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REVIEW

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Diagnostic accuracy, available treatment, and diagnostic methods of dental caries in practice: a meta-analysis

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Abstract

Background: Diagnosis of dental caries and identification of patients with dental caries is the biggest challenge in dentistry. For this diagnostic accuracy, several methods are studied. The present study attempts to re-study the published data in the last 50 years, between 1960 and 2020.

Main body: Based on designed keywords, we made a thorough search of 4 different databases and found 3887 articles after removing the duplicate. The included database was PubMed, Ovid, Web of Science, and Cochrane library. On keen screening of the articles, we included 19 articles in the review. All the articles were analyzed based on the Cochrane risk assessment method. Maximum studies of up to 80% of caries management are based on children from 1 to 10 years of age. About 47% of articles were found based on reported use of drugs against dental caries, whereas 52.6% of articles were based on the behavioral and socio-demographic study of the mother and caretakers. We found that attentive parents and caretakers of the children can help in reducing the prevention of caries. Frese et al. (Sci Rep. 8(1):16991, 2018. https://doi.org/10.1038/s41598-018-34777-x), Liu et al. (PLoS ONE 8(11):e78723, 2013. https://doi.org/10.1371/journal.pone.0078723), and Innes et al. J Dent Res 99(1):36–43, 2020. https://doi.org/10.1177/0022034519888882) were the studied articles with high quality and low bias risk. These methods were based on the use of stannous fluoride for dental caries, the study of the effect of smoking on older adults, by checking the anxiety level of the participants.

Short conclusions: Tooth decay is a common condition in the general population and affects mostly children. The method with high accuracy and low risk can be recommended for routine treatment.

Keywords: Dental decay, Dental health service, Oral medicine

1 Background

In the present scenario, dental caries have emerged as a significant health issue [1]. They appear due to bioacid formation in the oral cavity, which is responsible for the chemical dissolution of the enamel [2–4]. It is considered as demolition of the cementum, enamel, and dentin [2]. Identifying patients with higher and lower caries risk is essential for better, cost-effective, and specified reliable treatment. The patients having exposure to low caries risk must receive lesser dental examinations followed by reduced interventions.

In contrast, the patients exposed to the higher caries risk require higher interventions and examinations with intense awareness for their oral health. Routine dental examinations are required for such overexposed patients, along with the visual examination of the previous caries risk [3]. Generally, for assessing risk bias in dental health, recurrence of the previous caries is adequate. Also, radiography is being preferred to increase the accuracy and

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efficacy of the treatment. Microbiological examinations are also preferred to investigate the presence of lactobacilli and mutants of streptococci. Few other parameters such as buffer capacity, oral hygiene, salivary flow, and carbohydrate intake frequency, including socio-demographic aspects, also play a vital role in the appearance of dental caries [3]. For modern dental examinations against caries, a cardiogram has also emerged as a valuable treatment in practice. The heterogeneous results of caries risk management indicate variations with misinterpreting risk of clinical values for caries management [3]. A caries risk assessment system helps in identifying the fact that information collected on a large number of facts is comparatively lesser from the aspects of reported cases [4]. Several systematic reviews are conducted to summarize the assessment in health research. To study the complexity of available diagnostic tools, different review methods are developed. QUADAS and QUADAS-2 are widely used methods [5] that work on all the facts associated with caries [6]. To overcome other drawbacks of systematic review, PRISMA and AMSTAR are used [7, 8]. The present meta-analysis endeavors to analyze the methods studied for diagnostic accuracy of dental caries reported in the last 50 years, under different study designs exploring all the reported parameters. It provides cumulative details of caries risk management.

PICO Question: What are the necessary treatment and interventions against dental caries? Including the disease exposure, altered treatment, etiology, patient–parent perspectives, and the risk factors.

2 Main text

In the present review, we conducted the study according to the CRD's guideline and PRISMA guidelines [8, 9].

2.1 Literature mining

To achieve this, a literature search was conducted in four (4) different databases such as PubMed, Web of science, OVID, and Cochrane library. It was conducted from March 19 to March 28, 2021. The search was conducted to answer the POIC question raised from keywords such as dental caries + specificity + selectivity + diagnostic methods + microbiodata. The articles downloaded after the searches were those that covered the topic between the period of January 1960 and December 2020 (Table 1).

2.2 Inclusion criteria

In the present review, the randomized clinical trials, cohort studies, clinical trials, and cross-sectional studies were included. During our search, we focused on the risk assessment, treatment, and education-based articles on dental caries, including the management of risk factors (Table 2).

2.3 Exclusion criteria

In this study, it was excluded the articles that dealt with a review of the literature on dental caries and the articles published before the year 1960. It was also excluded the articles that dealt with some factors responsible for dental caries such as smoking, illiteracy of parents, and alcohol consumption (Table 2).

Table 1 Literature mining

Database	PubMed, Web of Science, OVID, Cochrane library
Keywords	PubMed: Dental caries + specificity + selectivity + diagnostic methods + microbiodata OVID: Specificity + diagnostic tools + selectivity + caries + microbiodata Web of Science: Selectivity + microbiodata + dental caries + specificity Cochrane library: Selectivity + microbiodata + dental caries + specificity + diagnostic accuracy
Criteria selected	Articles published in English languages, Published from 1960 to 2020

Table 2 Inclusion and exclusion criteria

Inclusion criteria	Exclusion criteria
Randomized Clinical Trials, Cohort studies and cross-sectional study	Review articles and comments
Prevalence of dental caries relationship-based, risk assessment, awareness-based, and treatment-based	Studies other to the included criteria
Risk factor of reappearance of dental caries	Other factors responsible such as smoking, alcohol intake, parent illiteracy etc.
All the research papers published in last 50 years on dental caries and risk management	Research paper based on studies before 1960

Based on the selected search criteria, a total of 6387 articles were identified from the designed keywords. A total of 3387 articles were filtered after eliminating duplicates. Based on the defined exclusion criteria and the double filtering of articles, 19 articles were finally included in this review (Fig. 1). The included articles and their findings are listed in Table 3, and the risk assessment is presented in Table 4.

2.4 Publication reclamation

The authors thoroughly studied all the abstracts and articles. The articles discussing the present issue were thoroughly analyzed under CRD's guidelines [9]. We followed the search based on PRISMA guidelines (Fig. 1); the Cochrane risk assessment method was used for risk of bias assessment. In the present study, Cochrane, the risk assessment tool, was used based on seven questions. The questions are presented in Table 3, and they are based on selection bias, allocation bias, detection bias, attrition bias, reporting bias, performance bias, and other biases. The articles were analyzed based on their quality and were marked positive, negative, and unclear (Table 3).

3 Conclusions

The present meta-analysis attempts to summarize all the articles published in the last 50 years on the treatment and management of dental caries. Among extracted 6387 articles, only 19 articles were included in the study based on different yields and treatments available for existing dental caries in practice. All the articles are summarized as follows.

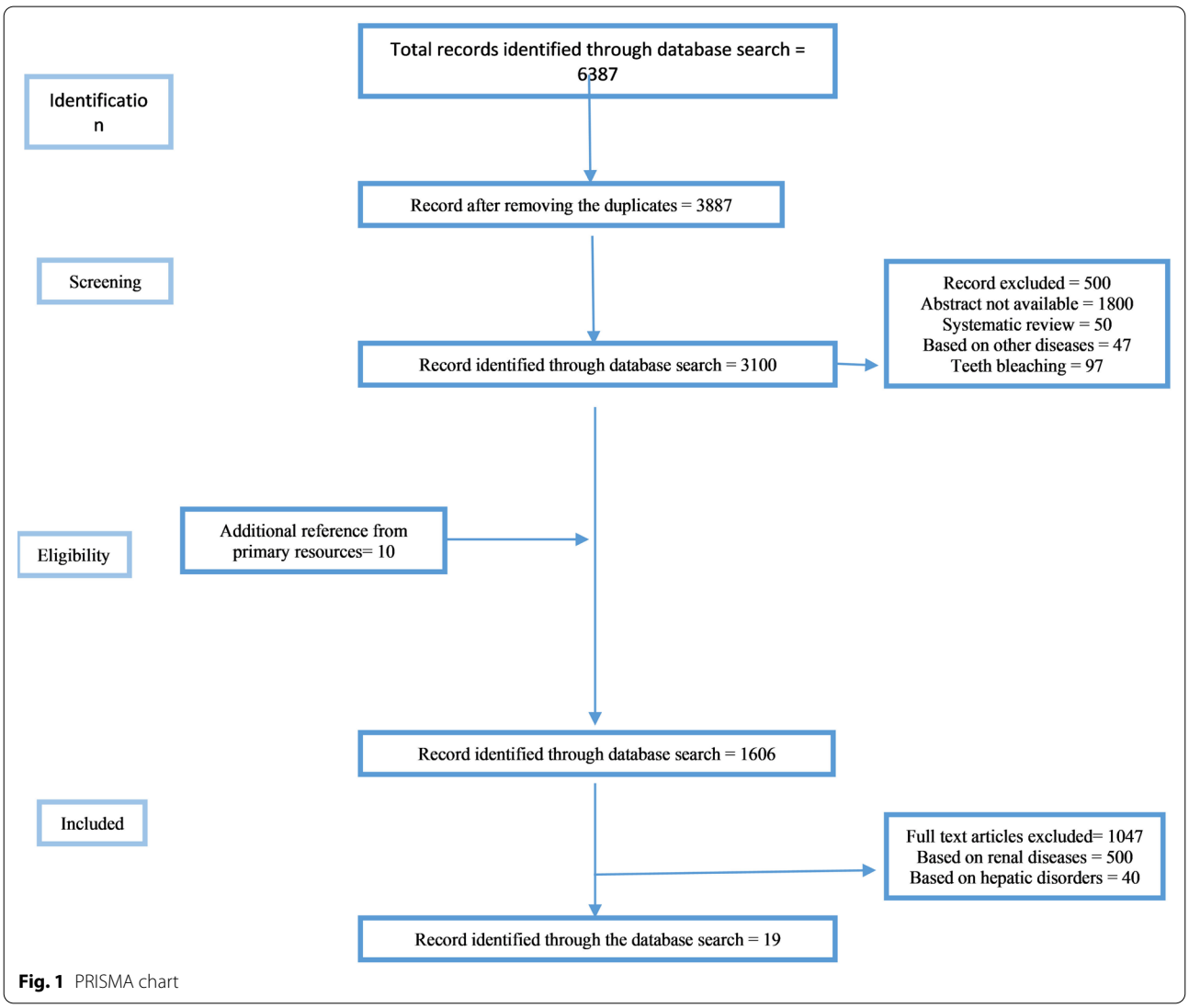

Fig. 1 PRISMA chart

Table 3 Cochrane risk assessment table defining the assessment questions

S. No	Questionnaire of quality scoring analysis
Q1	Random sequence generation (Selection bias)
Q2	Allocation concealment (selection bias)
Q3	Blinding of outcome assessment (detection bias) Self-reported outcome
Q4	Incomplete outcome data (attrition bias)
Q5	Selectivity reporting (reporting bias)
Q6	Blinding of participant and personnel (performance bias)
Q7	Other bias

Quality	Score	Risk bias	Interpretation
High	+	Low	Results are unlikely to be altered due to plausible bias
Low	?	Unclear	Bias rises doubt on the result
Medium	-	High bias risk	Bias weaken the confidence of the result

Table 4 Summary of methods and conclusions of the articles included in this meta-analysis

S.no	Author/year	Method	Age and number of participants	Techniques for dental caries	Conclusion
1	Innes et al. (2020)	Randomized controlled trial	1462 children of 3 to 7 years	Children oral health-related quality life and modified child dental anxiety scale was studied	They divided their study into 3 groups. The groups were prevention and biological management, prevention and conventional carious management, and central administration with variable length random permuted block. They concluded no evidence of any difference in pain sensation and sensitivity among all the three groups and also included in their results that all the three groups were equally prone to dental caries
2	Pine et al. (2020)	Randomized clinical trial	241 children of 5 to 7 years	DR-BNI	Out of the total studied children, 119 received DR-BNI led from trained nurses and another group had parent nurse conversation about the oral health of children. They concluded 29% lowered risk of appearance of dental caries in the DR-BN1 group. They further advocated changing preventive dental practice in children
3	Santos et al. (2019)	Randomized controlled trial	1589 children of 8–10 years of age	dental pain management	Conducted a randomized clinical trial in which the dental pain was reported by the students themselves. They also examined the possibilities and presence of caries in these children and concluded that this dental pain can be due to clinical, socio-demographic, and psychosocial indicators
4	Jamieson et al. (2019)	Randomized controlled trial	448 mother and care givers		Conducted their study on 448 caregivers or mothers and found that the children who are cared for till their 5 years of age and those who are not living in metropolitans are less prone for caries
5	Tickle et al. (2019)	Randomized controlled trial	1147 participants of all age groups	Used 5000 ppm fluoride toothpaste	Conducted randomized clinical trial on adults and fluoride-containing toothpaste of 5000 ppm concentration to be effective to avoid dental caries in adult individuals
6	da Silva et al. (2019)	Randomized clinical trial	the sample size is not clear, children between 4 and 8 years of age were selected	HVGIC	Conducted a randomized clinical trial to study the existing appropriate treatment for deep caries in primary teeth. They reported the use of HVGIC for dental caries without the use of rubber dam and anesthesia
7	Fernando et al. (2019)	Randomized controlled trial	not clear	CPP-ACP, and SnF2	Conducted a randomized controlled trial and found CPP-ACP and SnF2 combination effective against dental caries and erosion

Table 4 (continued)

S.no	Author/year	Method	Age and number of participants	Techniques for dental caries	Conclusion
8	Stafuzza et al. (2019)	Randomized clinical trial	36 molar teeth of children of age 5–8	dental barrier thickness and radiographic study	Conducted clinical trial on 36 patients with follow-up for one year and found that on the removal of early caries chances of infection of other teeth are reduced
9	Milgrom et al. (2018)	Randomized controlled trial	38 children	Silver diamine fluoride 38%	Conducted their study on preschool children divided into 2 groups. Children of both groups were having dental lesions. They collected dental plaques of all the children pre-treatment and after application of silver diamine fluoride 38% for 3 days. They evaluated that risk of caries was lower in the treatment group as compared to the placebo group. On RNA sequencing, they found less microbial presence in the treatment, and hence, they concluded 38% silver diamine caries to be a better treatment for dental caries
10	Frese et al. (2018)	Randomized controlled trial	54 athletes	stannous fluoride application	Conducted a randomized controlled clinical trial for 4 years on athletes, they included 54 patients in control and test groups. The test group was treated with specific stannous fluoride in a significant examination time and found it effective for the treatment of dental caries
11	Megalaa et al. (2018)	Randomized controlled trial	60 patients	Tulsi and black myrobalans as mouth cleaner	Conducted a randomized controlled trial on 60 patients with severe dental caries and asked them to rinse their mouth with a mixture of black myrobalans and tulsi and found this mixture effective in the treatment of dental caries
12	Arrow and Klobas, (2017)	Randomizedcontrolled trial	234 children	ECC management	Compared dental anxiety of children in two groups the test group received ECC. They concluded that an increase in treatment helped decrease the anxiety in children regarding their dental caries
13	Jordan et al. (2016)	Cohort study			Conducted a clinical trial for 15 years and concluded that the patients having dental caries in infections are more prone to caries in their older ages
14	Mathur et al. (2016)	Randomized clinical trial	94 children of 7 to 10 years	CBCT, IPT, and HU	Conducted a randomized clinical trial they found HU, CBCT, and IPT equally effective for oral treatment
15	Heima et al. (2015)	Randomized controlled trial	423	dental examination through the international dental caries assessment system	Reported in their study that the behavior of caregivers plays an important role in reducing the chances of appearance of dental caries

Table 4 (continued)

S.no	Author/year	Method	Age and number of participants	Techniques for dental caries	Conclusion
16	Peterson et al. (2013)	Clinical trial	8	genetic investigation of plaque	Conducted a 16S rDNA profiling of two groups one with dental caries and without dental caries to study the microbiome of dental plaque. They reported significant heterogeneity to define the progression and onset of dental caries
17	Liu et al. (2013)	Randomized controlled trial	2376 individual among 50–60	DMFT	Conducted a study on 2376 elderly people, they found that the Chinese population is more prone to dental caries especially elderly people who are smokers and don't have any dental insurance
18	Alkarimi et al. (2012)	Randomized controlled trial	86 children of 75 to 92 months	random dental checkups	Conducted a study on 86 children divided into two equal groups. In their study, they concluded that treatment of severe dental caries in children can improve their appetite
19	Kopycka-Kedzierawski and Billings (2011)	Randomized controlled trial (cross-sectional study)	234 children of12 to 60 months	tactile oral examination and teledentistry examination	Conducted randomized controlled trial on 234 children among them 28% had dental caries and 61% never had dental caries. They reported that continued efforts and checkups can avoid the chances of the appearance of dental caries

3.1 Study characteristics

The different studies used for this meta-analysis formed groups with the study population to achieve the objectives. This is the case, for example, of the work of Innes et al. [13] who divided their study into three groups, whereas Pine et al. [14] conducted their study on caregivers with DR-BNI and parents here; in DR-BNI groups, the parents received guidance from the trained nurses. In 2019, Jamieson et al. [15] studied 448 mothers and caregivers of children up to 5 years (Table 3). Milgrom et al. [16] also divided their study into two groups with and without dental lesions. Similarly, Arrow and Klobas [17] divided their study into two groups with and without Early Childhood Caries (ECC). Rest studies were conducted on the total sample size.

3.2 Characteristics for interventions of dental caries

Among all the included studies, 56% were based on preventive treatments for dental caries. Treatment was used against dental caries and pain management by Tickle et al. [18], da Silva et al. [19], Fernando et al. [20]; Milgrom et al. [16]; Frese et al. [12], Megalaa et al. [21] and Mathur et al. [22] reported use of 5000 ppm fluoride treatment, HVGIC, CPP-ACP and SNF2, 38% silver diamine fluoride, stannous fluoride, tulsi and myrobalans, ECC and Hu, CBCT, and IPT, respectively. They found these drugs effective against caries treatment.

3.3 Risk assessment analysis

In the article published by Innes et al. [13], the sample size was not precise, and reporting bias was unclear with low research quality (Table 4); in the study published by Pine et al. [14], unclear reporting and performance bias were analyzed. No detection bias was seen in the study published by Santos et al. [23], but a high allocation risk was found. In the study reported by Jamieson et al. [15], unclear reporting and performance bias were analyzed with risk of selection, allocation, and detection bias. In the article published by Heima et al. [24], we analyzed the low risk of attrition bias and other bias, with unclear results on performance bias. Unclear detection bias was seen in the article with a high risk of selection bias [10]. Unclear detection bias was seen in the article, with a high risk of selection bias (Alkarimi et al. [25]). The article published by Kopycka-Kedzierawski and Billings [26] was analyzed with high performance and selection bias. High selection and detection bias was seen in the article published by Stafuzza et al. [27], Mathur et al. [22], da Silva et al. [19], Tickle et al. [18], Milgrom et al. [16], Fernando et al. [20], Megalaa et al. [21] and Frese et al. [12], and these articles were categorized by us with low bias risk of attrition bias with unclear reporting bias.

All the included articles are based on diagnostic techniques for caries and their preventions. In the present study, we included 19 out of 6387 articles, which were further filtered for duplicate, and a total of 3887 articles was included in the study. After keen analysis and screening, we included 19 articles in the study. These articles were based on caries prevention. A similar review published by Senneby et al. [28] included eight articles in their study with poor study methodology. Prados-Privado et al. [29] conducted a systematic review to diagnose dental caries and detect their neural connection. They included 13 articles in their study and used Cochrane risk assessment for analysis. A different neural detection and connection were identified in every study; hence, they concluded that comparing the neural network and dental caries is also essential (Table 5).

In the present study, all the included articles are randomized controlled trials except two. The article published by Jordon et al. [30] was a cohort study, whereas Peterson et al. [11] was a clinical trial. Innes et al. [13] designed a randomized controlled trial and divided their study subjects into three groups. Group 1 was solely based on caries prevention, group 2 on biological management of caries, and group 3 on presentational and conventional caries management. They found an equal risk of caries in all the patients. In another article based on RCT, 241 children were included falling in the age group of 5 to 7 years. In this RCT, the participants were divided into two groups. Group 1 (BNI group) was the group under the supervision of trained nurses, and the participants in group 2 were solely based on the conversation between the parents and nurses. In this study, 29% low caries risk was seen in the BNI group [14]. Another study on children aged 8–10 years reported dental pains and their relationship with caries [23]. In a study published in 2019, 448 mothers and caregivers and their children were included in the study [15]. A similar study based on caretakers' behavior reported the importance of consciousness of the caretakers for children in reducing their dental caries [24]. The article published by Liu et al. [10] on 2376 elderly Chinese people reported more dental caries in the Chinese population; this can be due to their socio-demographic condition and high smoking habits. Alkarimi et al. [25] reported a co-relation of dental caries with appetite. They claimed cured caries could increase the appetite in young children.

Similarly, another study reported on socio-demographic conditions was published by Kopycka-Kedzierawski and Billings [26] where 234 children were included in the study and 28% of them had a history of dental caries, while another 61% of the study subject

Table 5 Risk bias assessment of the screened articles according to Cochrane risk assessment tool

S.no	Author/ year	Q1.	Q2.	Q3.	Q4.	Q5.	Q6.	Q7.
1	Innes et al. (2020)	-	+	+	+	?	+	-
2	Pine et al. (2020)	+	+	-	+	?	?	-
3	Santos et al. (2019)	+	-	-	+	?	?	-
4	Jamieson et al. (2019)	-	-	-	+	?	?	-
5	Tickle et al. (2019)	-	-	+	+	?	?	?
6	da Silva et al. (2019)	+	-	-	+	?	?	-
7	Fernando et al. (2019)	+	-	-	+	?	+	+
8	Stafuzza et al. (2019)	-	+	-	+	?	+	-
9	Milgrom et al. (2018)	-	+	+	+	+	+	-
10	Frese et al. (2018)	+	+	-	+	+	+	-
11	Megalaa et al. (2018)	+	-	-	+	-	-	-
12	Arrow and Klobas., (2017)	+	+	?	+	+	-	-
13	Jordan et al. (2016)	+	-	-	+	?	-	-
14	Mathur et al. (2016)	+	-	-	+	?	?	?
15	Heima et al. (2015)	-	-	-	+	-	?	+
16	Peterson et al. (2013)	+	-	-	+	-	+	+
17	Liu et al. (2013)	-	+	?	+	+	+	+
18	Alkarimi et al. (2012)	+	+	-	+	+	+	-
19	Kopycka-Kedzierawski and Billings (2011)	+	-	+	+	?	-	?

All the 19 included articles are enlisted in the table where the articles were analyzed based on seven questions included in the Cochrane risk assessment. The green color indicates low bias risk, the red color indicates high bias risk, and the yellow color indicates the articles with unclear bias

never had caries, and they found that routine check-ups and awareness can avoid the chances of appearance of caries. Stafuzza et al. [26] reported their study on 36 patients with caries and concluded that early caries removal could reduce the chances of caries in the appearance of new caries. Jordan et al. [30] reported that more caries in childhood can cause high caries risk in older ages. Different kinds of comparative studies showed that awareness of oral health in parents and caretakers is critical. Furthermore, studies are required from the aspect of treatment of dental caries and pain management.

The present meta-analysis was a literature search of the articles published in different databases. Based on the designed keywords and the inclusion and exclusion

criteria, 19 articles were included in this study after careful reading. The methodology studied by the authors was transparent except for a few. We conducted risk bias analysis and found Frese et al. [12], Liu et al. [10], and Innes et al. [13], where the articles can be ranged as high quality with low bias risk. Stannous fluoride emerged as a more proper treatment for the prevention of dental caries.

The study based on the effect of smoking in elderly adults by checking the anxiety level of the participants was found as a significant cause of the appearance of caries in older adults, whereas in children awareness of parents toward the oral health played an essential role in caries prevention. Previous caries history plays a pivot role for risk caries management to provide better treatment and caries prevention. New emerging techniques are also advancing dental care and oral health. The method with high accuracy and low risk can be recommended for routine treatment. Yet more advanced methods are required for caries detection in people of different ages.

Abbreviations

QUADAS: Quality Assessment of Diagnostic Accuracy Studies; PRISMA: Preferred Reporting Items for Systematic Reviews and Meta-Analyses; AMSTAR: Assessment of multiple systematic reviews; ECC: Early Childhood Caries.

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Author contributions

All authors were involved in data curation, formal analysis, investigation, methodology, and reviewing and editing the manuscript. FK and MM drafted the work and design of the work; CH and AF have substantively revised the work. All authors read and approved the final manuscript.

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Declarations

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Consent for publication

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Competing interests

The authors declare that they have no competing interests.

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