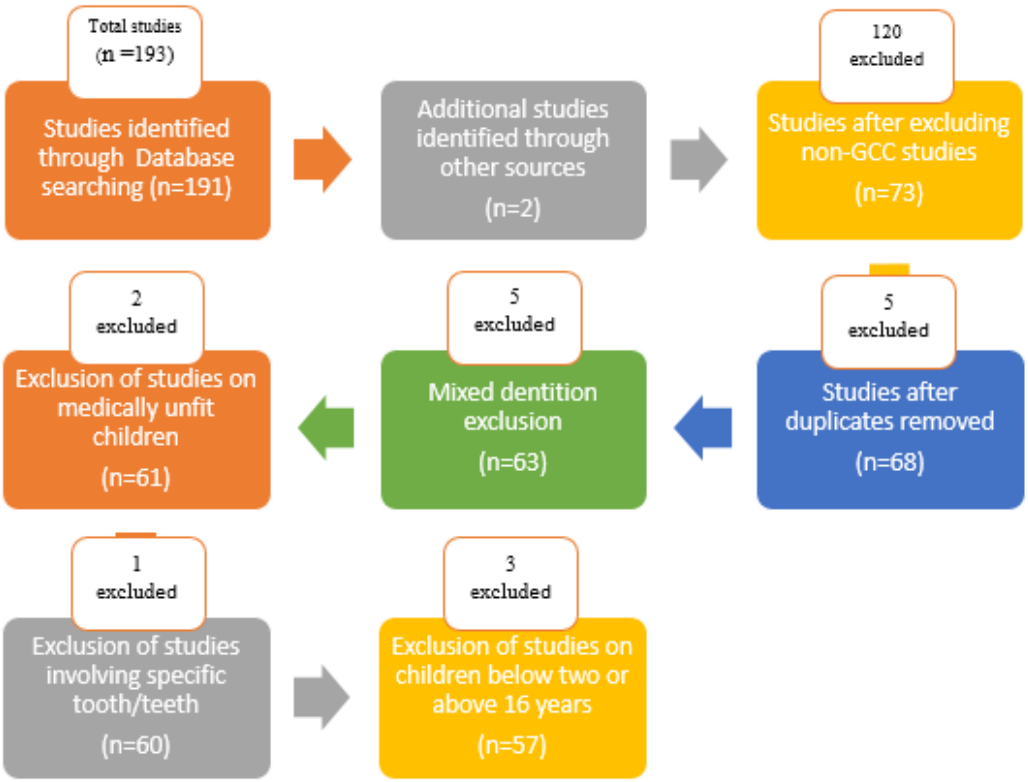


Figure 2: Flow diagram of literature search

3.40 Selection of studies and data extraction

The principle investigator and the thesis supervisor assessed the retrieved records for inclusion independently. They were not blinded to the identity of the authors, their institution or the results of the research. The principal investigator obtained and assessed the full report of the records considered to meet the inclusion criteria. Disagreements were resolved by discussion or consultation with the thesis co-supervisors. Data collection forms were used to record the following desired information (Tables 2 and 3).

- Author/Authors' names
- Year of publication
- Country
- Sample size
- Age of participants
- DMFT/*dmft* and standard deviation
- Prevalence

If the published data needed any clarification, then attempts were made to contact the corresponding author.

3.50 Data synthesis and assessment of heterogeneity and publication bias

Information was gathered into two separate tables (Tables 2 and 3) for primary teeth caries (prevalence and *dmft* data) and another for permanent teeth caries (prevalence and DMFT data). The pattern of information in different studies was different: some revealed information about the prevalence and severity of caries in primary teeth, others about the prevalence and severity of dental caries in permanent teeth, while a few other studies studied both.

The overall prevalence and severity in different studies were expressed as standardized values (i.e. the Standardized Mean Difference[SMD]) together with the relevant 95% Confidence Interval [CI], in order to enable quantitative synthesis and analysis [125]. The random effects methods for meta-analysis was used in combining data from studies that reported similar measurements in appropriate statistical forms[126, 127], since they were expected to differ across studies due to differences in study populations, sample size and study design.

All analyses were carried out with comprehensive Meta –Analysis software 2.2046 (2007 Biostat Inc.). Significance was set at $p < 0.05$, except for 0.10 used for the heterogeneity (Ioannidis, 2008) [128].

3.51 Consideration of heterogeneity

Consideration of the consistency of a group of studies is an important issue. If confidence intervals for the results of individual studies (generally depicted graphically using horizontal lines) have a poor overlap, this is usually an indication of the presence of statistical heterogeneity.

Here, the chi-squared (χ^2) test is included in the Forest plots in Cochrane reviews. This assesses if the observed differences in results could credibly result from chance alone. A low P value (or a large χ^2statistic relative to its degree of freedom) is an indicator of the degree of heterogeneity (variation in effect estimates beyond chance).

In addition, in an attempt to accurately test the presence and extent of heterogeneity, a test for homogeneity, I^2 statistics was used and calculated as follows:

$$I^2 = \left(\frac{Q - df}{Q}\right) \times 100\%$$

Where Q is the chi-squared statistic and df is its degrees of freedom. This describes the percentage of the variability in effect estimates that is due to heterogeneity rather than sampling error (chance).

As a rough guide, the I^2statistic test may be interpreted as follows: [129]

- 0% to 40%: might not be important
- 30% to 60%: may represent moderate heterogeneity
- 50% to 90%: may represent substantial heterogeneity
- 75% to 100%: considerable heterogeneity.

3.52 Consideration of bias

In an ideal world every piece of scientific work should be given the same opportunity of publication, but in the real world and any work can suffer discrimination for a variety of reasons including: statistical significance, popularity of its topic, having an interested project sponsor and the language of the manuscript. In a meta-analysis, a funnel plot demonstrates the magnitude of effect of all the studies so as to address the question of publication bias. The published effects may be greater than the true effects just because of sampling variation. The plot should show symmetry, in which case that studies should fall equally on both sides of the funnel plot[130]. Such symmetry in a funnel plot indicates no publication bias while an asymmetrical one signifies there is publication bias.

Egger's plot is a specific test, which was used to confirm the presence or absence of publication bias seen in a funnel plot. This tool plots the regression line between precision of the studies (independent variable) and the standardized effect (dependent variable).

4.00 RESULTS

The results' data of all studies included in the systematic review were compiled into two tables. (Table 2) shows the studies reporting on caries in primary dentition and (Table 3) presents the studies reporting on caries in permanent dentition. The following data were presented for each study: author or authors' name, year of publication, country, sample size, age in years, mean *dmft* or DMFT, standard deviation and prevalence.

4.10 Results of the systematic review

Following implementation of all of the inclusion criteria, 57 studies were included in the systematic review. Out of these 57 studies, 34 studied dental caries in primary teeth (Table 2) and 23 in permanent teeth (Table 3). In 11 studies the mean *dmft*/DMFT data were not recorded, while in 8 studies the prevalence was not reported.

4.11 Results of the systematic review by country

4.11.1 Kuwait

In the state of Kuwait, the four studies in preschool children (Table 2), which met the inclusion criteria showed a wide range of caries level in primary dentition in terms prevalence (24 – 61%), only one study among them reported *dmft* (4.1). The main reported reasons for caries in preschool children were prolonged bottle feeding and poor oral hygiene. Regarding permanent dentition, only three studies (Table 3) were included with a mean DMFT range of (2.91 – 3.25) and prevalence of (18.83 – 52 %) with no statistically significant deference between Kuwaiti and

non-Kuwaiti children; males were affected more than females and the most important reported reason for caries was the lack of access to dental care.

4.11.2 Kingdom of Saudi Arabia (KSA)

The majority of studies included in the systematic review were from the KSA. The number of studies in primary and permanent dentitions was 19 and 13 respectively. In the primary dentition, the mean *dmft* ranged between 0.91 and 8.6 and prevalence between 20.8 and 96%. Dental caries was higher in low socioeconomic groups. While, in the permanent dentition the mean DMFT range was 0.41-7.3 and the prevalence was 57.2-92.3%. The most reported cause of caries in the permanent dentition was exposure to a cariogenic diet.

4.11.3 Oman

Only a few studies were conducted in Oman to measure the *dmft*/DMFT and prevalence of dental caries. The number of studies regarding primary dentition was only one, while for the permanent dentition, there were two studies. In the primary dentition, the mean was 4.61 and the prevalence was 84.5%. In the permanent dentition, the mean DMFT range was 1.53 – 3.23 and the prevalence was 58.1%. The main causes reported were poor oral hygiene, plaque and calculus accumulation.

4.11.4 Qatar

There were also few studies conducted in Qatar that met the inclusion criteria and were therefore included in our systematic review. The number of studies in primary and permanent dentitions was one and two respectively. In primary dentition the mean *dmft* was 7.6 and

prevalence was 89.2%. While in the permanent the mean DMFT was 4.5 and prevalence was 73 – 85%. One of the most common risk factors that affected the prevalence of caries in Qatar was the socio-demographic factor.

4.11.5 United Arab Emirates (UAE)

In the UAE, eight studies in preschool children (Table 2), which met the inclusion criteria, showed a wide range of caries level in primary dentition in terms of mean *dmft* (3.07 – 10.9) and prevalence range (41.5 – 99.4%). In the permanent dentition, there were three studies (Table 3). The DMFT range was 1.6 – 3.27 and prevalence 54 – 65%. The education of the parents and improving dietary habits, good oral hygiene practices like brushing twice daily were the reported reasons for the decreased prevalence of the caries in last few years in the UAE.

Table 2: Studies and variables included after inclusion criteria on reported caries in primary teeth as mean *dmft* and prevalence

Author	Year	Country	Sample	Age	dmft(SD)	Prevalence (%)
Nasseb *et al*.*		Bahrain		5	-	85
Murtomaa *et al*.[131]	1995	Kuwait	450	3 - 7	4.1(3.6)	61
Al-Dashti *et al*.[132]	1995	Kuwait	227	1.5- 4	-	53
Al-Mutawa *et al*.[133]	2010	Kuwait	639	4	-	32
Al-Mutawa *et al*.[133]	2010	Kuwait	638	5	-	24
Al-Malik *et al*.[63]	2000	KSA	80	4 - 5	0.95(2.03)	30
Al-Banyan *et al*.[66]	2000	KSA	272	5 - 12	3.8(3.2)	-
Gandeh *et al*.[65]	2000	KSA	82250	6 - 11	-	83
Khan *et al*.[134]	2001	KSA	457	6 - 7	4.45(3.76)	82.9
Wyne *et al*.[61]	2001	KSA	77	4	0.91(2.42)	20.8
Wyne *et al*.[62]	2001	KSA	1016	4.51	8.6(3.4)	27.3
Wyne *et al*.[135]	2002	KSA	449	7 - 11	6.3(3.5)	94.4
Wyne *et al*.[60]	2002	KSA	322	4 - 5	2.92(3.51)	62.7
Al-Malik *et al*.[58]	2003	KSA	987	2 - 5	4.8(4.87)	73
Paul *et al*.[59]	2003	KSA	103	5	7.1(5.7)	83.5
Al-Dosari *et al*.[57]	2004	KSA	249	6 - 7	6.53(4.3)	91.2
Al-Dosari *et al*.[57]	2004	KSA	182	6 - 7	6.35(3.83)	91.2
Al-Malik *et al*.[56]	2006	KSA	300	6 - 7	8.06(4.04)	96
Wyne *et al*.[55]	2007	KSA	789	3 - 5	6.1(3.9)	74.8
Farsi *et al*.[136]	2010	KSA	510	4 - 5	3.9(3.185)	45.4
Al-Majed *et al*.[137]	2011	KSA	522	8 - 10	4.96(3.03)	86.2
Alkarimi *et al*.[54]	2014	KSA	436	6 – 8	5.7(4.2)	87.1
Farooqi *et al*.[51]	2015	KSA	397	6 – 9	3.66(3.13)	78
Al-Meedani *et al*.[50]	2016	KSA	388	3 – 5	3.4(3.6)	69
Al-Ismaily *et al*.[71]	1997	Oman	3114	6	4.61	84.5
Alkhtib *et al*.[76]	2016	Qatar	250	4 – 5	7.6(5.1)	89.2
Al-Hosani *et al*.[11]	1998	UAE	217	2	-	41.5
Al-Hosani *et al*.[11]	1998	UAE	204	4	-	78.5
Al-Hosani *et al*.[11]	1998	UAE	219	5	8.4	88
El-Nadeef *et al*.[12]	2010	UAE	1340	5	5.1	83
Hashim *et al*.[74]	2010	UAE	518	5	4.0(4.1)	72.9
Hashim *et al*.[74]	2010	UAE	518	6	4.9(4.3)	80
Kowash *et al*.[73]	2015	UAE	176	2 - 5	10.9	99.4
Kowash *et al*.** [138]	2017	UAE	540	3 – 6	3.07 (0.14)	74.1

* Unpublished study ** Unpublished study during data collection

Table 3: Studies and variables included after inclusion criteria on reported caries in permanent teeth as mean DMFT and prevalence

Author/Authors	Year	Country	Sample	Age	DMFT (SD)	Prevalence (%)
Al-Mutawa *et al.*[80]	2006	Kuwait	2290	12 - 14	3.25(3.73)	18.825
Alsumait *et al.*[139]	2015	Kuwait	440	11 - 12	2.91(2.75)	-
Ali *et al.*[79]	2016	Kuwait	486	12 - 16	-	52
Akpata *et al.*[69]	1992	KSA	363	12 - 13	2.02	76.5
Al-Shammery *et al.*[67]	1999	KSA	1873	12 - 13	-	>89
Al-Banyan *et al.*[66]	2000	KSA	272	5 - 12	2(1.9)	-
Wyne *et al.*[135]	2002	KSA	449	7 - 11	1.6(1.5)	-
Dosari *et al.*[140]	2003	KSA	429	16.4	7.35(4.99)	91.1
Dosari *et al.*[140]	2003	KSA	305	16.4	7.05(4.58)	90.5
Al-Dosari *et al.*[57]	2004	KSA	392	12 – 13	5.06(3.65)	92.3
Al-Dosari *et al.*[57]	2004	KSA	281	12 - 13	4.53(3.57)	87.9
Al-Malik *et al.*[56]	2006	KSA	300	6 - 7	0.41(0.86)	-
Al-Dosari *et al.*[141]	2010	KSA	3904	12 - 13	2.93(3.2)	-
Al Agili *et al.*[53]	2014	KSA	1655	9 & 14	-	83.13
Bhayat *et al.*[52]	2014	KSA	360	12	1.53(1.88)	57.2
Farooqi *et al.*[51]	2015	KSA	314	10 - 12	1.94(2)	68
Al-Ismaily *et al.*[72]	1996	Oman	3435	12	1.53	58.1
Al-Ismaily *et al.*[70]	2004	Oman	2860	15	3.23(3.73)	-
Bener *et al.*[78]	2013	Qatar	1752	6 -15	4.5(4.2)	73
Al-Darwish *et al.*[77]	2014	Qatar	2113	12 - 14	-	85
Mustahsen *et al.*[142]	2008	UAE	242	11 &14	3.27	-
El-Nadeef *et al.*[75]	2009	UAE	1323	12	1.6	54
El-Nadeef *et al.*[75]	2009	UAE	1328	15	2.5	65

4.20 Results of the meta-analysis

The data were compiled into two tables: Table 2 presents the studies reporting on the prevalence of caries in primary teeth while Table 3 presents the studies on the prevalence of caries in permanent teeth. The sum of sample sizes of those studies in primary teeth prevalence (Figure 4) was 98,497 and for permanent teeth prevalence (figure 6) was 18,699. While sample size for the mean *dmft* was 15,421; however for mean DMFT, it was 23,152. A large proportion of the studies were carried out in KSA (32 of total studies included). Bahrain, however, did not have any publications. Meta-analysis was used separately for primary and permanent teeth caries data.

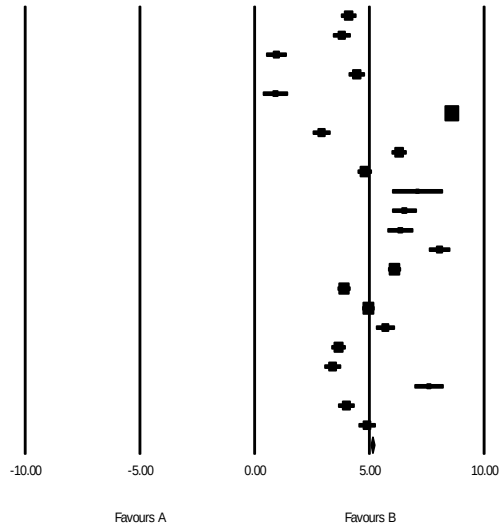
4.21 *dmft* and primary teeth caries prevalence

A forest plot (Figure 3) represents studies that had mean *dmft* values. Visual inspection of the forest plot indicates the presence of heterogeneity; a Q statistic (chi-square test) was used to authenticate the presence of heterogeneity. The test provided a significant P-value (<0.001), which confirms the heterogeneity between studies. A high level of heterogeneity was found as demonstrated by Q-value of 2,538.501 (df = 21) and I^2 value of 99.17%. A random effect model was used to find mean *dmft* by employing Table 2. The average of *dmft* was estimated at 5.136 (0.038) with 95% confidence interval (5.016-5.211).

A forest plot (Figure 4) shows that the overall estimation of the prevalence of caries in primary teeth was 80.9% and with 95% confident interval (80.6%-81.1%). It was very clear that the width of the CI was very small due the large number of participants in the analysis. As in the *dmft* forest plot, high heterogeneity was found as demonstrated by a Q-value of 4,139.441 (df = 30) and I^2 of 99.27% (p-value <0.00).

Average of dmft

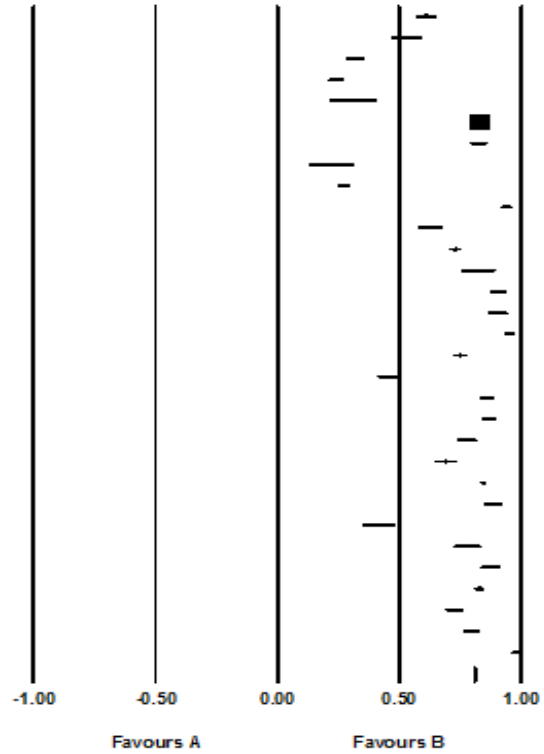
Model	Study name	Statistics for each study							Residual (Fixed)					
		Mean	Standard error	Variance	Lower limit	Upper limit	Z-Value	p-Value	Std Residual	Std Residual	Std Residual	Std Residual	Std Residual	Std Residual
	Murtomaa et al, 1995, Kuwait	4.100	0.170	0.029	3.767	4.433	24.159	0.000	-6.27			-0.44		
	Al-Banyan et al,2000, KSA	3.800	0.194	0.038	3.420	4.180	19.585	0.000	-7.02			-0.59		
	Al-Malik M et al, 2000,KSA	0.950	0.227	0.052	0.505	1.395	4.186	0.000	-18.71			-2.06		
	Khan et al,2001,KSA	4.450	0.176	0.031	4.105	4.795	25.301	0.000	-4.00			-0.26		
	Wyne et al, 2001,KSA	0.910	0.276	0.076	0.369	1.451	3.300	0.001	-15.47			-2.07		
	Wyne A et al, 2001, KSA	8.600	0.107	0.011	8.391	8.809	80.624	0.000	34.77			1.89		
	Wyne AH et al, 2002, KSA	2.920	0.196	0.038	2.537	3.303	14.928	0.000	-11.55			-1.05		
	Wyne AH,2002 , KSA	6.300	0.165	0.027	5.976	6.624	38.141	0.000	7.24			0.70		
	Al-Malik MI et al, 2003, KSA	4.800	0.155	0.024	4.496	5.104	30.965	0.000	-2.24			-0.08		
	Paul TR, 2003, KSA	7.100	0.562	0.315	5.999	8.201	12.642	0.000	3.50			1.07		
	Al-Dosari R1 et al,2004,KSA	6.530	0.273	0.074	5.996	7.064	23.963	0.000	5.17			0.81		
	Al-Dosari Q1 et al,2004,KSA	6.350	0.284	0.081	5.794	6.906	22.367	0.000	4.32			0.72		
	Al-Malik et al,2006,KSA	8.060	0.233	0.054	7.603	8.517	34.555	0.000	12.71			1.60		
	Wyne AH, 2007, KSA	6.100	0.139	0.019	5.828	6.372	43.934	0.000	7.22			0.59		
	Farsi,2010,KSA	3.900	0.141	0.020	3.624	4.176	27.653	0.000	-9.10			-0.54		
	Al-Majed et al, 2011, KSA	4.960	0.133	0.018	4.700	5.220	37.400	0.000	-1.39			0.00		
	Alkarimi HA et al, 2014, KSA	5.700	0.206	0.042	5.297	6.103	27.714	0.000	2.79			0.39		
	Farooqi FA 1 et al, 2015, KSA	3.660	0.157	0.025	3.352	3.968	23.299	0.000	-9.69			-0.67		
	Al-Meedani LA et al, 2016, KSA	3.400	0.183	0.033	3.042	3.758	18.603	0.000	-9.71			-0.80		
	Alkhtib et al, 2016, Qatar	7.600	0.323	0.104	6.968	8.232	23.562	0.000	7.69			1.35		
	Hashim1 et al, 2010, UAE	4.000	0.180	0.032	3.647	4.353	22.205	0.000	-6.45			-0.49		
	Hashim2 et al, 2010, UAE	4.900	0.189	0.036	4.530	5.270	25.935	0.000	-1.28			-0.03		
Fixed		5.136	0.038	0.001	5.061	5.211	134.662	0.000						



Model	Effect size and 95% confidence interval						Test of null (2-Tail)		Heterogeneity		
Model	Number Studies	Point estimate	Standard error	Variance	Lower limit	Upper limit	Z-value	P-value	Q-value	df (Q)	P-value
Fixed	22	5.136	0.038	0.001	5.061	5.211	134.662	0.000	2538.501	21	0.000
Random	22	4.951	0.424	0.180	4.120	5.782	11.679	0.000			

Figure 3: Study-specific and summary effect estimates [mean and 95% confidence interval (CI)] for mean decayed, missing and filled teeth (dmft) in studies, 1992–2016.

Model	Study name	Event rate	Lower limit	Upper limit	Z-Value	p-Value
	Murtomaa et al, 1995, Kuwait	0.611	0.565	0.655	4.674	0.000
	al-Dashti et al, 1995, Kuwait	0.529	0.464	0.593	0.862	0.388
	Al-Mutawa et al , 2010, Kuwait1	0.319	0.284	0.356	-8.923	0.000
	Al-Mutawa et al , 2010, Kuwait	0.240	0.208	0.274	-12.442	0.000
	Al-Malik et al, 2000,KSA	0.300	0.210	0.409	-3.473	0.001
	Gandeh MB et al, 2000, KSA	0.830	0.827	0.833	170.820	0.000
	Khan et al,2001,KSA	0.829	0.792	0.861	12.714	0.000
	Wyne A1 et al, 2001, KSA	0.208	0.131	0.313	-4.765	0.000
	Wyne A2 et al, 2001, KSA	0.273	0.246	0.301	-13.929	0.000
	Wyne AH,2002 , KSA	0.944	0.919	0.962	13.755	0.000
	Wyne AH et al, 2002, KSA	0.627	0.573	0.678	4.518	0.000
	Al-Malik MI et al, 2003, KSA	0.730	0.702	0.757	13.900	0.000
	Paul , 2003, KSA	0.835	0.750	0.895	6.108	0.000
	Al-Dosari R1 et al,2004,KSA	0.912	0.869	0.941	10.452	0.000
	Al-Dosari Q1 et al,2004,KSA	0.912	0.861	0.945	8.937	0.000
	Al-Malik et al,2006,KSA	0.960	0.931	0.977	10.787	0.000
	Wyne AH, 2007, KSA	0.748	0.716	0.777	13.258	0.000
	Farsi,2010,KSA	0.455	0.412	0.498	-2.034	0.042
	Al-Majed et al, 2011, KSA	0.862	0.830	0.889	14.438	0.000
	Alkarimi et al, 2014, KSA	0.871	0.835	0.899	13.054	0.000
	Farooqi t al , 2015, KSA	0.781	0.737	0.819	10.473	0.000
	Al-Meedani et al, 2016, KSA	0.691	0.643	0.735	7.315	0.000
	al-Ismaily et al , 1997, Oman	0.845	0.832	0.857	34.243	0.000
	Alhitib et al, 2016, Qatar	0.892	0.847	0.925	10.361	0.000
	Al-Hosani1 et al , 1998, UAE	0.415	0.351	0.481	-2.499	0.012
	Al-Hosani2 et al , 1998, UAE	0.784	0.723	0.835	7.584	0.000
	Al-Hosani3 et al , 1998, UAE	0.881	0.831	0.918	9.596	0.000
	El-Nadeef et al , 2010, UAE	0.830	0.809	0.849	22.140	0.000
	Hashim R et al, 2010, UAE	0.730	0.690	0.766	10.039	0.000
	Hashim R2 et al, 2010, UAE	0.799	0.763	0.832	12.595	0.000
	Kuwash, 2015, UAE	0.994	0.961	0.999	5.150	0.000
Fixed		0.809	0.806	0.811	171.368	0.000



Model	Effect size and 95% interval				Test of null (2-Tail)		Heterogeneity				Tau-squar
Model	Number Studies	Point estimate	Lower limit	Upper limit	Z-value	P-value	Q-value	df (Q)	P-value	I-squared	Tau Squared
Fixed	31	0.809	0.806	0.811	171.368	0.000	4139.441	30	0.000	99.275	0.899
Random	31	0.742	0.671	0.802	6.062	0.000					

Figure 4: Study-specific and summary effect estimates [mean and 95% confidence interval (CI)] for prevalence of caries in primary dentition.

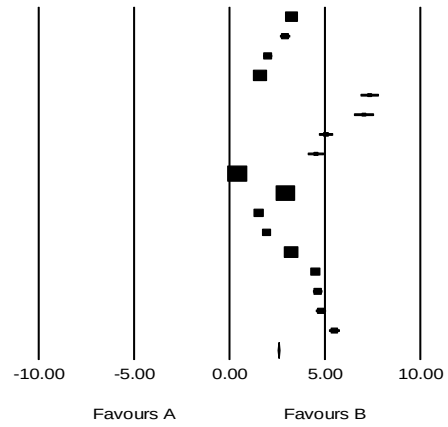
4.22 DMFT and permanent teeth caries prevalence

Analysis was again performed over the data set that had mean DMFT values (Figure5). Heterogeneity was checked first by forest plot and then by a chi-square test. Visual inspection of the forest plot and chi-square ($P < 0.001$) gave adequate evidence of heterogeneity in the data set and the index of heterogeneity was also very high Q-value of 4,806.020 (df = 16) and I^2 value of 99.67%. The random effect model was used to estimate mean DMFT and this was found to be 2.577 (0.022) with 95% confidence interval (2.533-2.620).

A forest plot (Figure 6) shows that the overall estimation of the prevalence in permanent teeth was 64.7% and with 95% confidence interval, the range was 63.9-65.4%. It is very clear that the width of the CI is very small due the large number of participants in the analysis. A high heterogeneity was found as demonstrated by Q-value of 3,048.074 (df = 15), I^2 of 99.5% and p-value <0.001.

Average of DMFT

Study name	Mean	Standard error	Variance	Lower limit	Upper limit	Z-Value	p-Value
Al-Mutawa et al, 2006, Kuwait	3.250	0.078	0.006	3.097	3.403	41.696	0.000
Alsumait et al, 2015, Kuwait	2.910	0.131	0.017	2.653	3.167	22.197	0.000
al-Banyan et al, 2000, KSA	2.000	0.115	0.013	1.774	2.226	17.360	0.000
wyne et al, 2002, KSA	1.600	0.071	0.005	1.461	1.739	22.602	0.000
DosariR et al,2003 , KSA	7.350	0.241	0.058	6.878	7.822	30.508	0.000
DosariQ et al,2003 , KSA	7.050	0.262	0.069	6.536	7.564	26.883	0.000
Al-Dosari R et al,2004,KSA	5.060	0.184	0.034	4.699	5.421	27.447	0.000
Al-Dosari Q et al,2004,KSA	4.530	0.213	0.045	4.113	4.947	21.271	0.000
Al-Malik et al, 2006, KSA	0.410	0.050	0.002	0.313	0.507	8.257	0.000
Al-Dosari et al,2010,KSA	2.930	0.051	0.003	2.830	3.030	57.210	0.000
Bhayat A et al ,2014, KSA	1.530	0.099	0.010	1.336	1.724	15.441	0.000
Farooqi 1 et al, 2015, KSA	1.940	0.113	0.013	1.719	2.161	17.188	0.000
Al-Ismaily2 et al , 2004, Oman	3.230	0.069	0.005	3.094	3.366	46.686	0.000
Bener et al , 2013, Qatar	4.500	0.100	0.010	4.303	4.697	44.847	0.000
Al-Darwish1 et al , 2014, Qatar	4.620	0.121	0.015	4.384	4.856	38.307	0.000
Al-Darwish2 et al , 2014, Qatar	4.790	0.132	0.017	4.531	5.049	36.312	0.000
Al-Darwish3 et al , 2014, Qatar	5.500	0.139	0.019	5.227	5.773	39.469	0.000
	2.577	0.022	0.000	2.533	2.620	116.217	0.000

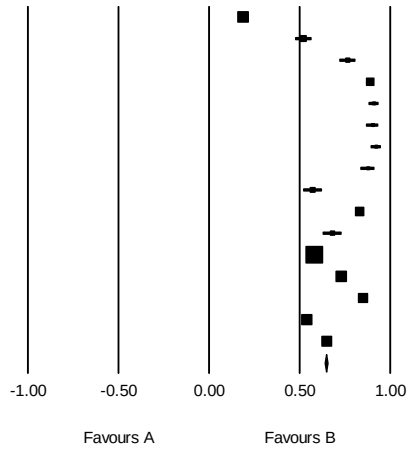


Model	Number Studies	Point estimate	Standard error	Variance	Lower limit	Upper limit	Z-value	P-value	Q-value	df (Q)	P-value
Fixed	17	2.577	0.022	0.000	2.533	2.620	116.217	0.000	4806.020	16	0.000
Random	17	3.707	0.397	0.157	2.929	4.485	9.344	0.000			

Figure 5: Study-specific and summary effect estimates [mean and 95% confidence interval (CI)] for Mean Decayed, Missing and Filled teeth (DMFT) in studies, 1992–2016

Prevalence of permenant teeth

Study name	Event rate	Lower limit	Upper limit	Z-Value	p-Value	Std Residual	Std Residual	Std Residual
Al-Mutawa et al, 2006, Kuwait	0.188	0.173	0.205	-27.341	0.000	-40.86		
Ali DA, 2016, Kuwait	0.521	0.476	0.565	0.907	0.364	-5.85		
Akpata et al ,1992 ,KSA	0.766	0.720	0.807	9.561	0.000	4.73		
al-Shammery, 1999, KSA	0.890	0.875	0.903	28.312	0.000	20.71		
DosariR et al,2003 , KSA	0.911	0.881	0.935	13.719	0.000	10.22		
DosariQ et al,2003 , KSA	0.905	0.867	0.933	11.542	0.000	8.48		
Al-Dosari R et al,2004,KSA	0.923	0.893	0.946	13.108	0.000	9.97		
Al-Dosari Q et al,2004,KSA	0.879	0.835	0.912	10.841	0.000	7.57		
Bhayat A et al ,2014, KSA	0.572	0.521	0.622	2.731	0.006	-2.98		
Al Agili et al , 2014, KSA	0.831	0.813	0.849	24.304	0.000	15.66		
Farooqi FA 1 et al, 2015, KSA	0.682	0.628	0.731	6.281	0.000	1.31		
al-Ismaily et al, 1996, Oman	0.581	0.564	0.597	9.461	0.000	-9.26		
Bener et al , 2013, Qatar	0.730	0.709	0.750	18.484	0.000	7.67		
Al-Darwish et al , 2014, Qatar	0.850	0.834	0.865	28.470	0.000	19.36		
El-Nadeef et al, 2009, UAE1	0.540	0.513	0.566	2.884	0.004	-8.50		
El-Nadeef et al, 2009, UAE	0.650	0.624	0.675	10.749	0.000	0.26		
	0.647	0.639	0.654	34.745	0.000			

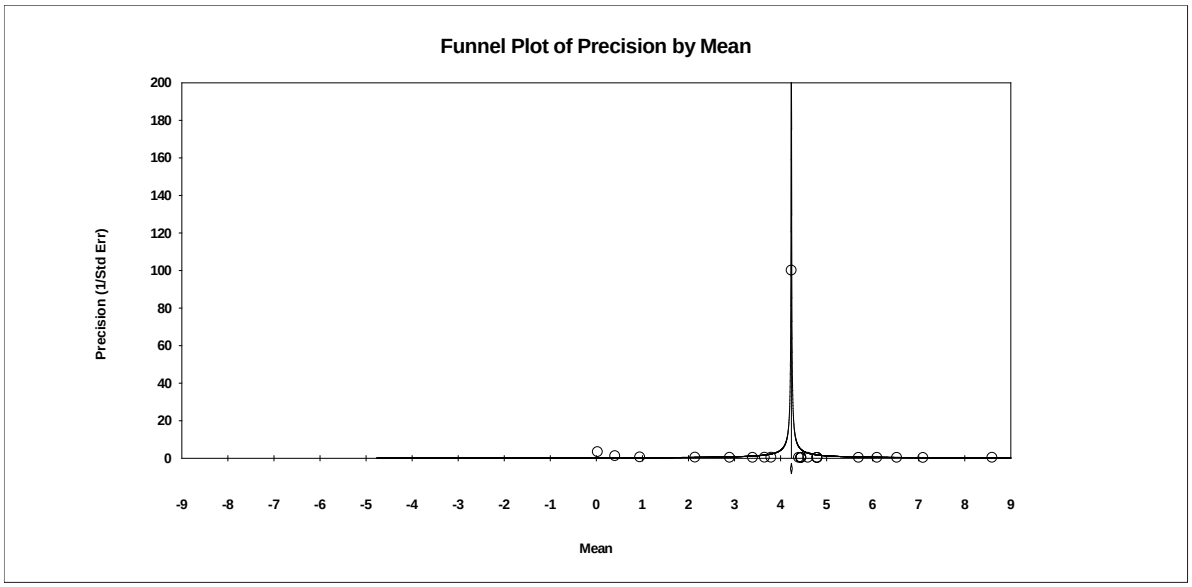


Model	Number Studies	Point estimate	Lower limit	Upper limit	Z-value	P-value	Q-value	df (Q)	P-value	I-squared	Tau Squared
Fixed	16	0.647	0.639	0.654	34.745	0.000	3048.074	15	0.000	99.508	1.044
Random	16	0.747	0.641	0.830	4.206	0.000					

Figure 6: Study-specific and summary effect estimates [mean and 95% confidence interval (CI)] for prevalence of caries in permanent dentition

4.30 Publication bias

The funnel plot for the primary dentition shows a symmetrical profile at the bottom of both *dmft* and prevalence studies in primary dentition funnel plots (Figures 7 and 8). Egger's regression statistical test (Table 4) was used for confirmation. An insignificant result (Egger's test P =



0.179 – 0.358) indicated no publication bias.

Figure 7: Bias in Mean decayed, missing and filled teeth (dmft) according to precision of the mean dmft in primary dentition studies

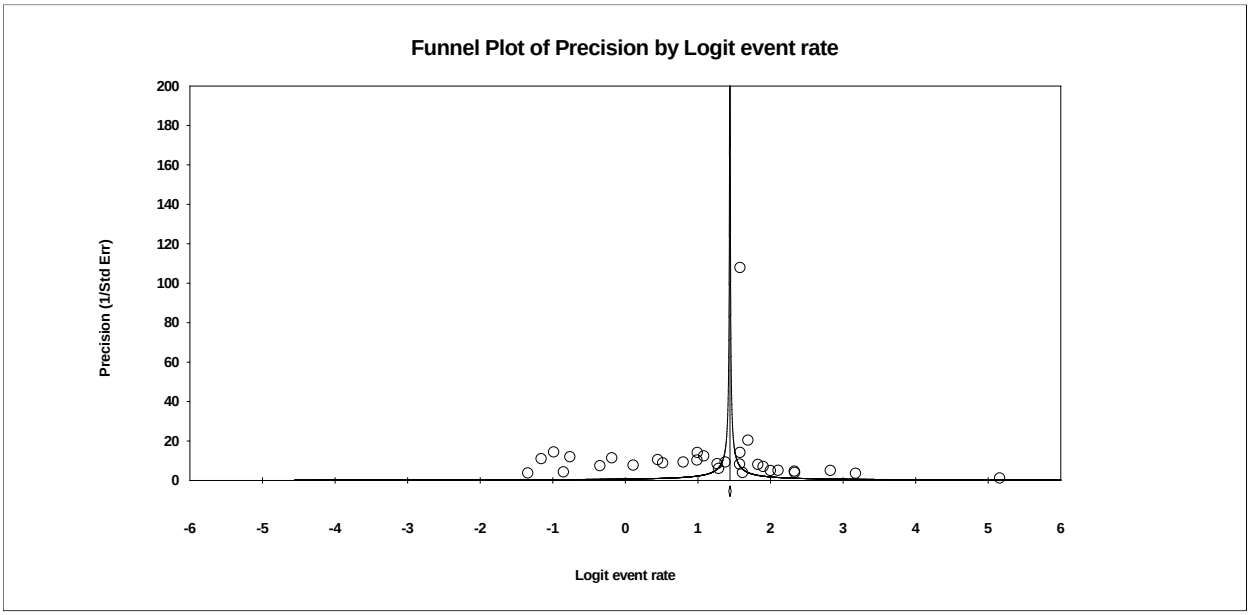


Figure 8: Bias in the prevalence of primary dentition studies

Table 4: Confirmation of publication bias in primary and permanent dentition studies using Egger's regression statistical test

Egger's regression intercept	Dmft	DMFT
Intercept	-0.56044	25.55587
Standard Error	0.59758	7.48523
95% lower limit (2-tailed)	-1.79664	9.60149
95% upper limit (2-tailed)	0.67576	41.51025
t-value	0.93784	3.41417
Df	23.00000	15.00000
P-value (1- tailed)	0.17904	0.00192
P-value (2- tailed)	0.35807	0.00384

The funnel plots for permanent dentition exhibited clear asymmetry among both DMFT and prevalence studies (Figure 9 and 10). There was an asymmetrical profile, especially at the

bottom of the plot, indicating the presence of publication bias. Egger's regression statistical test (Table 4) was used for confirmation of publication bias. A significant result (Egger's test P = 0.001 – 0.003) indicated the presence of publication bias.

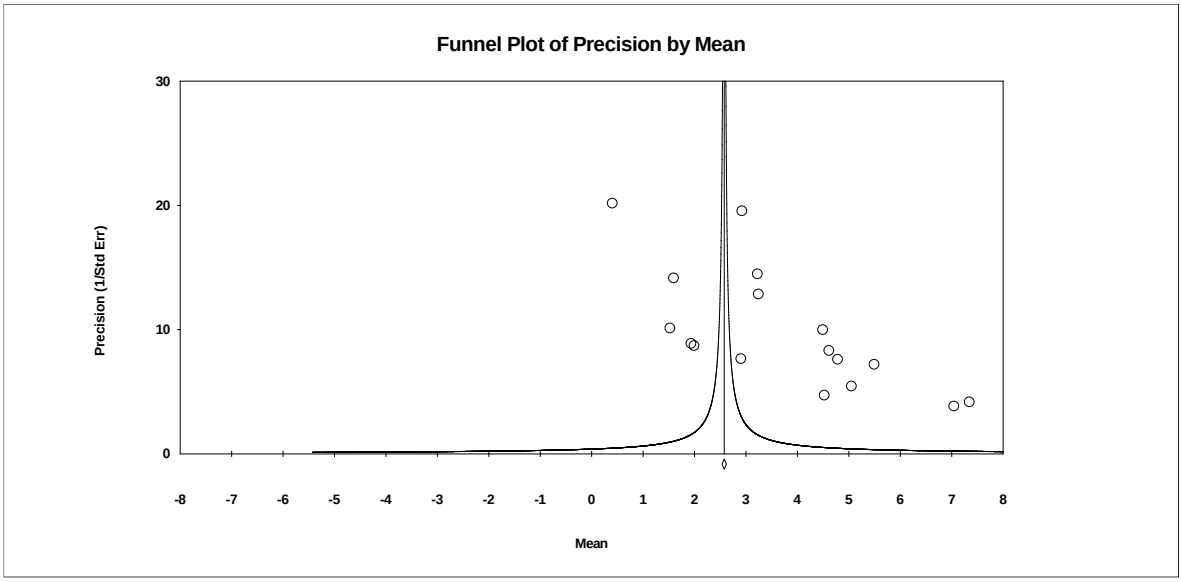


Figure 9: Mean decayed, missing and filled teeth (DMFT) according to precision of the mean DMFT in permanent dentition studies.

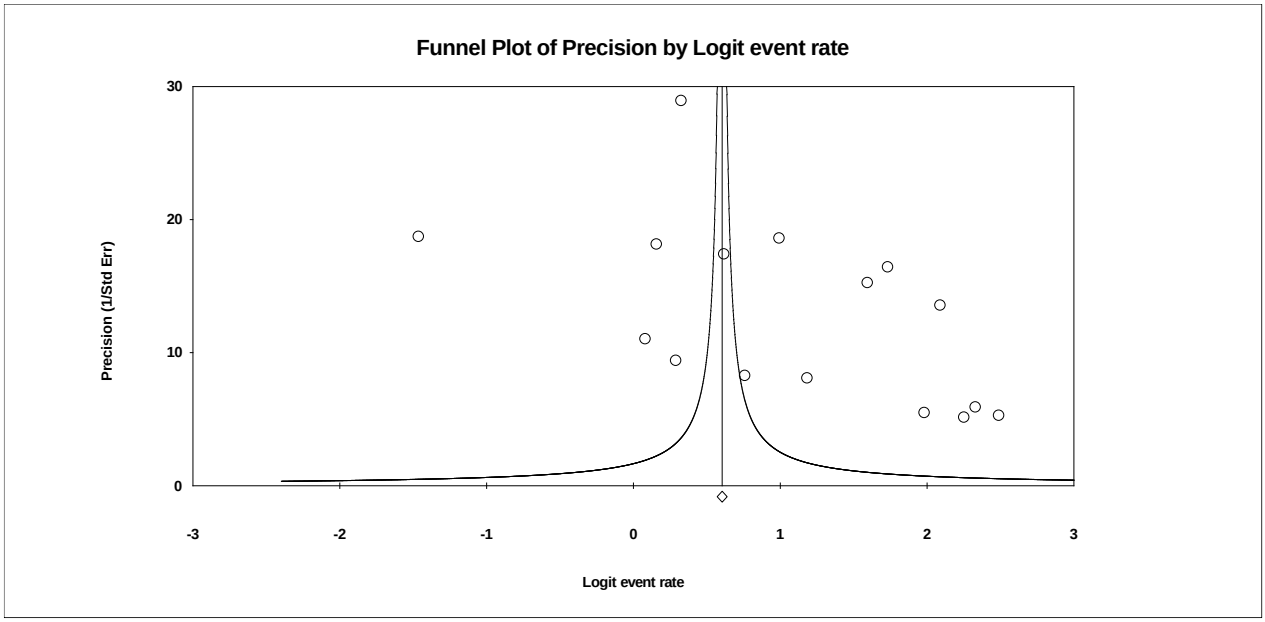


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Figure 10: Bias in the prevalence of permanent dentition studies

5.00 DISCUSSION

5.10 The importance and rationale of the study

The oral health of children is now the subject of worldwide concern with dental caries being the commonest chronic disease among children[143]. It afflicts, for example, five to eight times as many children than asthma does [144]. The global prevalence of ECC varies considerably, with the extremes being reported to be between 3% and 94%. Developing countries exhibit above average prevalence, with the UAE comprising a prime example of this trend since ECC is easily the commonest disease of childhood with a reported prevalence of as high as 93.8% in 5-year-old children[11]. Not only is ECC an irreversible condition, but treating it very expensive, both financially and in terms of occupying the time of precious medical resources. The majority of cases require a full dental rehabilitation by a pediatric dentist and involve general anesthesia. This often results, unfortunately, even in the developed world, in the carious teeth being extracted. The alternative strategy is prevention, something achievable by making new and prospective parents aware of the causes and consequences of the disease and by the careful identification of children likely to be at a high risk of ECC[145]. Complementary strategies have focused on the individual mother and child; the aim here being the prevention of the transfer of cariogenic bacteria from the mother to the child by the use of preventive agents such as fluoride in conjunction with education about good oral hygiene practices[146]. There have also been research into applying community-based approaches. Kowash *et al.*[147] have reported a successful attempt to employ this approach involving the use of trained, but non-professional staff to conduct a program of systematic home visiting to provide dental health education in an area of Leeds, in the UK, which had a combination of low socioeconomic status and high-caries incidence. The results of this study showed a significantly reduction in the prevalence of ECC after a period of three years.

A number of studies have been conducted to determine the prevalence and or severity of caries in GCC area children, however there has, to date, been no comprehensive review of such published literature.

Therefore, the main aim of this systematic review and meta-analysis was to evaluate the prevalence and severity of dental caries in the GCC countries with the aim of assisting the development of systematic cost-effective approaches for prevention of dental caries in children. The carrying out of meta-analyses enhances the power of the analysis and the use of research-based information to reach conclusions and proper decisions which are appropriate for clinical practice[120]. With regards to dental health, meta-analysis assists the dental practitioners to make correct judgments that assist in improving dental practice[115]. Meta-analysis produces much more robust statistics when compared to other forms of statistics and research. Meta-analysis is also beneficial in the sense that it provides the ability to confirm the data analysis used for the research[29].

5.20 Results of the systematic review

The 57 studies selected from an initial sample of 193 research papers published and unpublished during the period from 1992 to 2016 met the inclusion criteria and were included in the systematic review, 34 studied dental caries in primary teeth and 23 in permanent teeth. Khan[148] in a meta-analysis study in 23 countries of Arab league during the period from 1999 to 2012 reported that 35 research papers met the inclusion criteria and were included in their study.

In the current study, the majority of studies were from the KSA. The number of KSA studies in primary and permanent dentitions was 19 and 13 respectively. Regarding primary dentition, the mean *dmft* range (0.91-8.6) and prevalence range was (20.8 – 96%). Dental caries was higher in

low socioeconomic groups. While, for the permanent dentition, the mean DMFT range was (0.41-7.35) and the prevalence (57.2-92.3%). The most reported cause was exposure to a cariogenic diet. The UAE came second in terms of the number of published studies, with eight studies in preschool children with mean *dmft* range (3.07 – 10.9) and prevalence range of (41.5 – 99.4%). Concerning the permanent dentition, there were only three UAE studies with DMFT range (1.6 – 3.27) and prevalence (54 – 65%). The education of the parents and improving the dietary habits, good oral hygiene practices like brushing twice daily were the reported reasons for the decreased prevalence of caries over the last few years in the UAE.

The number of included studies regarding primary dentition in Oman and Qatar was a solitary study. While regarding the permanent dentition, two studies met the inclusion criteria. In primary the dentition of Omani children, the mean *dmft* was 4.61 and the prevalence was 84.5%. In the permanent teeth the mean DMFT range was 1.53 – 3.23 and the prevalence was 58.1%. The main causes of dental caries reported were poor oral hygiene, plaque and calculus accumulation. In the primary dentition of children in the state of Qatar, the mean *dmft* was 7.6 and prevalence was 89.2%. While in the permanent the mean DMFT and the prevalence range were 4.5 and 73 – 85%, respectively. One of the most common reported risk factor of caries in Qatar was the socio-demographic factor.

The above results clearly show high caries levels, both in terms of prevalence and severity regarding *dmft*/DMFT sores. There was a wide range both in prevalence and severity in different studies. This is in line with the conclusions of Richardson *et al*. (1981) that the prevalence of caries in children varies greatly in different studies, which may be due to several factors such as: 1) the children studied; their age and the accessibility for examination; 2) socio-economic status; 3) ethnic and cultural factors and 4) criteria used for diagnosis. Moreover, the prevalence of ECC

in one country is usually not directly comparable with another, thus the results from one ethnic group cannot be extrapolated beyond that group, even within the same country[149].

Most of the studies included in the systematic review used the WHO (1997)[150]method of caries diagnosis which is also widely used in international epidemiological studies. It is efficient in detecting dental cavities, but not the non-cavitated lesions, and this would probably result in an underestimate of caries prevalence. Certainly, the inclusion of non-cavitated lesions would provide a better estimate of the disease prevalence and severity, which means a better understanding of treatment needs. The WHO criteria of caries diagnosis however, are still a recognized and valid method in dental caries epidemiological studies and their use allows comparison between studies. Also, clinical diagnosis of pre-cavitated lesion in epidemiological screenings would be challenging, especially in preschool children, and using radiographs to detect non-cavitated lesions for screening purposes would neither be ethical nor practical[150].

5.21 Caries risk factors

The precise etiology underlying dental caries is still uncertain. Nevertheless, there is a substantial body of scientific evidence to support the idea that the occurrence of dental caries requires the presence of four main factors, together with some other minor or predisposing factors. In this multifactorial etiology[151] the four most important factors are: a susceptible host (teeth and saliva), a substrate (fermentable carbohydrate), micro-organisms (mainly *streptococci* and *lactobacilli*) and, the passage of time. The possible predisposing factors include: feeding habits, oral hygiene practices, general health and nutritional status. Other factors, contributing to a lesser extent, may include socio-economic factors (parental education and occupation, family income, number of siblings, parental attitude and knowledge of dental health); while

demographic factors such as race, age, gender and aspects, may also be involved. The presence of such factors frequently comprise the indicators used to identify caries risk in children.

Despite the parents having a relatively high social economic living status and a high level of professional education, their children may still suffer a high prevalence of dental caries. There can be several reasons for this including mothers and fathers being in full time employment and the children being cared for by in home-nannies. They, the nannies, may be less aware of the dimensions of the caries problem, and thus neglect proper care of the child's teeth and also provide them with sweets. The other problems involve parents and nannies having inadequate levels of awareness concerning the importance of primary tooth care**.**

The main contributing factors to dental caries reported in the systematic review were poor oral hygiene and high sugar diets. Different studies have reported this association when investigating the relationship between frequency of tooth-brushing and dental caries, with a positive relationship being reported in several studies [(73, 147, 152-154)]. Recently Mejare *et al*. (2014) reported that the level of oral hygiene is significantly associated with caries in univariate analysis, however the degree of predictive accuracy has been proven to be poor in most of the studies[(155)]. Optimal exposure to fluoride is important to all dentate infants and children [(156)]. Although in the GCC countries the drinking water is not optimally fluoridated, in the UAE, for example, parents lacked adequate knowledge concerning fluoride and its role in the prevention of dental decay and were reluctant to give fluoride supplements to their children [(73)]. Decisions concerning the administration of fluoride need to be based on the unique needs of each patient, and the use of fluoride for the prevention and control of caries is documented to be both safe and effective especially in at-risk populations[(157)].

The link between the quantity and frequency of sugar intake at a population level is well established [(158)] but the predictive accuracy is limited as is the quality of evidence regarding

individual patients. Similarly, Sundin *et al.* (1983) reported that there was no consistent correlation between the frequency of sugar consumption and dental caries[159]. Recently, Turton *et al.* (2016) reported that despite the snacking on sweet foods and drinks being found to be associated with ECC, it did not feature in the predictive model[154].

5.30 Results of the meta-analysis

The total number of sample sizes of those studies in primary teeth caries prevalence (Figure 4) was 98,497 and for permanent teeth prevalence (figure 6) 18,699. While, sample size for the mean *dmft* was 15,421 however for mean DMFT it was 23,152. A large proportion of studies were carried out in the KSA (32 out of 57).

5.31 *dmft* and primary teeth caries prevalence

The prevalence and severity of caries (*dmft*) in primary teeth from a random effect model (Figures 2 and 3) were found to be high (80.9 %) with (95% CI 80.6-81.1%) and *dmft* of 5.14 with (95% CI 5.02-5.2). A Khan *et al*. study (2013) reported almost identical mean *dmft* [5.38 with (95% CI: 4.314 - 6.436)] in a study in the KSA regarding review papers published during the period from 1999–2008 but the mean *dmft* in the current study was higher than the Arab League meta-analysis study[148], which was 4.341 (95% CI 3.714 - 4.969). Al Agili *et al* (2013), in a KSA systematic review, reported a similar high prevalence (80%) and a similar mean *dmft* (5.0)[1]. Al-Ansari (2014) in a 30 year literature review (1982-2012) in the KSA reported a higher prevalence (95%) in 3-7 year-old children and a higher mean *dmft* of 7.34[160].

Developed countries normally have a lower caries prevalence and a decline in caries levels in older children as a result of previous research studies and preventive programs focusing on caries

prevention. However, ECC is still a continuing oral health problem, even in countries with a very effective oral health system such as the Scandinavian countries[161]. The results of the Child Dental Health Survey 2013 in England, Wales and Northern Ireland showed that the prevalence of caries in 5-year-old children was 31%[162]. In the USA a 2011-2012 National Health and Nutrition Examination Survey showed a lower prevalence than the current study (23% vs 80.9%) in preschool children [42]. In a recent Australian state study conducted in 2015 in 2,214 children aged 5 to 8 years, the prevalence of dental caries in primary teeth was also lower than the current study (47.1%)[43].

5.32 DMFT and permanent teeth caries prevalence

Although less than the primary dentition, both the prevalence and severity of caries in permanent teeth from a random effect model (Figures 4 and 5) were also high (64.7 %) with (95% CI 63.9-65.4%) and a mean DMFT of 2.577 with (95% CI 2.53-2.62). A Khan *et al* study (2013) reported a slightly higher mean DMFT of 3.34 (95% CI: 1.97-4.75) in a KSA review of papers published during the period from 1999–2008. A higher prevalence and mean DMFT were also reported in KSA children by Al-Ansari (2014) in his 30 year literature review study. The prevalence was 91% and the mean DMFT was 7.35 in 12 to 19 year-olds. Al Agili *et al* (2013), in a systematic review, reported a slightly higher prevalence and a mean DMFT (70% and 3.5, respectively)[1]. However, the mean DMFT of the current study was comparable with that reported by Khan's (2014)[148] Arab League meta-analysis study (2.469 with 95% CI 2.019-2.919).

When comparing the results of the present study and the aforementioned studies on prevalence of permanent dentitions caries in GCC countries and those from developed countries, it is clearly evident that the GCC population exhibits a higher prevalence. For example, the Child Dental

Health Survey 2013 in England, Wales and Northern Ireland reported lower prevalence in 12-year-olds (34%) and in 15 year-olds (40%)[162]. In the USA National Health and Nutrition Examination Survey (2011-2012) the prevalence of dental caries in the permanent teeth of children aged 6–11 years old was 21% while in the current meta-analysis it was 64.7% [42]. In 2015, an Australian state study of dental caries of 3,186 children (9- to 14-year-olds) from 207 schools was carried out. The reported prevalence of dental caries for the permanent dentitions (38.8%), which was also lower than our study [43].

The present study on the prevalence and severity of dental caries over the past 24 years in the GCC countries has shown that the prevalence and severity of caries, both in primary and permanent dentitions, were high and alarming. In 1981, WHO and the World Dental Federation (FDI) jointly formulated goals for oral health to be achieved by the year 2000 as follows: 50% of children aged 5-6 years to be caries free; global average of DMFT not to be >3 for 12-year-old children and 85% of the population should retain all their teeth at the age of 18 years[163]. In addition, according to WHO's basic global indicator of oral health 2000, DMFT >6.6 for the children aged 12 years is considered very high, between 4.5-6.5 is high and 2.7-4.4 is moderate[164]. It is clear from the results of this study that GCC countries fell short of these goals and recommendations and that caries in primary dentitions is very high, and in permanent dentition, moderate. This continuing problem is disturbing not only because of its high burden of caries management costs on the economy of GCC countries but also its negative effects on children's growth, development and quality of life.

5.33 Consideration of heterogeneity

Heterogeneity can be determined by visual inspection of the forest plot. If confidence intervals for the results of individual studies (generally depicted graphically using horizontal lines) have

poor overlap, this generally indicates the presence of statistical heterogeneity. Higgins (2003) [165] argued that, since clinical and methodological diversity always occur in a meta-analysis, statistical heterogeneity is inevitable.

In this study additional statistical tests (Q and I) were used to verify the presence of visual heterogeneity. In the primary dentition studies a Q statistic (chi-square test) of 2,538.501 (df = 21) provided a significant P-value (<0.001) and I^2 value of 99.17% confirmed the presence of heterogeneity between studies. In the permanent dentition also, visual inspection of the forest plot and chi-square (P < 0.001) gave adequate evidence of heterogeneity in the data set and the index of heterogeneity was also very high Q-value of 4,806.020 (df = 16) and I^2 value of 99.67%. Khan (2014) has reported the presence of heterogeneity both in primary and permanent dentition studies, visually and statistically, by obtaining a significant Q test value with p <0.001 and I^2 value of > 90%. Khan *et al*. (2013) also reported the presence of heterogeneity between studies as indicated by a significant Q test value with p =0.00 and I^2 value of > 75%.

5.34 Consideration of publication bias

As a result of sampling variations between studies, published effects may be larger than true effects. If studies are distributed symmetrically on both sides of the funnel plot, it indicates absence of publication bias which can also be verified using statistical tests. In the current study, the funnel plot for the primary dentition showed a symmetrical shape at the bottom of both *dmft* and prevalence studies in primary dentition (Figures 7 and 8). This was confirmed by Egger's regression statistical test (Table 4). An insignificant result (Egger's test P = 0.179 – 0.358) indicated no publication bias. Khan *et al.* (2013) [166]and Khan [148](2014) reported the absence of publication bias in primary dentition studies visually and statistically (Egger's test P = 0.3 and P =0.2, respectively).

However, in permanent dentition there was a publication bias seen visually by the asymmetrical distribution of studies (Figures 9 and 10) and also statistically (Egger's test P = 0.001 – 0.003). This is happen because of there was noticed that there is variation in the ages among the found studies caused the publication bias. Similar results were reported by Khan (2014) in his Arab League meta-analysis study (Egger's test P = 0.0.0016). Khan *et al* (2013) in a KSA study also reported the possibility of publication bias among permanent dentition studies (Egger's test P = 0.018)[166].

5.40 Limitations of the study

Although this systematic review and meta-analysis study provided valuable information about the prevalence and severity of dental caries in children of GCC countries, it is clear that majority of the studies were carried out in KSA and the UAE with few studies in Kuwait, Oman, Qatar and no published studies in Bahrain. Furthermore, even in the KSA, most of the studies were conducted in major cities like Riyadh and Jeddah. Therefore, the current meta-analysis may not be representative of the overall populations in the GCC countries or even within individual countries. However, it could be argued that the participants are all GCC nationals who have similar socioeconomic and cultural backgrounds.

Another possible weakness, which is common in most dental caries studies, was the use of different methodologies including: sample size, methods of diagnosis and recording, randomization and type of study. Other inevitable limitations in most meta-analysis studies are heterogeneity and publication bias, the latter was only evident in permanent dentition studies in this meta-analysis study.

6.00 CONCLUSIONS AND RECOMMENDATIONS

The prevalence and severity of dental caries in terms of mean *dmft*/DMFT are high in children of the GCC countries, especially in the primary dentition. The main reported contributing factors were poor oral hygiene and the consumption of a high-sugar diet. There is important and urgent need to conduct high quality research studies in all GCC countries, including small cities and rural areas in each country, to accurately evaluate the levels and the extent of the dental caries burden. This significantly assist oral health policy makers in GCC countries to plan cost-effective preventive strategies, especially community-based preventive programs. There should be more emphasis on prevention of ECC, because by preventing caries in the very young population will result in lasting beneficial effects on oral health throughout the whole population life. This can be achieved by education of pregnant mothers and parents with young children through close cooperation between the dental and medical professions, especially antenatal clinic staff and pediatricians. This study did not provide a comprehensive picture of caries prevalence and severity in GCC because, in many of these countries only a few studies had been performed. Therefore, additional studies are needed to better evaluate the prevalence and severity of caries in children and adolescence in GCC countries.

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8.00 APPENDICES

Appendix I: Ethical approval letter from (HBMCDM) Research Ethics Committee

Hamdan Bin Mohammed
College of Dental Medicine

Athanasios E. Athanasiou, D.D.S., M.S.D., Dr. Dent.
Acting Dean
Professor & Program Director in Orthodontics
Hamdan Bin Mohammed College of Dental Medicine

Ref: HBMCDM/EC/2024
Date: October 8, 2015

Dr. Wafa AlAyyan Hassooni
Resident, Pediatrics Dentistry Department
Hamdan Bin Mohammed College of Dental Medicine
PO Box 505097
Dubai Healthcare City
Dubai

Title of project: A systematic review of population-based dental caries studies among children in Gulf States
Reference: EC0915-002

Dear Dr. Wafa,

Thank you for submission of your proposal for approval to the Ethics Committee.

The proposal was reviewed by the Ethical Committee and came to a decision that the study comes under systematic review category and does not require an approval by the Ethics Committee.

The Committee, however, recommends revising the title page of the proposal to include the appropriate title of the Supervisors.

Yours sincerely,

Professor Athanasios E. Athanasiou
Chairman, Research & Ethics Committee

Appendix II: PRISMA 2009 checklist

PRISMA 2009 Checklist

Section/topic	#	Checklist item	Reported on page #
TITLE			
Title	1	Identify the report as a systematic review, meta-analysis, or both.	
ABSTRACT			
Structured summary	2	Provide a structured summary including, as applicable: background; objectives; data sources; study eligibility criteria, participants, and interventions; study appraisal and synthesis methods; results; limitations; conclusions and implications of key findings; systematic review registration number.	
INTRODUCTION			
Rationale	3	Describe the rationale for the review in the context of what is already known.	
Objectives	4	Provide an explicit statement of questions being addressed with reference to participants, interventions, comparisons, outcomes, and study design (PICOS).	
METHODS			
Protocol and registration	5	Indicate if a review protocol exists, if and where it can be accessed (e.g., Web address), and, if available, provide registration information including registration number.	
Eligibility criteria	6	Specify study characteristics (e.g., PICOS, length of follow-up) and report characteristics (e.g., years considered, language, publication status) used as criteria for eligibility, giving rationale.	
Information sources	7	Describe all information sources (e.g., databases with dates of coverage, contact with study authors to identify additional studies) in the search and date last searched.	
Search	8	Present full electronic search strategy for at least one database, including any limits used, such that it could be repeated.	
Study selection	9	State the process for selecting studies (i.e., screening, eligibility, included in systematic review, and, if applicable, included in the meta-analysis).	
Data collection process	10	Describe method of data extraction from reports (e.g., piloted forms, independently, in duplicate) and any processes for obtaining and confirming data from investigators.	
Data items	11	List and define all variables for which data were sought (e.g., PICOS, funding sources) and any assumptions and simplifications made.	
Risk of bias in individual studies	12	Describe methods used for assessing risk of bias of individual studies (including specification of whether this was done at the study or outcome level), and how this information is to be used in any data synthesis.	
Summary measures	13	State the principal summary measures (e.g., risk ratio, difference in means).	
Synthesis of results	14	Describe the methods of handling data and combining results of studies, if done, including measures of consistency (e.g., I^2) for each meta-analysis.	

PRISMA 2009 Checklist

Section/topic	#	Checklist item	Reported on page #
Risk of bias across studies	15	Specify any assessment of risk of bias that may affect the cumulative evidence (e.g., publication bias, selective reporting within studies).	
Additional analyses	16	Describe methods of additional analyses (e.g., sensitivity or subgroup analyses, meta-regression), if done, indicating which were pre-specified.	
RESULTS			
Study selection	17	Give numbers of studies screened, assessed for eligibility, and included in the review, with reasons for exclusions at each stage, ideally with a flow diagram.	
Study characteristics	18	For each study, present characteristics for which data were extracted (e.g., study size, PICOS, follow-up period) and provide the citations.	
Risk of bias within studies	19	Present data on risk of bias of each study and, if available, any outcome level assessment (see item 12).	
Results of individual studies	20	For all outcomes considered (benefits or harms), present, for each study: (a) simple summary data for each intervention group (b) effect estimates and confidence intervals, ideally with a forest plot.	
Synthesis of results	21	Present results of each meta-analysis done, including confidence intervals and measures of consistency.	
Risk of bias across studies	22	Present results of any assessment of risk of bias across studies (see Item 15).	
Additional analysis	23	Give results of additional analyses, if done (e.g., sensitivity or subgroup analyses, meta-regression [see Item 16]).	
DISCUSSION			
Summary of evidence	24	Summarize the main findings including the strength of evidence for each main outcome; consider their relevance to key groups (e.g., healthcare providers, users, and policy makers).	
Limitations	25	Discuss limitations at study and outcome level (e.g., risk of bias), and at review-level (e.g., incomplete retrieval of identified research, reporting bias).	
Conclusions	26	Provide a general interpretation of the results in the context of other evidence, and implications for future research.	
FUNDING			
Funding	27	Describe sources of funding for the systematic review and other support (e.g., supply of data); role of funders for the systematic review.	

From: Moher D, Liberati A, Tetzlaff J, Altman DG, The PRISMA Group (2009). Preferred Reporting Items for Systematic Reviews and Meta-Analyses: The PRISMA Statement. PLoS Med 6(7): e1000097. doi:10.1371/journal.pmed1000097

For more information, visit: www.prisma-statement.org.