Dental caries in primary and permanent teeth in children’s worldwide, 1995 to 2019: a systematic review and meta-analysis

Mohsen Kazeminia 1, Alireza Abdi 1, Shamarina Shohaimi 2, Rostam Jalali 1, Aliakbar Vaisi-Raygani 1, Nader Salari 3* and Masoud Mohammadi 1*

Abstract

Background: Early childhood caries (ECC) is a type of dental caries in the teeth of infants and children that is represented as one of the most prevalent dental problems in this period. Various studies have reported different types of prevalence of dental caries in primary and permanent teeth in children worldwide. However, there has been no comprehensive study to summarize the results of these studies in general, so this study aimed to determine the prevalence of dental caries in primary and permanent teeth in children in different continents of the world during a systematic review and meta-analysis.

Methods: In this review study, articles were extracted by searching in the national and international databases of SID, Magiran, IranMedex, IranDoc, Cochrane, Embase, ScienceDirect, Scopus, PubMed, and Web of Science (ISI) between 1995 and December 2019. Random effects model was used for analysis and heterogeneity of studies was evaluated by using the $I^2$ index. Data were analyzed by using the Comprehensive Meta-Analysis (Version 2) software.

Findings: In this study, a total of 164 articles (81 articles on the prevalence of dental caries in primary teeth and 83 articles on the prevalence of dental caries in permanent teeth) were entered the meta-analysis. The prevalence of dental caries in primary teeth in children in the world with a sample size of 80,405 was 46.2% (95% CI: 41.6–50.8%), and the prevalence of dental caries in permanent teeth in children in the world with a sample size of 1,454,871 was 53.8% (95% CI: 50–57.5%). Regarding the heterogeneity on the basis of meta-regression analysis, there was a significant difference in the prevalence of dental caries in primary and permanent teeth in children in different continents of the world. With increasing the sample size and the year of study, dental caries in primary teeth increased and in permanent teeth decreased.

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Conclusion: The results of this study showed that the prevalence of primary and permanent dental caries in children in the world was found to be high. Therefore, appropriate strategies should be implemented to improve the aforementioned situation and to troubleshoot and monitor at all levels by providing feedback to hospitals.

Keywords: Caries, Tooth, Primary and permanent, Prevalence, Meta-analysis

Background

Early childhood caries (ECC) is a type of dental caries in the teeth of infants and children that is represented as one of the most prevalent dental problems in this period [1] which can lead to pain, infection, interference with eating, increased risk of new dental caries in primary and permanent teeth, and, ultimately, worse effects on the eruption of permanent teeth [2]. These manifestations can range from demineralization to loss of tooth structure or complete destruction of the crown, a process of dynamic and active decay characterized by various periods of destruction and repair [3].

According to the American Academy of Dentistry, early childhood caries (ECC) is defined as “the presence of 1 or more decayed (non-cavitated or cavitated lesions), missing (due to caries), or filled tooth surfaces in any primary tooth” in children [1]. Overall, 50% of children have one or more decayed primary teeth by the end of toddler age, but the importance of these teeth should not be overlooked, because, as has been said, healthy teeth in childhood have an important role in the eruption of healthy permanent teeth, healthy nutrition, and one’s aesthetic appearance [2, 3]. Factors such as malnutrition, genetic predisposition, poor health performance, specific eating habits, the presence of organisms affecting tooth decay such as streptococci, and fluoride and vitamin D deficiency, excessive sugar consumption and prolonged bottle-feeding, and other factors such as age, gender and place of residence of children are effective in causing tooth decay [4].

The World Health Organization (WHO) has represented the early childhood caries as a worldwide problem with a prevalence of between 60 and 90% [5]. According to the statistics provided by the European countries, 61% of children aged 6 to 12 years have at least one decayed tooth, and due to widespread dental caries in all social classes, this disease can impose a great financial burden on the society [6]. In Iran the mean decay-missing-filled (DMF) index of primary teeth in children aged 3 to 6 years was 1.7 and DMF index of permanent teeth was reported to be 0.2 in 6- to 9-year-old children, 0.9 to 1.5 in 12-year-old children, and 3.3 to 4.8 in 9-year-old children [7]. The decay-missing-filled (DMF) index is used as an appropriate measure for the detection of dental caries in the society in which 12-year-old children are considered as a target group [8].

Primary teeth begin to erupt in infants’ mouths at about 6 months of age, and are completed at age 3 to 5, including 10 teeth in the maxilla and 10 in the mandible to meet nutritional needs in infancy [6]. Since primary teeth are the basis of permanent teeth, on the one hand, and they have a high susceptibility to caries, on the other hand, these teeth are very important and maintaining their health is considered a serious health concern for children [3, 9].

Due to the influence of different factors on the prevalence of primary and permanent dental caries in children and lack of general statistics about this issue worldwide, we decided to review the studies in this area and to statistically analyze the results of these studies to compile a general statistics on the prevalence of dental caries in primary and permanent teeth in children in different continents of the world to open a window to more precise planning to reduce the complications of primary and permanent dental caries in children.

Methods

In this systematic review and meta-analysis, the prevalence of dental caries in primary and permanent teeth in children was evaluated based on studies conducted between 1995 and December 2019. To this end, articles published in the national databases of SID, MagIran, IranMedex, and IranDoc, and in the international databases of Google scholar, Cochrane, Embase, ScienceDirect, Scopus, PubMed, and Web of Science (ISI) were searched by using Persian and English keywords such as Prevalence, Caries, Rampant caries, Milky tooth, Permanent tooth and Children.

Selection of studies

Initially, all articles referring to the prevalence of dental caries in primary and permanent teeth in children in the world were collected by the researchers and accepted based on the inclusion and exclusion criteria. The inclusion criteria were observational (non-interventional) studies and their full text availability. For more information, the sources of the articles reviewed were also reviewed for access to other articles.
Exclusion criteria included irrelevant cases, case reports, interventional studies and other review, case control, cohort, duplication of studies, unclear methodology, and full text unavailability. In order to reduce bias, the articles were searched independently by two researchers, and if they disagreed on a study, the article was reviewed by the group supervisor (blinded about the decision by the first two independent researchers’ decision). A total of 180 studies entered the third stage, quality assessment.

Duplicate publication and multiple publications from the same population will be removed using citation management, software EndNote (version X7, for Windows, Thomson Reuters).

**Quality assessment of studies**
The quality of the articles was first evaluated on the basis of selected and related items of the 22-item STROBE checklist that could be evaluated in this study (study design, background and literature review, place and time of study, outcome, inclusion criteria, sample size, and statistical analysis) and also mentioned in the previous studies. Articles referring to 6 to 7 criteria were considered as high quality articles, articles that did not mention 2 items and more than 2 items from the seven items were considered as medium and low methodological quality articles, respectively [10]. In the present study, 164 articles with high quality and medium quality were entered the systematic review and meta-analysis, and 16 articles were of poor quality and were excluded.

**Data extraction**
All final articles entered into the meta-analysis process were prepared to be extracted by a pre-prepared checklist. The checklist included article title, first author’s name, year of publication, place of study, sample size, mean age of sample, prevalence of dental caries in primary and permanent teeth.

**Statistical analysis**
Since prevalence has binomial distribution, prevalence variance was calculated using the binomial distribution variance formula, and weighted mean was used to combine the prevalence rate of different studies. In order to evaluate the heterogeneity of the selected studies, $I^2$ test was used (heterogeneity was divided into three classes of less than 25% (low heterogeneity), 25–75% (moderate heterogeneity) and more than 75% (high heterogeneity). Meta-regression analysis was used to investigate the relationship between the prevalence of dental caries with the sample size and the year of study. In order to evaluate the publication error with respect to the large sample size of studies entered the review, the Begg and Mazumdar test at the significant level of 0.1 and its corresponding Funnel plot were used. Sensitivity analysis was used to evaluate the effect of individual studies on the final result. Data were analyzed by using the Comprehensive Meta-Analysis (Version 2) software.

**Results**
In this study, all studies conducted on the prevalence of primary and permanent dental caries in children in the world were systematically investigated without time limitation based on the PRISMA guidelines. In the initial search, 2870 articles were identified, form which 164 studies published between 1995 and December 2019 were eventually entered the final analysis (Fig. 1).

The total sample size for the prevalence of primary dental caries was 80,405 and for the prevalence of permanent dental caries was 1,454,871, given with the mean age of the subjects in each study. The specifications of the selected articles are presented in Tables 1 and 2.

**Heterogeneity and publication bias**
Based on the results of the heterogeneity evaluation test ($I^2$), the prevalence of dental caries in primary and permanent teeth was reported to be $I^2$: 99.2 and $I^2$: 99.8, respectively. Due to the heterogeneity of the selected studies, a random effects model was used to combine the studies and jointly estimate the prevalence of dental caries in primary and permanent teeth. The probability of publication bias was evaluated by the Funnel plot and the Begg and Mazumdar tests at a significant level of 0.1 (Figs. 2 and 3), indicating that the publication bias was not statistically significant in the investigation of the prevalence of primary dental caries ($P = 0.590$) and permanent dental caries ($P = 0.145$).

**Meta-analysis (primary dental caries)**
According to the results of the study in forest plot, the overall prevalence of dental caries in primary teeth in children in the world was 46.2% (95% CI: 41.6–50.8%) (Fig. 4). The middle point of each line shows the prevalence of primary dental caries in the world for each study, and the rhombic figure shows the prevalence of primary dental caries in the world for all studies.

**Meta-analysis (permanent dental caries)**
According to the results of the study in forest plot, the overall prevalence of dental caries in permanent teeth in children in the world was 53.8% (95% CI: 50–57.5%) (Fig. 5). The middle point of each line
shows the prevalence of permanent dental caries in the world for each study, and the rhombic figure shows the prevalence of permanent dental caries in the world for all studies.

Meta-regression
The prevalence of primary dental caries was evaluated by meta-regression analysis based on the year of study and the sample size, which reported that with increasing the year of study and the sample size, the prevalence of dental caries in primary teeth increased in both cases and the difference was statistically significant (P < 0.01) (Figs. 6 and 7).

The prevalence of permanent dental caries was evaluated based on the year of study and the sample size, which reported that with increasing the year of study and the sample size, the prevalence of dental caries in permanent teeth decreased in both cases and the difference was statistically significant (P < 0.01) (Figs. 8 and 9).

Sub-group analysis
Also, Table 3 and Fig. 10 report the results of the prevalence of dental caries in primary and permanent teeth in children in different continents. These changes were reported in the continents of Asia, Europe, Africa, USA, and Australia, according to which 100 Asian studies (50 studies on the prevalence of dental caries in primary teeth and 50 studies on the prevalence of dental caries in permanent teeth), 32 European studies (10 studies on the prevalence of dental caries in primary teeth and 22 studies on the prevalence of dental caries in permanent teeth), 21 American studies (14 studies on the prevalence of dental caries in primary teeth and 7 studies on the prevalence of dental caries in permanent teeth), 10 African studies (5 studies on the prevalence of dental caries in primary teeth and 5 studies on the prevalence of dental caries in permanent teeth), and 16 studies excluded for other reasons.
| Author, year, Reference | Age (years) | Country | Sample size | Prevalence % | Quality |
|------------------------|------------|---------|-------------|--------------|---------|
| Kalantari, 2014, [11]   | 6–7        | Iran    | 400         | 63.5         | High    |
| Abedini, 2013, [12]     | 2–6        | Iran    | 310         | 48.7         | High    |
| Hermatyar, 2009, [13]   | 3–7        | Iran    | 200         | 63.5         | High    |
| Nabipour, 2013, [14]    | 3–6        | Iran    | 838         | 71.8         | High    |
| Pahlavani, 2008, [15]   | 2–6        | Iran    | 414         | 61.6         | High    |
| Amir, 2017, [16]        | 4–6        | Iran    | 359         | 87.7         | High    |
| Ajami, 2005, [17]       | 6–7        | Iran    | 1938        | 76.5         | High    |
| Javadinezhad, 2008, [18]| 40.5 Month | Iran    | 100         | 77.0         | High    |
| Karimi, 2012, [19]      | 2–5        | Iran    | 211         | 82.9         | High    |
| Amanlou, 2011, [20]     | 3–6        | Iran    | 205         | 49.3         | High    |
| Toutouni, 2015, [21]    | 2–3        | Iran    | 239         | 61.1         | High    |
| Bagherian, 2013, [22]   | 2–5        | Iran    | 400         | 51.3         | High    |
| Mohebbi, 2006, [23]     | 1–3        | Iran    | 504         | 32.9         | High    |
| Ramos-Gomez, 1995, [24] | <6         | USA     | 220         | 30.0         | High    |
| Rosenblatt, 2002, [25]  | 1–3        | USA     | 468         | 28.4         | High    |
| Rajab, 2001, [26]       | 1–5        | Jordan  | 384         | 47.9         | High    |
| Douglass, 1999, [27]    | 3–4        | USA     | 517         | 37.9         | High    |
| Hallett, 1998, [28]     | 4–6        | Australia | 3375   | 37.6         | High    |
| Sayegh, 2002, [29]      | 4–5        | Jordan  | 1140        | 67.0         | Medium  |
| Hallett, 2003, [30]     | 4–5        | Australia | 2474   | 37.6         | High    |
| Peressini, 2000, [31]   | 3–5        | Canada  | 87          | 19.5         | High    |
| Chadwick, 2005, [32]    | 2–5        | UK      | 449         | 24.1         | High    |
| Schroth, 2015, [33]     | <6         | Canada  | 408         | 53.7         | High    |
| Tsai, 1997, [34]        | <6         | Taiwan  | 951         | 55.9         | Medium  |
| Mahejabeen, 2006, [35]  | 3–5        | India   | 1500        | 54.1         | Medium  |
| Du, 2002, [36]          | 3–5        | China   | 2014        | 55.3         | High    |
| Ferro, 2005, [37]       | 3–5        | Italy   | 4198        | 25.0         | High    |
| Schroth, 2004, [38]     | 1–5        | USA     | 834         | 71.0         | Medium  |
| Wyne, 2008, [39]        | 3–5        | Saludi Arabia | 789   | 74.8         | High    |
| Lawrence, 2004, [40]    | 1–5        | Canada  | 1275        | 72.7         | High    |
| Vazquez-Nava, 2005, [41]| 4–5        | Mexico  | 1160        | 17.9         | High    |
| Jigjid, 2005, [42]      | 1–5        | Japan   | 670         | 71.9         | High    |
| Senesombath, 2010, [43] | 36–47 Month | Thailand | 400   | 82.0         | Medium  |
| Slabinskiene, 2003, [44]| 3          | Lithuania | 950   | 50.6         | High    |
| Zhou, 2010, [45]        | 32 Month   | China   | 155         | 28.4         | High    |
| Rajshekar, 2005, [46]   | 1–6        | India   | 500         | 43.4         | Medium  |
| Ozer, 2011, [47]        | 3–6        | Turkey  | 226         | 49.6         | High    |
| Li, 2011, [48]          | 36–70 Month | China | 1523        | 56.8         | High    |
| Kumarhamy, 2011, [49]   | 1–2        | Sri Lanka | 410   | 32.2         | High    |
| Prakash, 2012, [50]     | 8–48 Month | India  | 1500        | 27.5         | Medium  |
| Singh, 2012, [51]       | 36–60 Month | India | 717         | 40.0         | High    |
| Perera, 2010, [52]      | 24–71 Month | Sri Lanka | 410   | 32.2         | Medium  |
| Phipps, 2011, [53]      | 12–71 Month | India | 8461        | 62.3         | High    |
| Parisotto, 2012, [54]   | 36–59 Month | Brazil | 351         | 39.9         | High    |
caries in primary teeth and 5 studies on the prevalence of dental caries in permanent teeth), and 4 Australian studies (3 studies on the prevalence of dental caries in primary teeth and 1 studies on the prevalence of dental caries in permanent teeth) were included in the meta-analysis. There was a significant difference in the prevalence of dental caries in primary and permanent teeth in different continents (Table 3 and Fig. 10).

### Cumulative meta-analysis

A cumulative meta-analysis of the included studies was performed based primary and permanent dental caries.

### Table 1: Characteristic of included studies prevalence of tooth decay (Continued)

| Author, year, Reference | Age (years) | Country       | Sample size | Prevalence % | Quality |
|-------------------------|-------------|---------------|-------------|--------------|---------|
| Zhang, 2012, [55]       | 5           | China         | 723         | 84.9         | High    |
| Tanaka, 2007, [56]      | 3           | Japan         | 2055        | 20.7         | Medium  |
| Colombo, 2019, [57]     | 48–71 Month | Italy         | 2522        | 38.0         | Medium  |
| Agouropoulos-1, 2019, [58] | <7          | USA           | 175         | 92.6         | High    |
| Agouropoulos-2, 2019, [58] | <7          | USA           | 175         | 53.7         | High    |
| Agouropoulos-3, 2019, [58] | <7          | USA           | 175         | 36.0         | High    |
| Musinguzi, 2019, [59]   | 3–5         | Kenya         | 432         | 48.1         | High    |
| Montes, 2019, [60]      | 5–7         | Brazil        | 415         | 42.9         | Medium  |
| Boustedt, 2019, [61]    | 5           | Sweden        | 336         | 13.1         | High    |
| Tonpe-1, 2019, [62]     | 3–5         | India         | 358         | 2.8          | High    |
| Tonpe-2, 2019, [62]     | 3–5         | India         | 358         | 4.2          | High    |
| Wang, 2019, [63]        | 6           | China         | 4936        | 87.7         | High    |
| Nomura, 2019, [64]      | 5–6         | Myanmar       | 187         | 81.3         | Medium  |
| Wu, 2019, [65]          | 5–6         | China         | 1350        | 51.4         | High    |
| Abbass, 2019, [66]      | 5–6         | Egypt         | 369         | 4.3          | Medium  |
| Goenka, 2018, [67]      | 5–7         | India         | 312         | 65.1         | High    |
| Chugh, 2018, [68]       | 24–61 Month | India         | 425         | 47.3         | High    |
| Vandana, 2018, [69]     | 2–6         | India         | 550         | 38.2         | High    |
| Iogic, 2018, [70]       | 3–6         | Serbia        | 250         | 38.4         | High    |
| Kato, 2017, [71]        | 3           | Japan         | 6315        | 36.0         | High    |
| Li, 2017, [72]          | 3–5         | China         | 1727        | 78.2         | High    |
| Mangla, 2017, [73]      | 1–3         | India         | 510         | 21.0         | High    |
| Owen, 2017, [74]        | 3–5         | Australia     | 623         | 14.1         | High    |
| Pal, 2017, [75]         | 5–6         | India         | 408         | 46.6         | High    |
| Wagne, 2017, [76]       | 6.7         | Germany       | 512         | 1.8          | High    |
| Shah, 2017, [77]        | 5–7         | India         | 829         | 33.2         | Medium  |
| Yuan, 2017, [78]        | 3           | China         | 959         | 28.1         | High    |
| Jiang, 2017, [79]       | 2–5         | China         | 1509        | 71.4         | High    |
| Massignan, 2016, [80]   | 3.7         | Brazil        | 565         | 39.1         | High    |
| Koya, 2016, [81]        | 24–71 Month | India         | 1897        | 42.0         | High    |
| Mothupi, 2016, [82]     | 4.8         | Africa        | 495         | 48.9         | High    |
| Alkhtib, 2016, [83]     | 4–5         | Qatari        | 250         | 89.2         | High    |
| Henry, 2016, [84]       | <3          | India         | 1486        | 40.6         | High    |
| Šaćić, 2016, [85]       | 3–5         | Bosnia and Herzegovina | 165 | 17.0 | Medium |
| Al-Meedani, 2016, [86]  | 3–5         | Saudi Arabia  | 388         | 69.1         | High    |
| Eldrissi, 2016, [87]    | 3–5         | Sudan         | 553         | 52.4         | Medium  |
| Gopal, 2016, [88]       | 3–6         | India         | 477         | 27.3         | High    |
| Author, year, Reference | Age (years) | Country        | Sample size | Prevalence % | Quality |
|-------------------------|------------|----------------|-------------|--------------|---------|
| Aghighi, 2010, [89]     | 6–15       | Iran           | 4666        | 66.3         | High    |
| Mortazavi, 1997, [90]   | 6–9        | Iran           | 220         | 65.5         | High    |
| Asdagh, 2015, [91]      | 6–12       | Iran           | 847         | 79.7         | Medium  |
| Memar, 1999, [92]       | 12         | Iran           | 439         | 84.3         | High    |
| Javadi nejad, 2006, [93]| 12         | Iran           | 340         | 82.1         | High    |
| Sadeghi, 2007, [94]     | 12         | Iran           | 563         | 68.6         | High    |
| Yousofi, 2015, [95]     | 7–12       | Iran           | 460         | 89.8         | High    |
| Eskandarizadeh, 2015, [96]| 6–12     | Iran           | 15,369      | 79.5         | High    |
| Mossaheb, 2011, [97]    | 6–11       | Iran           | 203         | 82.3         | High    |
| Qin, 2019, [98]         | 10–12      | China          | 5057        | 39.2         | High    |
| Alshehhi, 2019, [99]    | 8.1        | United Arab Emirates | 62     | 58.1         | High    |
| Cheng, 2019, [100]      | 10.3       | China          | 1,196,004   | 41.1         | High    |
| Villanueva-Gutiérrez, 2019, [101]| 9  | Spain          | 686         | 35.4         | High    |
| Lešić, 2019, [102]     | 6–15       | Croatia        | 1589        | 50.0         | High    |
| Mohd Nor, 2019, [103]   | 12         | Malaysia       | 595         | 74.3         | High    |
| Vanvitelli, 2019, [104] | 8–10      | Italy          | 530         | 29.1         | Medium  |
| Obregón-Rodríguez-1, 2019, [105]| 12 | Spain          | 1045        | 25.5         | High    |
| Obregón-Rodríguez-2, 2019, [105]| 15 | Spain          | 783         | 26.2         | High    |
| Mirmoza, 2019, [106]    | 7–10       | Italy          | 398         | 28.4         | Medium  |
| Abbass, 2019, [66]      | 6–12       | Egypt          | 369         | 27.9         | High    |
| Aldossary, 2018, [107]  | 6–9        | Saudi Arabia   | 1844        | 95.0         | High    |
| Goenka, 2018, [67]      | 8–10       | India          | 353         | 56.7         | High    |
| Ballouk, 2019, [108]    | 8–12       | Syria          | 1500        | 79.1         | High    |
| Alhabdan, 2018, [109]   | 6–8        | Saudi Arabia   | 578         | 82.9         | High    |
| Konde, 2018, [110]      | 12         | India          | 1000        | 13.6         | High    |
| Solis-Riggioni, 2018, [111]| 8–15     | Costa Rica     | 201         | 35.8         | High    |
| Musa, 2018, [112]       | 7–11       | China          | 24,521      | 32.4         | High    |
| Dutra, 2018, [113]      | 8–12       | Brazil         | 1211        | 32.4         | High    |
| Al-Akwa, 2018, [114]    | 6–12       | Yemen          | 17,599      | 67.6         | Medium  |
| Cruz, 2018, [115]       | 11–12      | Brazil         | 184         | 34.2         | High    |
| Andegiorgish, 2017, [116]| 12       | Eritrea        | 225         | 77.8         | High    |
| Albayale, 2017, [117]   | 6–9        | Saudi Arabia   | 17,891      | 64.6         | High    |
| Dobbiani-1, 2012, [118] | 10         | Italy          | 400         | 44.0         | Medium  |
| Dobbiani-2, 2013, [118] | 10         | Italy          | 400         | 18.5         | Medium  |
| Maran, 2017, [119]      | 6–12       | India          | 1204        | 73.2         | High    |
| Shah, 2017, [77]        | 12–15      | India          | 829         | 31.4         | High    |
| Kim, 2017, [120]        | 6–11       | Korea          | 514         | 49.4         | High    |
| Sköld, 2016, [121]      | 13         | Sweden         | 758         | 2.6          | High    |
| Plaka, 2017, [122]      | 12–15      | India          | 193         | 36.3         | High    |
| Hiremath, 2016, [123]   | 6–11       | India          | 13,200      | 78.9         | High    |
| Kottayi, 2016, [124]    | 12–15      | India          | 2000        | 3.9          | Medium  |
| Ponndurai, 2016, [125]  | 6–14       | India          | 2796        | 68.8         | High    |
| Djossou, 2013, [126]    | 6–15       | Benin          | 497         | 49.7         | High    |
| Weusmann, 2015, [127]   | 8          | Germany        | 25,020      | 60.9         | High    |
| Author, year, Reference | Age (years) | Country | Sample size | Prevalence % | Quality |
|-------------------------|------------|---------|-------------|--------------|---------|
| Goel-1, 2015, [128]     | 12         | India   | 992         | 34.3         | Medium  |
| Goel-2, 2015, [128]     | 15         | India   | 992         | 46.5         | High    |
| Farooqi, 2014, [129]    | 6–9        | Saudi Arabia | 711     | 73.0         | High    |
| Arora, 2014, [130]      | 12         | India   | 100         | 57.0         | High    |
| Sukhabogii-1, 2014, [131]| 12       | India   | 924         | 39.9         | Medium  |
| Sukhabogii-2, 2014, [131]| 15-       | India   | 951         | 46.7         | Medium  |
| Al-Darwish, 2014, [132] | 12–14      | Qatar   | 2113        | 85.0         | High    |
| Aidara, 2014, [133]     | 12–15      | Senegal | 677         | 96.0         | High    |
| Ingle, 2014, [134]      | 12–15      | India   | 1400        | 53.0         | Medium  |
| Sofola, 2000, [135]     | 6–12       | Nigeria | 513         | 16.6         | High    |
| Das, 2013, [136]        | 6–14       | West Bengal | 1764   | 28.1         | High    |
| Mahfouz-1, 2013, [137]  | 12         | Palestine | 677      | 40.6         | High    |
| Mahfouz-2, 2013, [137]  | 13         | Palestine | 677      | 41.8         | High    |
| Mahfouz-3, 2013, [137]  | 14         | Palestine | 677      | 60.4         | High    |
| Riziwaguli, 2013, [138] | 7–9        | China   | 1600        | 26.5         | Medium  |
| Joshi, 2013, [139]      | 6–12       | India   | 1600        | 69.1         | Medium  |
| Pieper, 2009, [140]     | 12         | Germany | 30,943      | 72.7         | High    |
| Yengopal, 2012, [141]   | 10.5       | Africa  | 882         | 27.6         | High    |
| Murthy, 2014, [142]     | 12–15      | India   | 1452        | 57.9         | High    |
| Koposova, 2013, [143]   | 12         | Russia  | 590         | 68.0         | High    |
| Dix, 2013, [144]        | 12–13      | Nepal   | 361         | 41.0         | Medium  |
| Suprabha, 2013, [145]   | 11–13      | India   | 857         | 59.4         | High    |
| Panagidis, 2012, [146]  | 12         | Germany | 951         | 32.6         | High    |
| Shailee-1, 2012, [147]  | 12         | India   | 1011        | 32.6         | Medium  |
| Shailee-2, 2012, [147]  | 15         | India   | 1011        | 42.2         | High    |
| Lagana, 2012, [148]     | 7–15       | Albanian | 2617     | 88.9         | Medium  |
| Subedi, 2011, [148]     | 12–13      | Nepal   | 325         | 53.2         | Medium  |
| Shekar, 2011, [149]     | 12–15      | India   | 474         | 56.3         | High    |
| Oulis-1, 2010, [150]    | 12         | Greece  | 1224        | 80.0         | High    |
| Oulis-2, 2010, [150]    | 15         | Greece  | 1257        | 83.0         | High    |
| Jarnelli, 2010, [151]   | 12         | Brazil  | 689         | 71.8         | High    |
| Kanagaratnam, 2009, [152]| 9         | New Zealand | 612     | 54.9         | High    |
| Bissar, 2008, [153]     | 11–14      | Germany | 570         | 42.3         | High    |
| Ferro, 2007, [154]      | 12         | Italy   | 260         | 56.9         | High    |
| Moreira, 2006, [155]    | 12–15      | Brazil  | 1665        | 50.9         | High    |
| Schulte, 2004, [156]    | 12         | Germany | 43,950      | 39.3         | High    |
| Paredes, 2005, [157]    | 6–10       | Spain   | 600         | 47.2         | High    |
| Mestriner, 2005, [158]  | 12         | Brazil  | 256         | 53.9         | High    |
| Traebert, 2002, [159]   | 12         | Brazil  | 803         | 62.1         | High    |
Cumulative risk of each study’s addition to the meta-analysis are reported in Figs. 11 and 12.

**Discussion**

In this study, the prevalence of dental caries in studies conducted throughout the world was investigated, and it was reported that the overall prevalence of dental caries in primary teeth in children was 46.2%. Early childhood caries (ECC) in developing countries was reported to be more than in developed countries [1]. Also, in the present study, the overall prevalence of dental caries in permanent teeth in children was 53.8%.

Differences in the prevalence of dental caries in developed and underdeveloped countries may be due to differences in the age groups studied, but may also be due to ethnic, cultural, geographic, racial, and developmental differences as well as access to dental services, behavioral habits, health care behaviors,
Fig. 4 Forest plot of the results of Prevalence of dental caries in primary teeth and 95% confidence intervals worldwide
nutritional habits and behaviors, and lifestyle [144]. The effects of parents’ lack of awareness of their children’s tooth decay status as well as neglect and attention discrimination can also be well documented in the study of Nag et al. [160], suggesting that in the age group of 6 to 18 years, caries rates were higher in girls than in boys, as girls are more neglected by parents than boys. Although there has been no difference
in the prevalence rate of both sexes in the current systematic study, terms of access to health services and lack of parental awareness of and attention to children’s dental caries are known as the most important factors in its development [2], so discrimination and inequality in the upbringing of children in the family can also multiply the impact of such a situation.

In the present meta-analysis study, the prevalence of dental caries in primary and permanent teeth in different continents is presented in Table 3 and Fig. 10, which was higher in the African continent and secondarily in the Asian continent.

According to the World Health Organization’s Healthy People Plan, 90% of children between the ages of 5 and 6 should be free of tooth decay by 2010. However, according to the findings of this study which were based on the reviews performed in the studies searched, the prevalence of dental caries in children in most countries was found to be very high. Such a situation gives rise to worrying conditions in terms of tooth decay in adulthood and will also
impose enormous tooth repair costs on the country's health sector. Such a situation in the country, in addition to what has been said, as well as conditions such as inequality in access to health care services, inequality in developmental and economic situation in different countries and different parts of countries may indicate that the lack of awareness of the health and preservation of primary teeth in all families with different socioeconomic status has been considered a serious problem [3] and a barrier to the provision of preventive and health services. Families and parents should know that child dental care must start from the mother's pregnancy; children born to mothers with multiple dental caries are more likely to develop caries in the later stages of their lives. Cariogenic bacteria are usually transferred through the use of a spoon or a bottle of milk from the mother's moth to the child's mouth for the first time, so breast feeding should be avoided as much as possible during the baby's sleep. Regular dental appointments should be provided from the beginning of the baby's primary teeth eruption, especially with the eruption of the first
permanent tooth, first molar tooth or the 6th tooth. The tooth develops immediately after the last primary tooth at the age of six and is most likely to be decayed. The American Academy of Pediatric Dentistry, the American Dental Association, and the American Academy of General Dentistry all recommend making sure to see a dentist 6 months after the eruption of teeth in children, before the age of one year’s [161–166]. One of the most important and available measures to prevent caries, especially primary teeth in children, is performing dental procedures such as fissure sealant and fluoride therapy. In the fissure sealant method, deep grooves in the surface of the tooth are covered with a thin layer of tooth-colored material, thereby preventing the spread of cariogenic bacteria in tooth grooves. Other methods are caries prevention [167] and [168].

Table 3 Investigating the prevalence of dental caries in primary and permanent teeth in children in different continents

| Tooth type               | continents | Number of articles | Sample Size | $i^2$ | Egger Test | Prevalence % |
|--------------------------|------------|--------------------|-------------|------|------------|--------------|
| Caries in primary teeth  | Asia       | 50                 | 54,680      | 99.3 | 0.756      | 52.6 (95% CI: 46.7–58.5) |
|                          | Europe     | 10                 | 9977        | 98.4 | 0.152      | 21.4 (95% CI: 15.3–29.1) |
|                          | America    | 14                 | 6825        | 98.7 | 0.742      | 45.8 (95% CI: 34.2–58)   |
|                          | Africa      | 5                  | 3004        | 95.5 | 0.220      | 53.1 (95% CI: 44.3–61.7) |
|                          | Australia   | 3                  | 6472        | 98.3 | 0.296      | 28.5 (95% CI: 20.3–38.5) |
| Permanent dental caries  | Asia       | 50                 | 1,334,133   | 99.8 | 0.284      | 58.8 (95% CI: 53.4–64)   |
|                          | Europe     | 22                 | 115,141     | 99.8 | 0.175      | 44.1 (95% CI: 36.1–52.5) |
|                          | America    | 7                  | 5009        | 98.2 | 0.763      | 48.9 (95% CI: 37.6–60.3) |
|                          | Africa      | 5                  | 2794        | 99.3 | 0.220      | 58.9 (95% CI: 29.4–83.1) |
|                          | Australia   | 1                  | 612         | –    | –          | 54.9 (95% CI: 50.9–58.8) |

Strength and limitation

The most important strength of this study is that it has been studied for the first time in the world, includes all data sources and high-quality studies, and also analysis based on different continents for the use of the World Health Organization. The most important limitation of the present study is inaccessibility to the full text of the articles, incomplete search, and poor quality of some studies, as well as restricted search based on Persian and English languages.
Fig. 11 Result of cumulative meta-analysis based on primary dental caries
Fig. 12 Result of cumulative meta-analysis based on permanent dental caries
Conclusion
The results of this study showed that the prevalence of dental caries in primary and permanent teeth in children in the world was found to be high. Therefore, appropriate strategies should be implemented to improve the aforementioned situation and to troubleshoot and monitor at all levels by providing feedback to hospitals. Also, the prevalence of dental caries in primary and permanent teeth in children of Africa is higher than other continents and requires special attention of the World Health Organization to this continent in improving the oral health of children. These strategies can include providing educational programs to parents, periodic dental care for children, and fluoride therapy in childhood for the African continent.

Abbreviations
ECC: Early Childhood Caries; WHO: World Health Organization; DMF: Decay-Missing-Filled; SID: Scientific Information Database; MESH: Medical Subject Headings; ISI: Web of Science; PRISMA: Preferred Reporting Items for Systematic Reviews and Meta-Analysis; STROBE: Strengthening the Reporting of Observational Studies in Epidemiology for cross-sectional Study

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Authors’ contributions
MK and AA contributed to the design, MM and RJ statistical analysis, participated in most of the study steps. AVR and SHSH prepared the manuscript. NS and MM assisted in designing the study, and helped in the interpretation of the study. All authors have read and approved the content of the manuscript.

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Author details
1Department of Nursing, School of Nursing and Midwifery, Kermanshah University of Medical Sciences, Kermanshah, Iran. 2Department of Biology, Faculty of Science, University Putra Malaysia, Serdang, Selangor, Malaysia. 3Department of Biostatistics, School of Health, Kermanshah University of Medical Sciences, Kermanshah, Iran.

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