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SYSTEMATIC REVIEW OPEN ACCESS

Prevalence of Early Childhood Caries in Africa: A Systematic Review

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ABSTRACT

Background: The prevalence of early childhood caries (ECC) continues to increase. It is recognised as a public health concern, particularly in developing countries. Early childhood caries has numerous adverse effects on children's growth and overall well-being. Despite the global burden of ECC, data from Africa remain limited, varied and are based on inconsistent diagnostic criteria and study methodologies.

Aim: The aim was to perform a systematic review to ascertain the prevalence of ECC in children across Africa between January 2000 and March 2025.

Materials and Methods: A systematic literature search of peer-reviewed articles published in English between January 2000 and March 2025 was conducted using multiple databases, including PubMed, SCOPUS, Google Scholar, AFRICA-WIDE INFO, African Journals Online (AJOL) and CINAHL. Prospero Registration: CRD42018112161.

Results: A total of 70 studies, representing 58 644 participants from 13 African countries, were included in the review. The overall prevalence of ECC was 37.9% (95% CI: 31.2–44.6), with variations observed among countries and urban/rural settings. The mean dmft score was 1.98 (95% CI: 1.86–2.10).

Discussion and Conclusion: The prevalence of ECC varies considerably across the African continent. This could be due to differences in education, access to dental care and human resources among countries and regions.

1 | Introduction

A 2024 systematic review and meta-analysis reported a 49% global prevalence of ECC for children [1]. This systematic review also established that the African continent had reported an ECC prevalence rate of 42%, which indicated that there is a major burden of dental caries in young children. The severity of dental disease is evident from the reported decayed, missing, filled teeth (dmft) index for deciduous teeth. The dmft score was reported to be 3.68 globally and 3.47 for Africa.

Higher dental caries rates are associated with low levels of socio-economic conditions. For countries with a gross national income (GNI) between USD 20 000 and USD 39 999, the prevalence rates for ECC were 30%; for countries with a low GNI of < USD 5000, the prevalence rate was reported to be 57% [1]. Although mineral-rich, Africa is one of the poorest continents in the world [2]. Furthermore, poverty has been associated with poorer dental outcomes in children [3]. There is a dose–gradient relationship between dental caries and carbohydrates [4]. It has been reported that populations with a low socio-economic

Summary

- Why this paper is important to pediatric dentists
  - Provides critical prevalence data for informed intervention.
  - Highlights disparities and identifies priority populations.
  - Supports advocacy for standardised care and policy reform.

status often have diets laden with sugars, as it is more palatable and cheaper [5].

Dental caries in young children has been associated with dental pain, school absenteeism [6], poorer academic outcomes [6], effects on Body Mass Index [7] and maternal quality of life [8]. Given the impact of oral health conditions on children, it is essential to align our human resources to be able to manage this burden. Unfortunately, Africa has one of the lowest dentist-patient ratios in the world [9] (0.44 dentists per 10 000 population), resulting in poor access to dental care and exacerbating the dental disease burden [9].

In some African countries, oral health is not prioritised, which implies that there is poor oral health education and practices [10]. In addition, many households obtain their water from dams or rivers, often containing very little or no fluoride. The lack of adequate fluoride is a risk factor for the development of dental caries [11]. Cultural beliefs can also impact on dental treatment-seeking behaviour, and often restorative dentistry is not encouraged, and prevention is not sought [12].

The aim of this study was to determine caries prevalence of ECC in Africa using a systematic review approach. The results can be used to identify and compare countries on the continent with high and low ECC prevalence rates. This could help in identifying specific factors that are responsible for the prevalence of ECC and interventions that may be available to be used in the reduction of ECC.

2 | Materials and Methods

The proposal for this systematic review was registered with PROSPERO (No. CRD42018112161). The systematic review was conducted and reported following the Preferred Reporting Items for Systematic reviews and Meta-Analyses guidelines [13]. Previously published literature was used to determine the search strategy for Africa [14]. The search strategy was developed, and studies in English and Arabic were included. Various databases were searched from January 2000 until 26th March 2025, which included the following databases: Academic Search Complete (via EBSCOhost); CINAHL (via EBSCOhost); Dentistry and Oral Sciences Sources (via EBSCOhost); Pubmed (Medline); Science Direct, AFRICA-WIDE INFO, Google Scholar, African Journals Online (AJOL) and SCOPUS.

The following mesh terms and title/abstracts were used ((((Early childhood caries, caries OR decay OR dmft OR dental OR oral OR ICDAS OR dmft[MeSH Terms]) OR (caries[Title/Abstract] OR decay[Title/Abstract] OR dmft[Title/Abstract] OR dental[Title/Abstract] OR oral[Title/Abstract] OR ICDAS[Title/Abstract] OR DMFT[Title/Abstract])) AND ((Child*[Title/Abstract]) OR ("Child*"[Mesh]))) AND ((prevalence[Title/Abstract]) OR (prevalence[MeSH Terms]))) AND ("Africa"[MeSH] OR Africa*[tw] OR Algeria[tw] OR Angola[tw] OR Benin[tw] OR Botswana[tw] OR "Burkina Faso"[tw] OR Burundi[tw] OR Cameroon[tw] OR "Canary Islands"[tw] OR "Cape Verde"[tw] OR "Central African Republic"[tw] OR Chad[tw] OR Comoros[tw] OR Congo[tw] OR "Democratic Republic of Congo"[tw] OR Djibouti[tw] OR Egypt[tw] OR "Equatorial Guinea"[tw] OR Eritrea[tw] OR Ethiopia[tw] OR Gabon[tw] OR Gambia[tw] OR Ghana[tw] OR Guinea[tw] OR "Guinea Bissau"[tw] OR "Ivory Coast"[tw] OR "Cote d'Ivoire"[tw] OR Jamahiriya[tw] OR Kenya[tw] OR Lesotho[tw] OR Liberia[tw] OR Libya[tw] OR Libia[tw] OR Madagascar[tw] OR Malawi[tw] OR Mali[tw] OR Mauritania[tw] OR Mauritius[tw] OR Morocco[tw] OR Mozambique[tw] OR Mocambique[tw] OR Namibia[tw] OR Niger[tw] OR Nigeria[tw] OR Principe[tw] OR Reunion[tw] OR Rwanda[tw] OR "Sao Tome"[tw] OR Senegal[tw] OR Seychelles[tw] OR "Sierra Leone"[tw] OR Somalia[tw] OR "South Africa"[tw] OR "St Helena"[tw] OR Sudan[tw] OR Swaziland[tw] OR Tanzania[tw] OR Togo[tw] OR Tunisia[tw] OR Uganda[tw] OR "Western Sahara"[tw] OR Zaire[tw] OR Zambia[tw] OR Zimbabwe[tw] OR "Central Africa"[tw] OR "Central African"[tw] OR "West Africa"[tw] OR "West African"[tw] OR "Western Africa"[tw] OR "Western African"[tw] OR "East Africa"[tw] OR "East African"[tw] OR "Eastern Africa"[tw] OR "Eastern African"[tw] OR "North Africa"[tw] OR "North African"[tw] OR "Northern Africa"[tw] OR "Northern African"[tw] OR "South African"[tw] OR "Southern Africa"[tw] OR "Southern African"[tw] OR "sub Saharan Africa"[tw] OR "sub Saharan African"[tw] OR "sub-Saharan Africa"[tw] OR "subSaharan African"[tw]) NOT ("guinea pig"[tw] OR "guinea pigs"[tw] OR "aspergillus niger"[tw]). This search strategy that was used was based on a previous publication done in Africa [14].

Screening the above-mentioned databases was supplemented by hand-searching, using forward and backward searching. Covidence (Covidence systematic review software, Veritas Health Innovation, Melbourne, Australia. Available at www.covidence.org) was employed to upload, de-duplicate and extract data for this systematic review.

2.1 | Screening and Selection Criteria

Four authors (AB, ZN, NS and HA) independently screened and selected the articles. Only studies conducted in Africa on children 6 years of age or younger were included in this review. Studies that did not include the number of children who had caries or did not report the total sample size were excluded from the prevalence component of the study. The search strategy only included articles published in English and Arabic from January 2000 until March 2025.

Caries severity was determined by the dmft index for primary teeth. Studies were included or excluded and listed in a PRISMA

flowchart. All data screening and selection were performed in Covidence. Disagreements between co-authors were settled via discussion.

If the size of the complete sample or the mean and standard deviation of the dmft were not reported, the study was excluded from the severity component of the review.

2.2 | Data Extraction

For each article, data were independently extracted by two of the four authors. Any disagreement was discussed until consensus was reached. An attempt was made to contact corresponding authors when data were missing.

Various data were collected from each included study, such as authors' names, year of publication, country, diagnostic criteria, caries prevalence, dmft index, study design and urban/rural setting. If unsure of the urban/rural classification, data were categorised as 'urban/rural'. Where possible, subgroup analysis was performed.

2.3 | Critical Appraisal

Included studies were critically appraised using the Joanna Briggs Institute (JBI) critical appraisal checklist for studies reporting prevalence data [13]. Each article was independently appraised by two of the four authors. Discussion was used to reach consensus where disagreements were found. Each low risk of bias was given a score of one, and a score of eight indicated the lowest risk of bias (Table 1).

2.4 | Data Synthesis

STATA Statistical Software: Release 17 (College Station, TX: StataCorp LLC) was used to conduct the meta-analyses. Statistical heterogeneity was assessed using the I^2 test and the Q test. Significant heterogeneity was found ($I^2 > 50\%$), which necessitated the use of a random effects model. Subgroup analyses were conducted for the country in which the study was conducted, the publication year, gender, income status of the country and the urban/rural status of the population.

3 | Results

3.1 | Search and Selection

A total of 4407 articles were identified, and of these, 1080 were duplicate articles; hence, a total of 3327 articles were screened. Thereafter, 3207 articles were excluded, as shown in the PRISMA flow diagram (Figure 1). Of the remaining 120 articles, 70 articles met the inclusion criteria (Table 1). A further 50 were excluded, as they were not eligible (Table 2).

There was a maximum of 60 articles that determined the prevalence of ECC and a maximum of 22 articles for the dmft meta-analysis. Dental caries was recorded utilising the World Health Organisation (WHO) criteria [118]. A total of 58 664 participants were included in this review. The overall prevalence was 37.9% (95% CI: 31.2–44.6) (Figure 2). The prevalence of caries was the highest in Gambia: 87.2% (95% CI: 79.6%–92.2%), followed by Congo 79.7% (95% CI: 72.8%–85.3%), while Nigeria had the lowest prevalence of 18.9% (95% CI: 15%–22.8%).

The prevalence of dental caries, by age group, exponentially increased as age increased; 5-year olds had the highest caries prevalence of 51.7% (95% CI: 39.7%–63.7%) (Figure 3). The lowest caries prevalence of 1.4% was seen in 1-year olds (95% CI: 0%–0.02%) (Table 3).

Both the dmft and prevalence increased exponentially with age. The dmft scores decreased as age decreased; 5-year olds had the highest dmft score 2.02 (95% CI: 1.62–2.79). Four-year olds had a score of 1.49 (1.1–1.89) (Table 4).

There was a decrease in the prevalence of dental caries from the 2010–2014 period to the 2020–2025 period from 45.8% to 22.2% (Table 5). Prior to 2010, the dental caries prevalence increased over time (Figure 4). By year category, the prevalence first increased from 2000 to 2004: 39.7% (95% CI: 23.4%–56.1%) for 2010–2014, then decreased to 17.2% (23.3%–50.6%) in 2020–2024 (Figure 4).

Males had a caries prevalence of 41.7% (95% CI: 26.4%–56.9%) (Figure 5). The highest caries prevalence for males was in South Africa (83.1% (95% CI: 73.3%–89.7%)). The caries prevalence for females was 38.3% (95% CI: 26.6%–50.1%) (Figure 6). Kenya and Egypt had the highest caries prevalence: 65.8% (95% CI: 58.0%–72.8%) and 61.9% (95% CI: 49.6%–74.2%) for females. The caries prevalence was 42.9% (95% CI: 34.3%–51.7%) in school settings, 41.1% (95% CI: 20.1%–62.1%) in hospital settings and 14.4% in other settings (Figure 7). The mean urban and rural prevalence was 37.2% (95% CI: 31.2%–44.6%) and 56.9% (95% CI: 35.3%–78.5%), while those studies that combined urban and rural settings had a prevalence of 34.2% (95% CI: 15.8%–52.6%). Not all the articles reported the prevalence by urban/rural setting; hence, the overall prevalence was different.

The overall dmft score for all participants was 1.98 (95% CI: 1.86–2.1), with Nigeria having the lowest dmft scores of 0.33 (95% CI: 0.24–0.41) and Kenya had the highest mean dmft of 3.94 (95% CI: 2.72–5.16) (Figure 8). The mean dmft scores for males ranged between of 6.02 (95% CI: 4.72–7.32) in Nigeria and 1.89 (95% CI: 1.31–2.47) in Uganda (Figure 9).

In females, the mean dmft scores were 2.45 (95% CI: 2.06–2.84) (Figure 10). Females in Uganda had the lowest mean dmft score of 1.75 (95% CI: 1.53–1.97). The dmft for urban/rural settings are 2.87 (95% CI: 2.25–3.49), 1.12 (95% CI: 0.88–1.36) for urban settings and 2.30 (95% CI: 1.97–2.63) for rural settings (Figure 11). The dmft was the highest in Congo (3.23 (95% CI: 2.73–3.73)) (Figure 12).

The caries prevalence by income group demonstrated that low-income countries (LICs) had a caries prevalence of 46.8% (95% CI: 33.4–60.2), low-middle-income countries (LMICs) had a caries prevalence of 33.3% (95% CI: 25.3–41.3), and

TABLE 1 | Critical appraisal.

Study ID	Were the criteria for inclusion in the sample clearly defined?	Were the study subjects and the setting described in detail?	Was the exposure measured in a valid and reliable way?	Were objective standard criteria used for measurement of the condition?	Were confounding factors identified?	Were strategies to deal with confounding factors stated?	Were the outcomes measured in a valid and reliable way?	Was appropriate statistical analysis used?
Oredugba 2008 [15]	Yes	Yes	Yes	Yes	Yes	No	No	No
Mziray 2006 [16]	Yes	Yes	Yes	Yes	Yes	No	Yes	No
Maro 2007 [17]	Yes	Yes	No	No	No	No	Yes	No
Gideon 2018 [18]	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Shalan 2018 [19]	Yes	Yes	Yes	Yes	Yes	Yes	No	No
Savani 2008 [20]	Yes	Yes	Yes	Yes	Yes	Yes	No	Yes
Cheruiyot 2019 [21]	Yes	Yes	Yes	Yes	Yes	Yes	No	Yes
Chepkwony 2016 [22]	Yes	Yes	Yes	Yes	Yes	No	No	Yes
Njoroge 2015 [23]	Yes	Yes	Yes	Yes	Yes	No	Yes	No
Hamza 2021 [24]	Yes	Yes	No	No	Yes	No	No	No
Molete 2018 [25]	Yes	Yes	Yes	Yes	Yes	No	No	No
Kosovic 2001 [26]	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
MacKeown 2000 [27]	Yes	Yes	Yes	Yes	No	No	Yes	No
Brindle 2000 [28]	No	Yes	Yes	Yes	Yes	No	Yes	Yes
Toi 2005 [29]	Yes	Yes	Yes	Yes	Yes	Yes	No	No
Bruce 2002 [30]	Unclear	Yes	No	Yes	No	No	Yes	No
Cleaton-Jones 2000 [31]	Yes	Yes	No	Yes	No	No	Yes	Yes
Rwakatema 2010 [32]	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No

(Continues)

TABLE 1 | (Continued)

Study ID	Were the criteria for inclusion in the sample clearly defined?	Were the study subjects and the setting described in detail?	Was the exposure measured in a valid and reliable way?	Were objective standard criteria used for measurement of the condition?	Were confounding factors identified?	Were strategies to deal with confounding factors stated?	Were the outcomes measured in a valid and reliable way?	Was appropriate statistical analysis used?
Masumo 2012 [33]	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Birungi 2016 [34]	No	No	Yes	Yes	Yes	Yes	No	Yes
van Wyk 2004 [35]	Yes	Yes	No	Yes	No	No	No	No
Birungi 2015 [36]	Yes	Yes	Unclear	Yes	No	No	Yes	Yes
Wanjau 2006 [37]	No	Yes	No	Yes	No	No	Yes	No
Folayan 2020 [38]	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Cleaton-Jones 2008 [39]	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Songo 2013 [40]	No	No	No	Yes	Yes	Yes	Yes	Yes
Masumo 2014 [41]	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Folayan 2016 [42]	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Kiwanuka 2004 [43]	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Folayan 2012 [44]	Yes	Yes	No	Yes	No	No	Yes	No
Olatosi 2014 [45]	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Abbass 2019 [46]	Yes	Yes	Yes	Yes	Yes	No	No	No
Olatosi 2015 [47]	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Musinguzi 2019 [48]	Yes	Yes	No	Yes	Yes	No	Yes	No
Peters 2022 [49]	Yes	Yes	Yes	Yes	Yes	No	No	No

(Continues)

TABLE 1 | (Continued)

Study ID	Were the criteria for inclusion in the sample clearly defined?	Were the study subjects and the setting described in detail?	Was the exposure measured in a valid and reliable way?	Were objective standard criteria used for measurement of the condition?	Were confounding factors identified?	Were strategies to deal with confounding factors stated?	Were the outcomes measured in a valid and reliable way?	Was appropriate statistical analysis used?
Alade 2021 [50]	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
AbdelAziz 2015 [51]	Yes	Yes	Yes	No	Yes	Yes	No	Yes
Folayan 2008 [52]	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Njoroge 2010 [53]	Yes	Yes	No	Yes	No	No	No	No
Ngatia 2001 [54]	Yes	Yes	Yes	Yes	Yes	No	No	No
Sowole 2007 [55]	Yes	Yes	Yes	Yes	Yes	Yes	No	No
Zaki 2015 [56]	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Ndekero 2021 [57]	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Folayan 2020 [58]	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Tobin 2017 [59]	Yes	Yes	Yes	Yes	Yes	No	No	No
Mothupi 2016 [60]	Yes	Yes	NA	Yes	No	No	Yes	No
Onyejaka 2021 [61]	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Macigo 2016 [62]	Yes	Yes	Yes	Yes	Yes	No	Yes	Yes
Elelmi 2021 [63]	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Folayan 2021 [64]	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Chouchene 2022 [65]	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Songa 2022 [66]	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No
Olatosi 2022 [67]	Yes	Yes	Yes	Yes	Yes	Yes	No	Yes

(Continues)

TABLE 1 | (Continued)

Study ID	Were the criteria for inclusion in the sample clearly defined?	Were the study subjects and the setting described in detail?	Was the exposure measured in a valid and reliable way?	Were objective standard criteria used for measurement of the condition?	Were confounding factors identified?	Were strategies to deal with confounding factors stated?	Were the outcomes measured in a valid and reliable way?	Was appropriate statistical analysis used?
Muhoozi 2018 [68]	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Adugna 2024 [69]	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Tesfay 2024 [70]	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Attia 2024 [71]	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Ligali 2024 [72]	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Bhayat 2024 [73]	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Mndzebele 2014 [74]	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
AbouElFadl 2019 [75]	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Adeniyi 2016 [76]	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Daouda 2016 [77]	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes
du Plessis 2000 [78]	Yes	Yes	Yes	Yes	No	No	Yes	Yes
Eigbobo 2015 [79]	No	Yes	Yes	Unclear	Yes	No	Yes	Unclear
Folayan 2015 [80]	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Folayan 2016 [42]	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Folayan 2019 [81]	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Folayan 2021 [64]	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

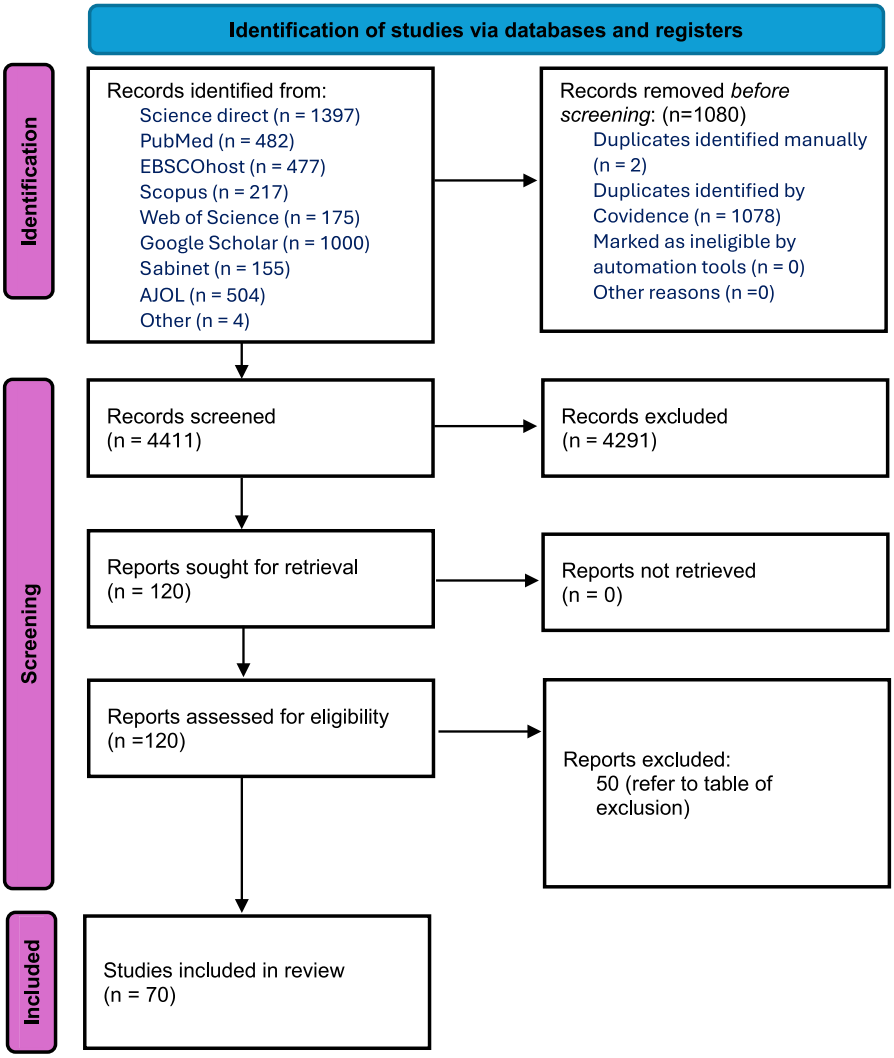

FIGURE 1 | PRISMA flow chart.

upper-middle-income countries (UMICs) had a caries prevalence of 45.7% (28.5–63.0), and the dmft scores were 1.86 (95% CI: 1.56–2.15) for LIC; 2.06 (95% CI: 1.93–2.2) for LMICs; and 1.64 (95% CI: 1.86–2.1) for UMICs (Figure 13).

3.2 | Publication Bias

Funnel plots were used to consider publication bias by assessing whether asymmetry existed in the estimates published. Egger's test was used to assess small-study effect while the Duval and Tweedie's 'Trim and Fill' method was used to assess publication bias for the prevalence of caries (Figure 14) and the dmft scores (Figure 15).

The funnel plot and Egger's test results indicated significant publication bias for the prevalence estimates of ECC. The 'Trim and Fill' method identified four missing studies, but the imputed prevalence estimate did not change, suggesting that while there may be some missing studies, their absence does not substantially affect the overall prevalence estimate.

Similar methods were applied to the dmft scores. The funnel plot and Egger's test again indicated significant publication bias. However, the 'Trim and Fill' method suggested no missing studies, with the imputed dmft score estimates remaining unchanged.

4 | Discussion

ECC has a dire impact on young children, affecting their mastication, which could lead to stunting, phonetics, which could impact on speech and educational growth, and negatively impact on their facial aesthetics. ECC affects children globally, and almost half of all preschool children have some form of ECC [119]. Marginalised and underprivileged children, across countries and continents, have been shown to be at a higher risk of developing ECC compared to their counterparts [120]. In Africa, there is a mix of developed and underdeveloped countries and districts within these countries. Hence, this review was undertaken to determine the ECC burden across the continent.

The overall prevalence of ECC in Africa was 37.9%; this was lower than that reported in a review done in India (50%) [121] and one done in Australia (more than 50%) [122]. The lower prevalence found could be attributed to a lack of refined

TABLE 2 | Excluded studies.

Title	Authors	Published year	Notes
Prevalence and pattern of early childhood caries in Ibadan, Nigeria [82]	Iyun OI; Denloye OO; Bankole OO; Popoola BO	2014	Full text cannot be found
Dental caries trends in 5- to 6-year-old and 11- to 13-year-old children in three UNICEF designated regions—Sub Saharan Africa, Middle East and North Africa, Latin America and Caribbean: 1970–2004 [83]	Cleaton-Jones P; Fatti P; Banecker M	2006	Wrong study design, systematic review
Oral health status of school children in Mbarara, Uganda [84]	Batwala V; Mulogo EM; Arubaku W	2007	Wrong outcomes; no dmft for age group concerned, no gender breakdown
Evaluation of a brief tailored motivational intervention to prevent early childhood caries [85]	Ismail AI; Ondersma S; Jedele JM; Little RJ; Lepkowski JM	2011	Wrong setting
Dental treatment needs of children in a rural subcounty of Uganda [86]	Nalweyiso N; Busingye J; Whitworth J; Robinson PG	2004	Wrong setting; combined results
Association between malocclusion, caries and oral hygiene in children 6 to 12 years old resident in suburban Nigeria [87]	Kolawole KA; Folayan MO	2019	Wrong patient population
Oral health in South Africa [88]	van Wyk PJ; van Wyk C	2004	Does not have large sample size
Dental caries status of primary school children aged 4–16 years in southwest Nigeria [89]	Sofola OO; Jeboda SO; Shaba OP	2004	Wrong age group; includes 6-year olds
Assessing causal effects of early life-course factors on early childhood caries in 5-year-old Ugandan children using directed acyclic graphs (DAGs): A prospective cohort study [90]	Birungi N; Fadnes LT; Kasangaki A; Nankabirwa V; Okullo I; Lie SA et al.	2017	Wrong outcomes; no dmft scores or caries prevalence reported
Early childhood caries: experience in Nigerian children at Lagos [91]	Sowole CA; Sote EO	2007	Wrong outcomes; abstract only
Mutans streptococci and other caries-associated acidogenic bacteria in 5-year-old children in South Africa [92]	Toi CS; Cleaton-Jones PE; Daya NP	1999	Wrong date
Prevalence of dental caries among children in a rural Tanzanian community [93]	Bloch B; Malele J; Tanner M; de Savigny D	1989	Wrong date
Developmental defects of enamel in primary teeth and association with early life course events: a study of 6–36-month-old children in Manyara, Tanzania [94]	Masumo R; Bardsen A; Astrom	2013	Wrong setting; excluded its more of developmental defects
Status of dental caries in the toddlers' residences of the Dakar area, Senegal [95]	Cisse D; Diouf M; Faye D; Lo CM; Sembene NM	2009	Wrong age group
The effect of choosing different units of analysis when estimating risk of presence of dental caries in the primary dentition [96]	Scheutz F; Frydenberg M; Matee MI; Poulsen S	2003	Wrong age group
Tooth decay in school environment at Brazzaville (Congo) [97].	Okoko AR; Ekouyabowassa G; Moyen E; Oko AP; Abessou LC; Mbika-Cardorelle A et al.	2013	Wrong age group

(Continues)

TABLE 2 | (Continued)

Title	Authors	Published year	Notes
Prevalence of tooth decay in children from age 3 to 14 at the Department of Odontology of Military Hospital of Bamako (IHB) in Mali [98]	Kane A; Diawara O; Niang A; Mariko D; Diallo B; Diarra D; Togo AK; Maiga AS; Diaby LM; Sanogo A; Bertha; Traora	2018	Wrong age group
Caries and gingivitis study among preschool children (2–5 years) of the region of Ziguinchor in Senegal. Strategies of prevention [99]	Yam AA; Ba M; Faye M; Sane DD	2000	Wrong indication
Oral Health Inequalities between Rural and Urban Populations of the African and Middle East Region [100]	Ogunbodede EO; Kida, IA; Madjapa HS; Amedari M; Ehizele A; Mutave R; Sodipo, B; Temilola S; Okoye L.	2015	Wrong setting
Dental caries in 6-, 12- and 15-year-old Venda children in South Africa [101]	Bajomo, A.S.; Rudolph, M.J.; Ogunbodede, E.O.	2004	Wrong patient population
Relationship between socio-demographic profile, parity and dental caries among a group of nursing mothers in South East, Nigeria [102]	Onyejaka NK; Eboh OF; Amobi EO; Nwamba NP.	2021	Wrong patient population
Dental caries management at a rural district hospital in northern Rwanda: a neglected disease [103]	Mukashyaka C; Uzabakiriho B; Amoroso C L; Mpunga T; Odhiambo J; Mukashem, P; Seymour BA; Sindayigaya J de D; Hedt-Gauthier B L	2015	Wrong setting; 100% caries prevalence, no dmft
Long-term effects of a randomised maternal education trial in rural Uganda: implications for child oral health [104]	Engh MS; Muhooz, GKM; Ngari M; Skaare AB; Westerberg AC; Iversen PO; Brusevold IJ; Atukunda P	2022	Wrong patient population; 7-year olds
Epidemiological profile of patients utilising dental public health services in the eThekwini and uMgungundlovu districts of KwaZulu-Natal province, South Africa [105]	MthethwaJM; Mahomed OH; Yengopal V.	2020	Wrong setting
Trends in dental caries prevalence and severity in South Africa [106]	Van Wyk, Candice	2007	Thesis
Characteristics of children under 6 years of age treated for early childhood caries in South Africa [107]	Mohamed, Nadia; Barnes, Jo	2008	Wrong outcomes; No prevalence done in this study
The prevalence of early childhood caries in the Southern Cape Karoo region [108]	Jacobs, Theodore Konrad	2006	Thesis
Dental caries experience and associated risk factors among pre-school going children in Bureti Sub-County, Kericho County, Kenya [109]	Masinde, David; Cheruiyot, Japheth		Thesis
The prevalence of dental caries and fluorosis among 5–7-year-old children in Ga-Rankuwa, South Africa: A descriptive study [110]	Kallner, Emma; Blomquist, Evelina	2016	Thesis
Caries experience of preschool children in selected sites in Johannesburg [111]	Kalil, Abdalraof Benaessa	2017	MSc Thesis
Dental caries experience and molar-incisor hypomineralisation in children: pattern and severity [112]	Oyedele, Titus Ayodeji; Chukwumah, Nneka Maureen; Adeyemo, Yewande Isabella	2020	Wrong patient population, dmft combined
Early childhood caries and feeding practices in kindergarten children [113]	Qadri G; Nourallah A; Splieth CH.	2012	Wrong setting

(Continues)

TABLE 2 | (Continued)

Title	Authors	Published year	Notes
Dietary intakes and caries experience in children in Limpopo Province, South Africa [114]	MacIntyre U. E.; du Plessis, J. B.	2006	Wrong age group
Caries prediction factors in children with primary dentition [115]	Botha, FS; Botha SJ; Kroon J; Steyn PL	2001	No full text
Early childhood caries among 3–5-year olds and their Caregivers' oral health knowledge, attitude and practice in Kiambaa division, Kenya [116]	Njoroge NW	2007	Thesis
Association between maternal socioeconomic factors, decision-making status, and dental utilisation by children with early childhood caries in sub-urban Nigeria [38]	Folayan, Alane, Adeniyi et al.	2020	Same as previous published study
Malnutrition, enamel defects, and early childhood caries in preschool children in a sub-urban Nigeria population [58]	Folayan, El Tantawi, Oginni et al.	2020	Same as previous published study
Association between nutritional status and early childhood caries risk profile in a suburban Nigeria community [117]	Folayan, Oginni, El Tantawi et al.	2020	Same as previous published study

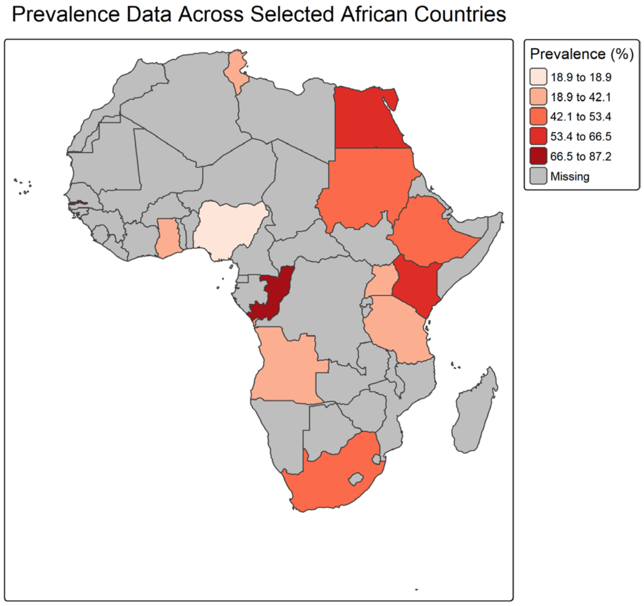

FIGURE 2 | GIS map of caries prevalence across Africa.

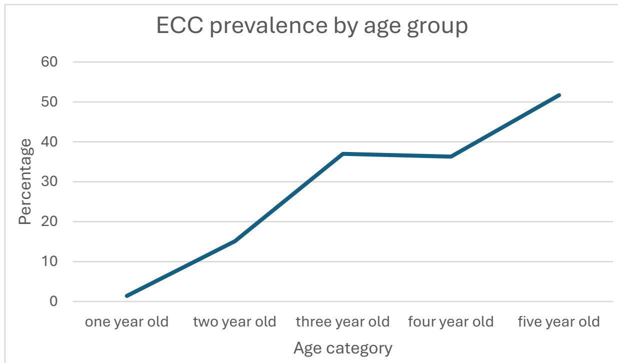

FIGURE 3 | ECC prevalence by age.

TABLE 3 | Caries prevalence by age.

Age	Prevalence
1-year old	1.4% (95% CI: 0.85% to 1.9%)
2-year old	15.1% (95% CI: 7.7% to 22.5%)
3-year old	37.0% (95% CI: 25.7% to 48.4%)
4-year old	36.3% (95% CI: 23.3% to 49.1%)
5-year old	51.7% (95% CI: 39.7% to 63.7%)

TABLE 4 | Dmft by age.

Age group	Dmft (95% CI)
1-year old	—
2-year old	—
3-year old	1.22 (95% CI 0.86–1.59)
4-year old	1.50 (95% CI: 1.12–1.88)
5-year old	2.22 (95% CI: 1.65–2.78)

TABLE 5 | Caries prevalence by year category.

Year category	Prevalence
2000–2004	39.7% (95% CI: 23.4–56)
2005–2009	45.3% (95% CI: 30.1–55.3)
2010–2014	45.8% (95% CI: 30.1–55.3)
2015–2019	32.1% (95% CI: 21.4–42.8)
2020–2024	22.2% (95% CI: 11.9–32.4)

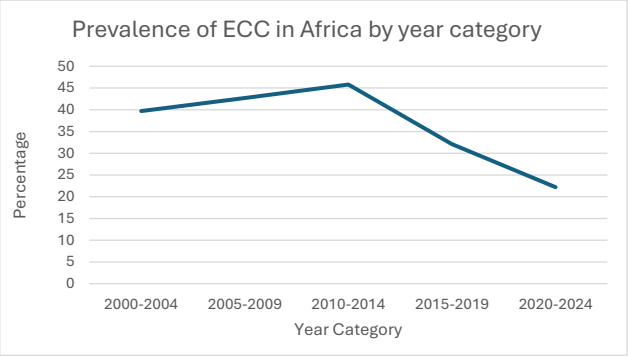

FIGURE 4 | Caries prevalence by year category.

carbohydrates in rural areas and possibly more healthy food options than in high socio-economic communities. This also highlights the multi-causal aetiology of dental caries and early childhood caries in particular, as reported by Folayan et al. [123].

Since African countries are very diverse, it was expected to have a different prevalence rates in different countries. There are 54 countries in Africa according to the UN, and of these, only 13 countries had data on ECC. The prevalence of caries in males was highest in Egypt (60.2%) followed by Sudan (53%). Nigeria had the lowest prevalence of 6.2%. The low caries prevalence rate in Nigeria could be as a result of the diet and oral hygiene practices of children attending preschools [124].

There was not much difference between the urban and rural prevalence rates, and this could indicate that in many African countries, the diet and oral health knowledge are similar across the two sectors. This was surprising, as many studies have indicated a difference in the urban and rural settings. The results from this systematic review highlight the need for more studies to be done in order to compare the differences, if any, regarding the urban–rural environments. In Africa, there has been major growth and development across the continent, with many communities being exposed to refined diets and a more modern

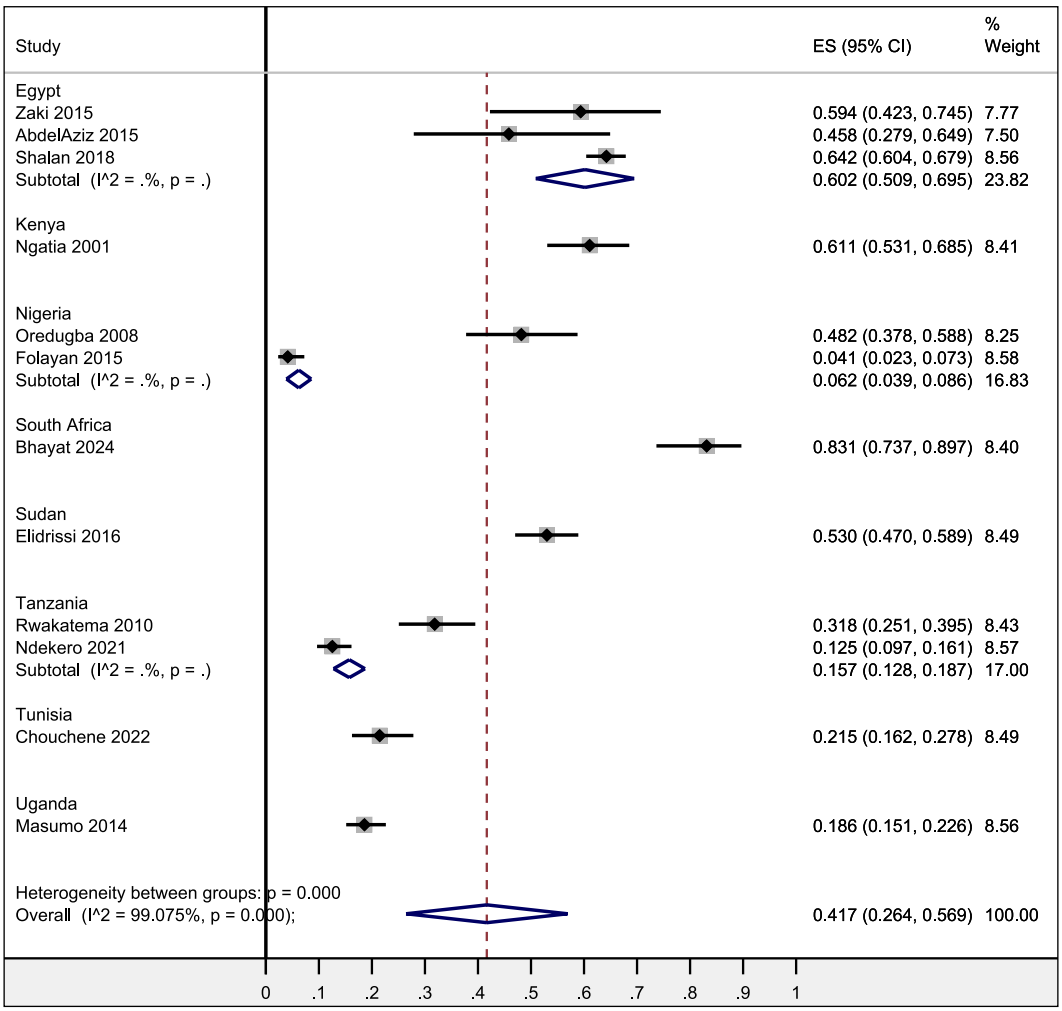

FIGURE 5 | Prevalence of early childhood caries in males.

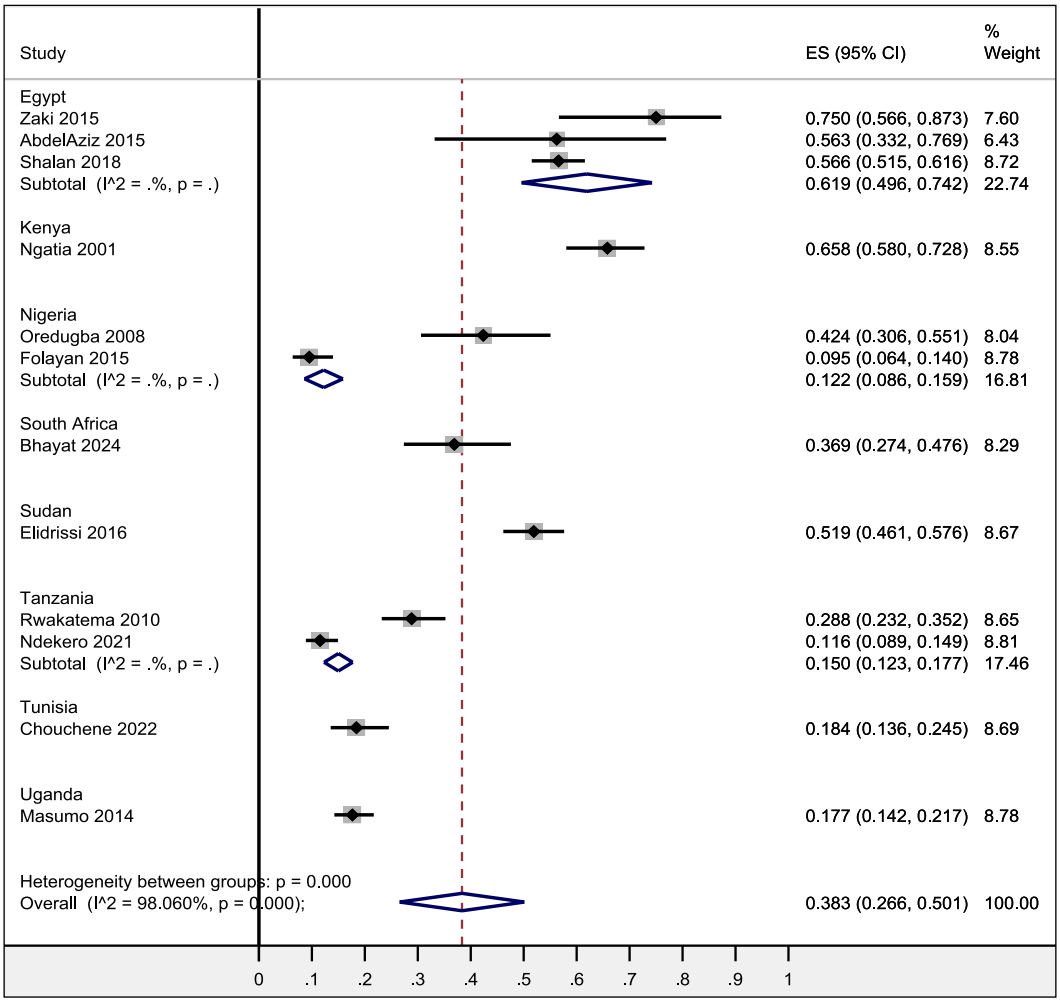

FIGURE 6 | Prevalence of early childhood caries in females.

lifestyle. There is also a lot of migration from rural to urban communities, and these factors could be responsible for the homogenous results identified [125].

Upper middle-income countries had the lowest dmft (1.64) score compared to the lower income (1.86) and lower middle-income countries (2.06). This could be due to a lack of access to oral health services, a lack of human resources, and poor diets, which are generally more prevalent in lower income countries compared to middle income countries [126].

Females tended to have a higher prevalence of caries compared to males. This was in contrast to results from other systematic reviews [121, 127], which reported males having a non-significantly higher prevalence than females. The difference in these results could be attributed to the study population and the fact that the teeth erupt earlier in females than in males.

Although the results of this study are not representative of the continent as it includes studies from only 13 countries, these results need to be interpreted with caution. All of the studies were cross-sectional in design; hence, no causal relationship could be identified. However, since the aims were to gather prevalence data, these cross-sectional designs were adequate and appropriate for the purpose.

In addition, due to limited resources, only articles published in the English and Arabic languages were included. The limitation is that many studies published in other languages have been excluded; hence, the results are not entirely generalisable to the continent.

The WHO has suggested various interventions to address ECC, which include the implementation of fluoride varnish applications, caries risk assessments, behavioural interventions that can impact on preventive self-care patterns and of brushing with fluoride toothpaste [128]. In addition, the WHO also recommends a 'shift from a more curative to a predominantly preventive approach' which could reduce the prevalence of ECC. These programmes, however, need to be implemented at crèches and ante-natal facilities so that young children are prevented from developing ECC. Unfortunately, it is unknown what intervention and curative programmes countries have in place to deal with the high disease burden.

The overall prevalence of ECC was relatively high in Africa. This indicates that even though many countries have preventive programmes, the impact is minimal. Further studies need to be done on those with high—compared to those with low—prevalence rates to determine the most effective interventions that countries have in place. The results of this review are useful to map countries with high ECC and to assist in the planning and policy development for different countries.

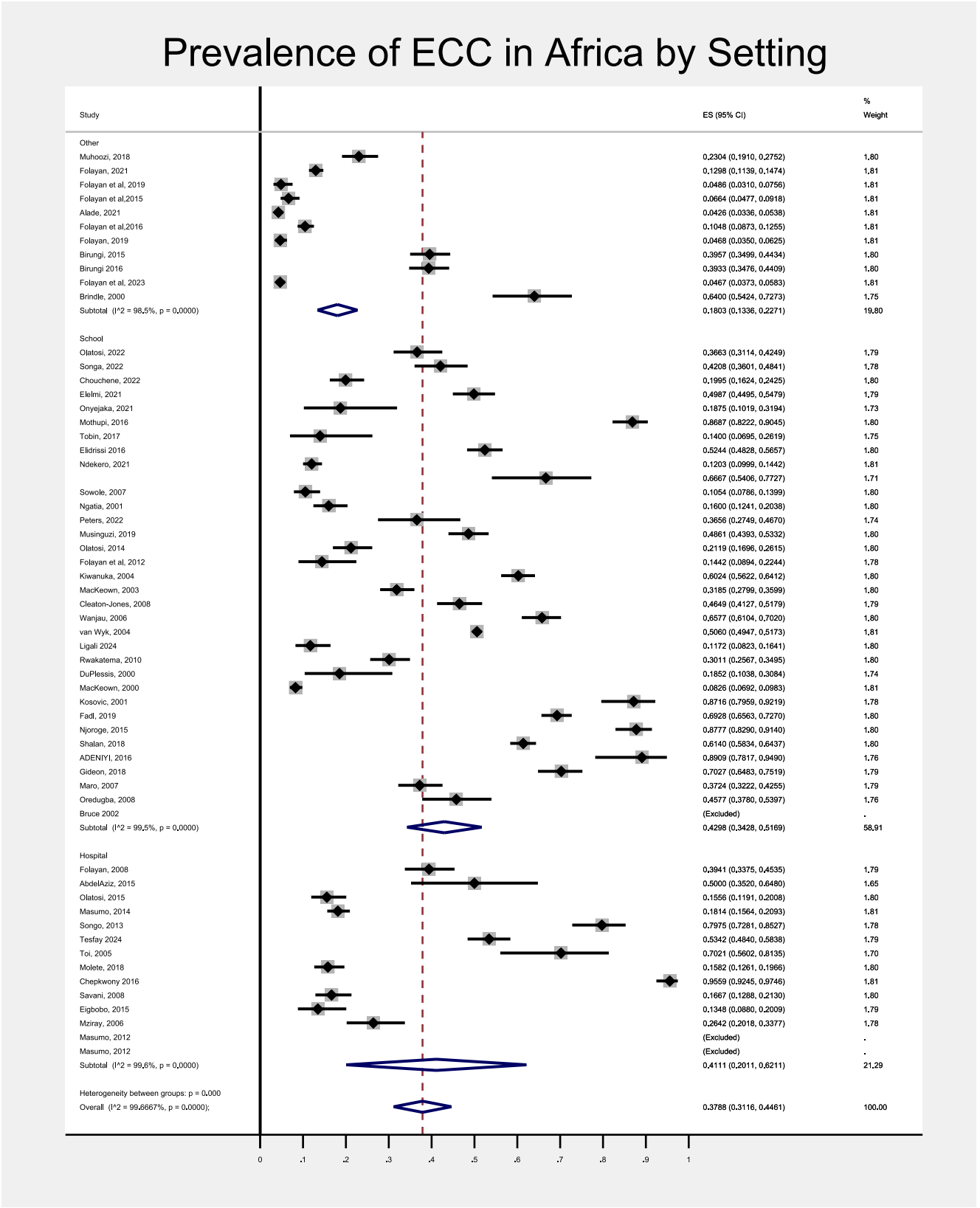

FIGURE 7 | Prevalence of early childhood caries by setting.

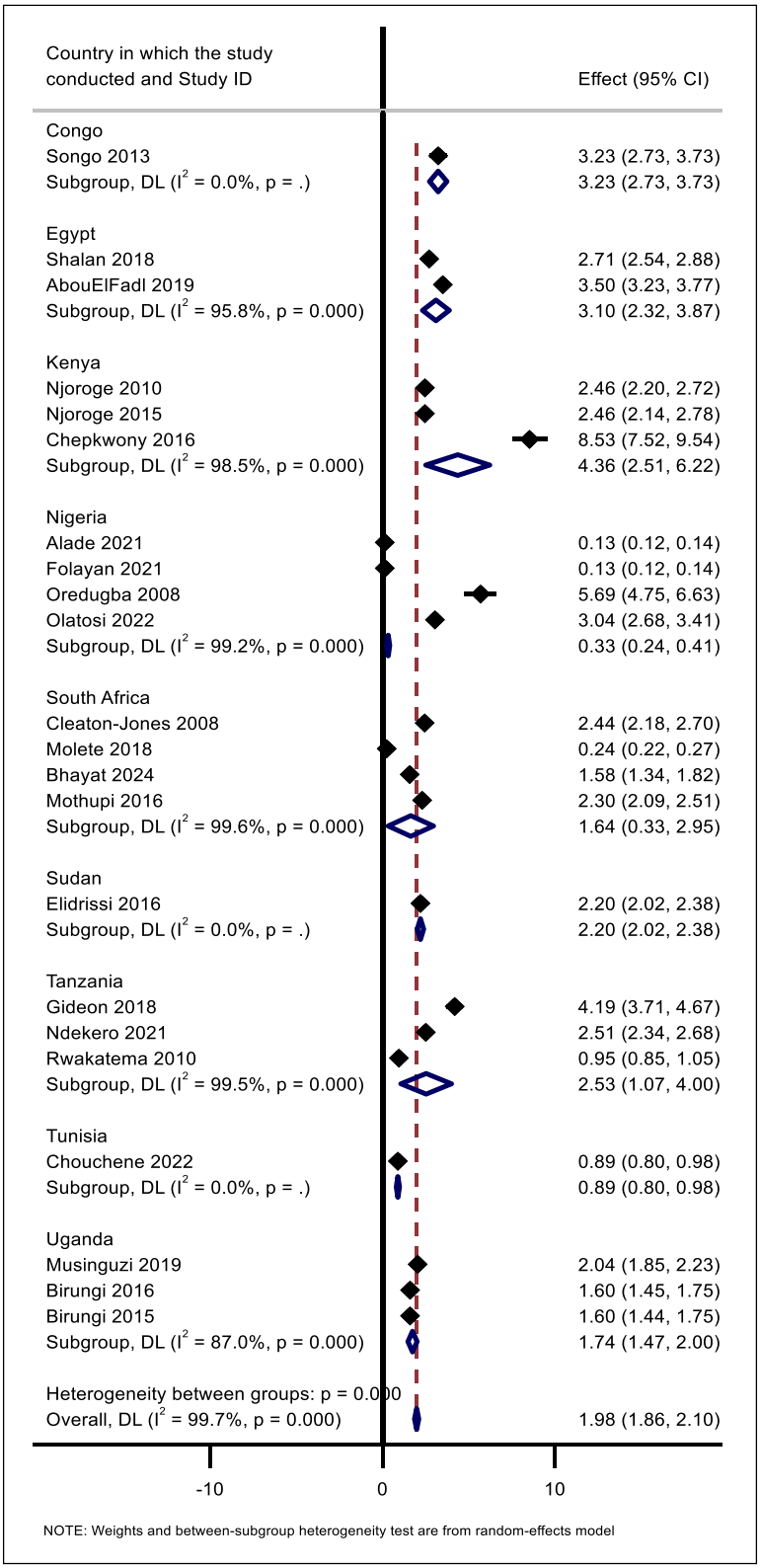

FIGURE 8 | Dmft by country.

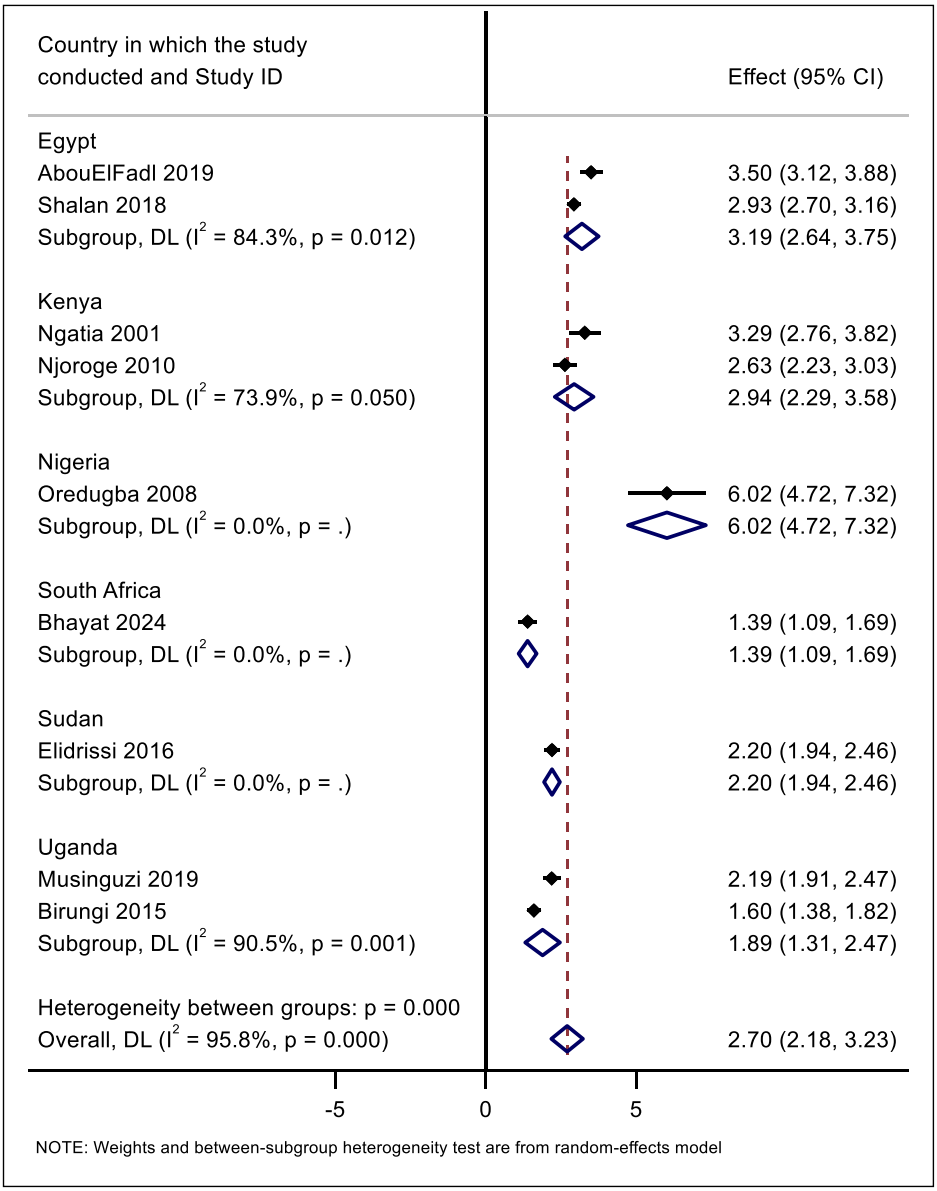

FIGURE 9 | Dmft of males.

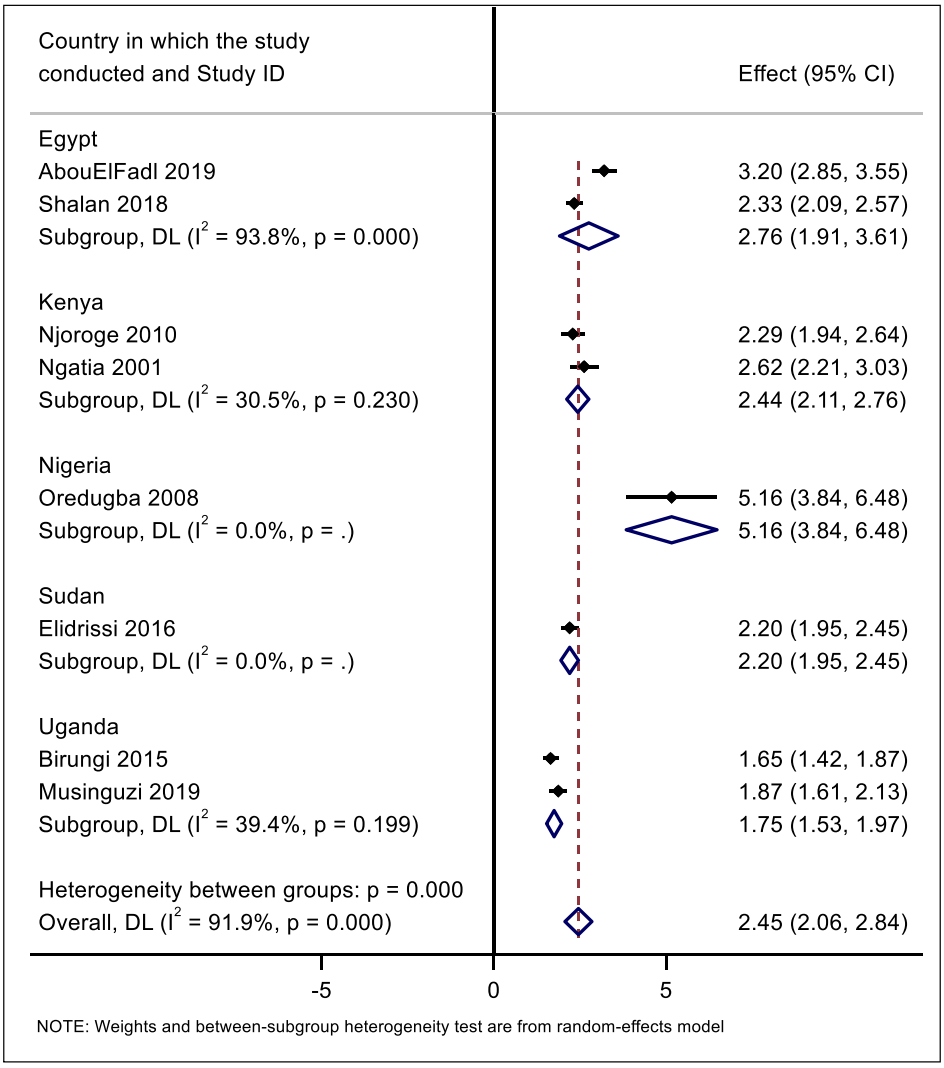

FIGURE 10 | Dmft of females.

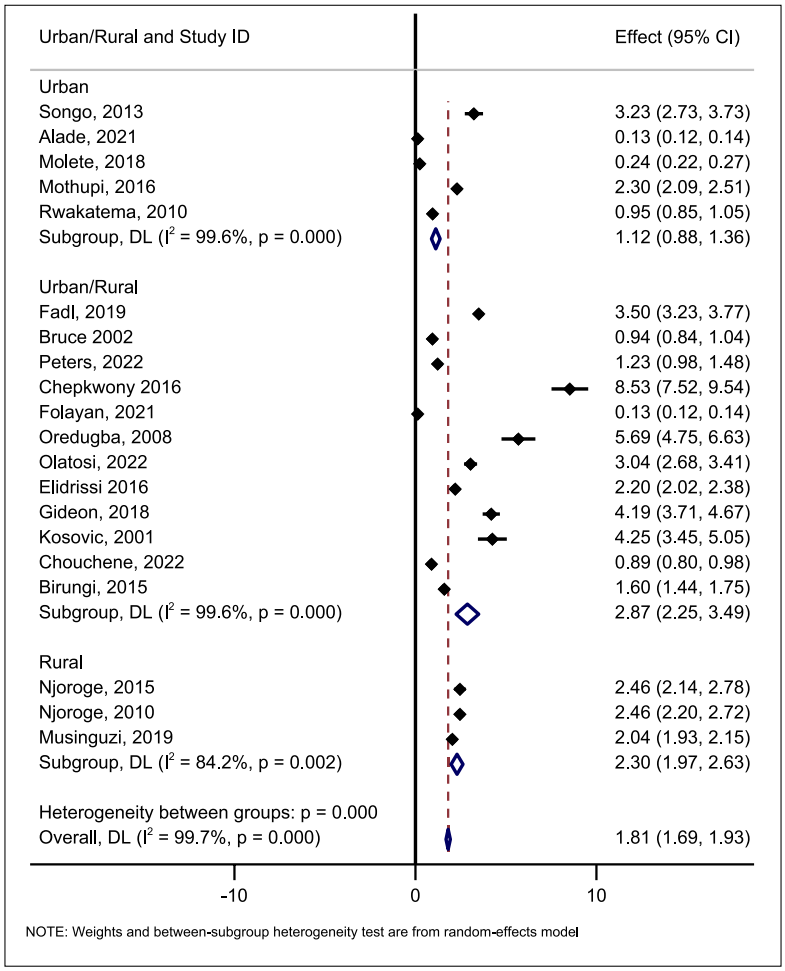

FIGURE 11 | Dmft by setting (urban and rural).

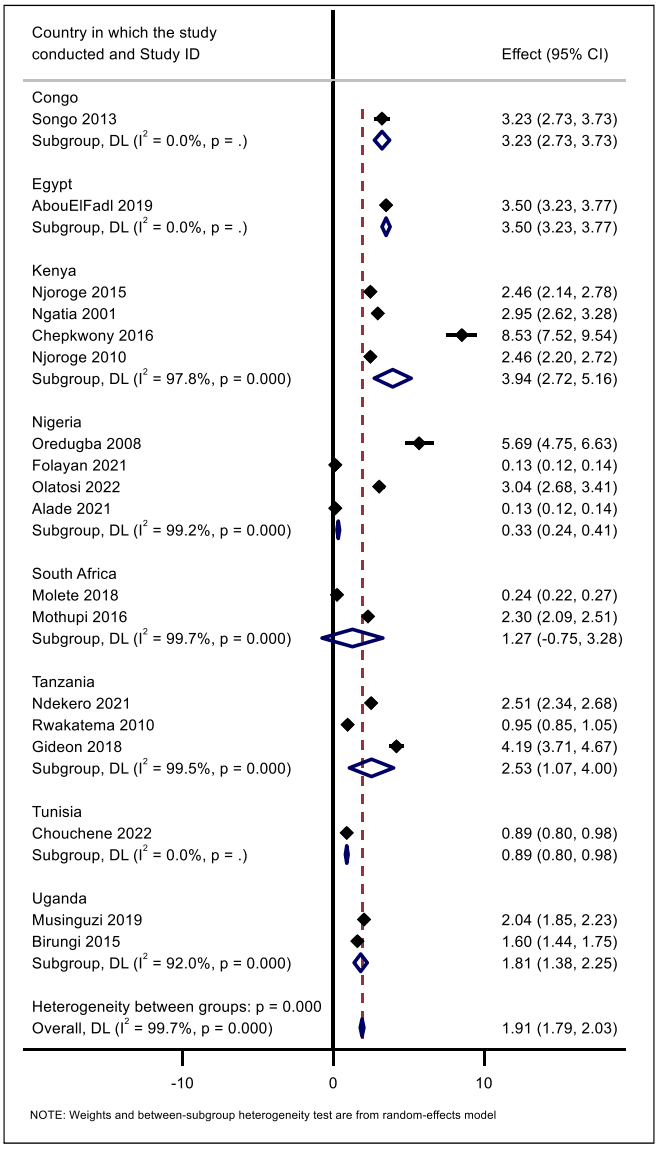

FIGURE 12 | Dmft of children in Africa by country.

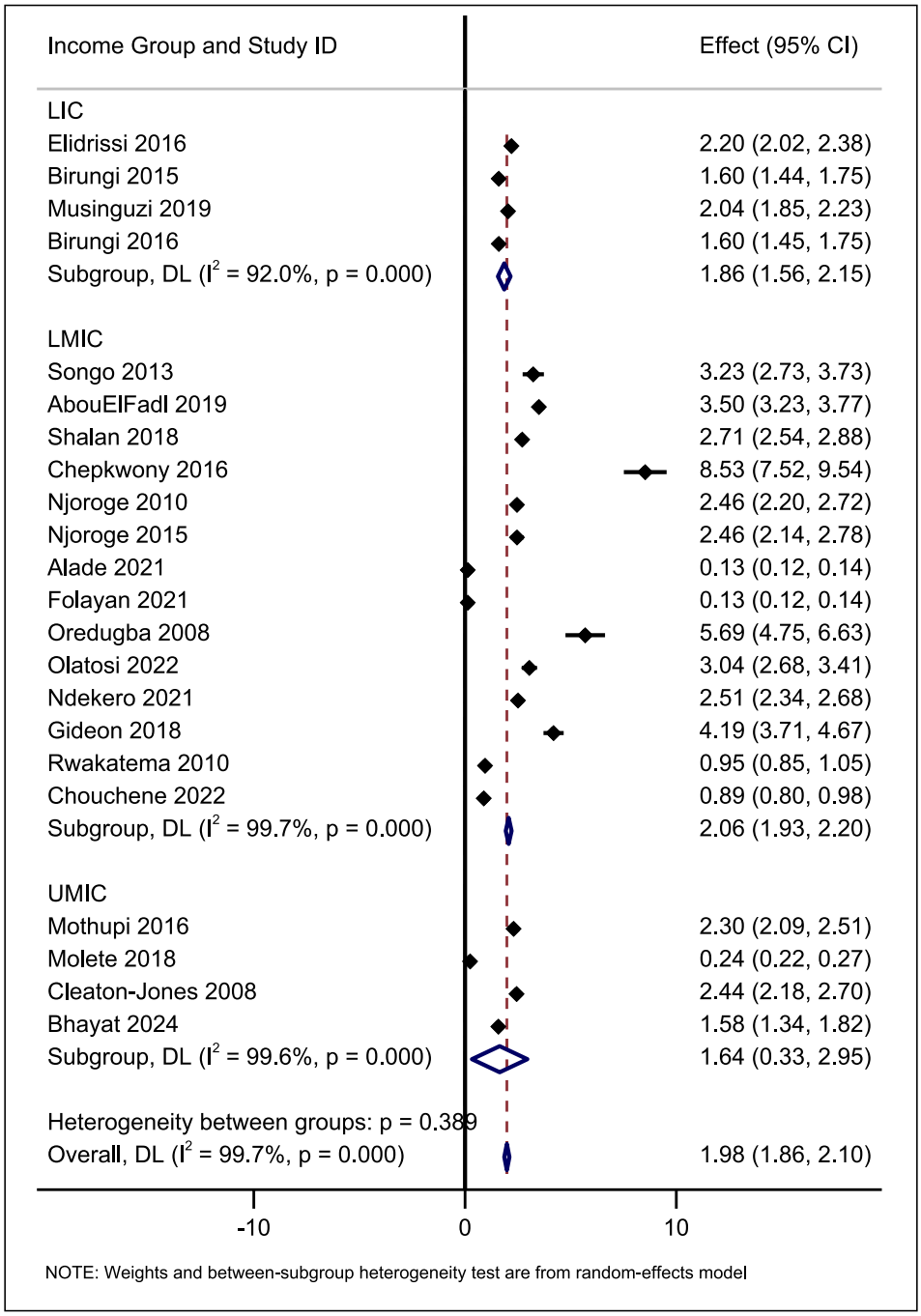

FIGURE 13 | Dmft by income group.

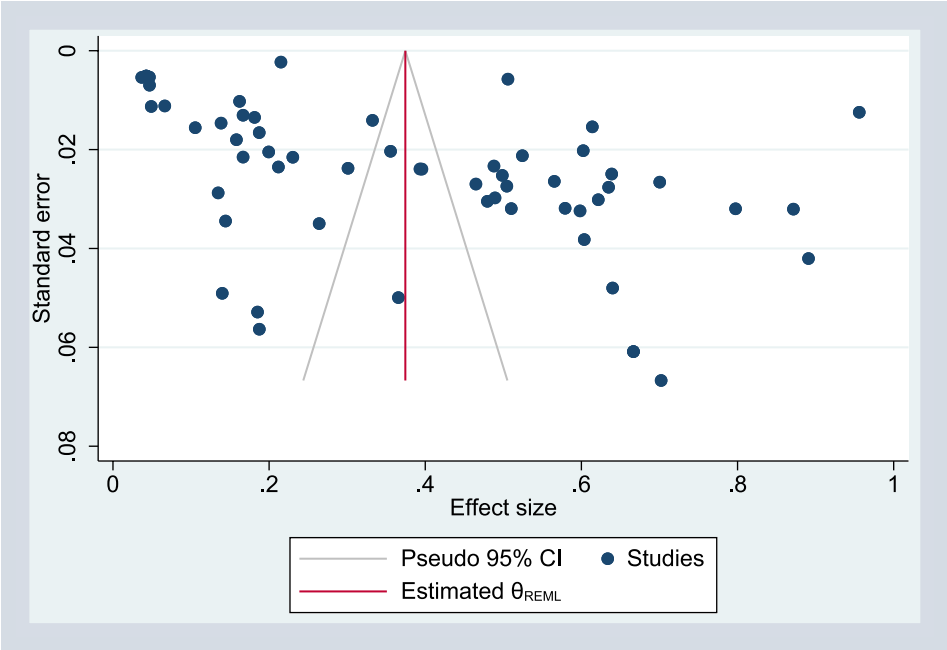

FIGURE 14 | Funnel plot showing publication bias for prevalence of early childhood caries.

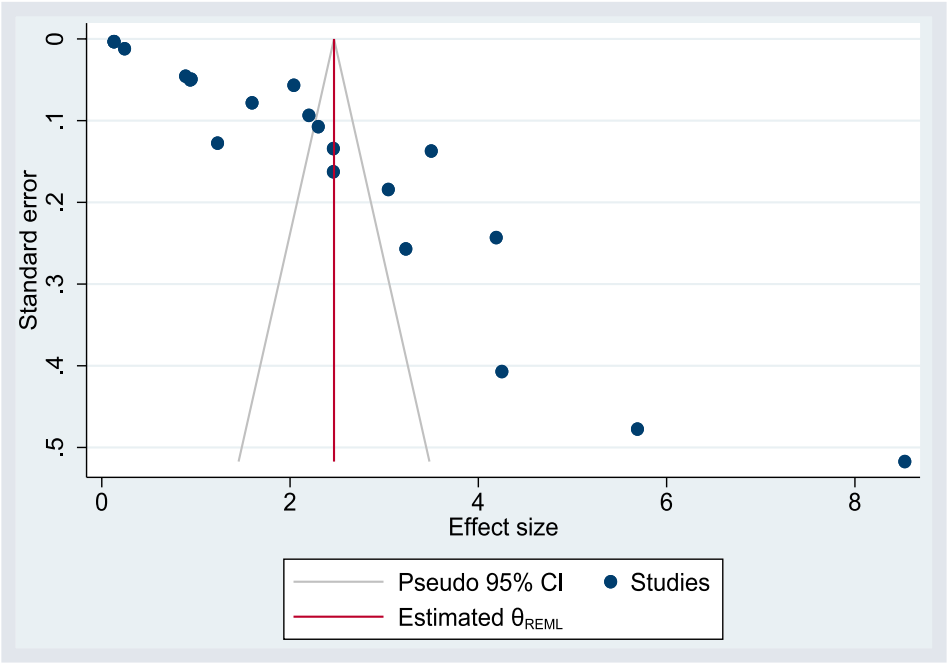

FIGURE 15 | Funnel plot showing publication bias for dmft scores.

Study ID	Country	Setting	Urban/rural	Study design	Population description	*n*
Folayan et al. 2021 [129]	Global	Other	Urban/rural	Ecological	Children 3–5 years	10 581
Bruce 2002 [130]	Ghana	School/crèche/ preschool	Urban/rural	Cross-sectional study	4–16-year-old children	352
Songa 2022 [66]	Angola	School/crèche/ preschool	Urban	Cross-sectional study	Children aged 5 and 12 years in public schools in Benguela	
Songo 2013 [40]	Congo	Hospital	Urban	Cross-sectional study		710
Shalan 2018 [19]	Egypt	School/crèche/ preschool	Rural	Cross-sectional study	One thousand children aged 3–6 years attending private and public kindergarten were included in the study	1000
Hamza et al. 2021 [24]	Egypt	Other	Urban/rural	Cross-sectional study	3 to 6 years	201
Fadl 2019 [75]	Egypt	School/crèche/ preschool	Urban/rural	Cross-sectional study	Preschool children 3–6 years	651
Abbass 2019 [131]	Egypt	Hospital	Urban/rural	Cross-sectional study	Children	113
AbdelAziz 2015 [51]	Egypt	Hospital	Urban/rural	Cross-sectional study	2–6-year olds with primary dentition	60
Zaki 2015 [56]	Egypt	School/crèche/ preschool	Urban	Cross-sectional study	Sixty healthy children recruited from the outpatient clinic of the Paediatric Dentistry Department at the Faculty of Dentistry (Dental School), Alexandria University, Egypt	60
Kosovic 2001 [26]	Gambia	School/crèche/ preschool	Urban/rural	Cross-sectional study	Children from urban and rural schools	109
Peters 2022 [49]	Ghana	School/crèche/ preschool	Urban/rural	Cross-sectional study	Ghanaian children aged 3 to 13 years in an urban and rural study population and to consider the effects of different associated factors on caries values	313
Cheruiyot 2019 [21]	Kenya	School/crèche/ preschool	Urban/rural	Cross-sectional study	Children 3.6 years	371
Chepkwony2016 [22]	Kenya	Hospital	Urban/rural	Cross-sectional study	Children	272
Njoroge 2015 [23]	Kenya	School/crèche/ preschool	Rural	Cross-sectional study	Three hundred and forty-three caregivers participated in the study. A pre-tested self-administered questionnaire on the causes of dental caries was sent to the caregivers, and 67% of them were returned	229
Njoroge 2010 [53]	Kenya	School/crèche/ preschool	Rural	Cross-sectional study	Stratified random sampling method was used to select public and private schools	336
Ngatia 2001 [54]	Kenya	School/crèche/ preschool	Urban	Cross-sectional study	Nursery school children in Nairobi, Kenya	325
Macigo 2016 [62]	Kenya	Other	Urban/rural		Children 3–15 years	

Study ID	Country	Setting	Urban/rural	Study design	Population description	*n*
Oredugba 2008 [15]	Nigeria	School/crèche/ preschool	Urban/rural	Cross-sectional study	Participants were children 18–71 months old who attended the paediatric dental clinics of the Lagos University Teaching Hospital, Massey Street Children Hospital and the Lagos State University Teaching Hospital, Lagos. Controls were children without caries matched for age and sex attending the Teaching Hospital crèche, the nursery/ kindergarten and primary schools of the University Staff School and a neighbouring private school	142
Eigbobo 2015 [79]	Nigeria	Hospital	Urban/rural	Cross-sectional study	Children 1–16 years	334
Adeniyi 2016 [76]	Nigeria	School/crèche/ preschool	Urban/rural	Cross-sectional study	Children 5–10 years	55
Folayan et al. 2023 [132]	Nigeria	Other	Urban/rural	Observational	Children	1564
Folayan 2020 [38]	Nigeria	Other	Urban/rural	Cross-sectional study	Children 6–71 months	1549
Folayan 2019 [81]	Nigeria	Other	Urban/rural	Cross-sectional study	3–5-year children	918
Folayan et al. 2016 [42]	Nigeria	Other	Urban/rural	Secondary analyses	1–12-year-old children	992
Folayan et al. 2012 [44]	Nigeria	School/crèche/ preschool	Urban/rural	Cohort study	Children 2–10 years	251
Olatosi 2014 [45]	Nigeria	School/crèche/ preschool	Urban	Cross-sectional study	Children attending immunisation and Well baby clinics at LUTH into the study	302
Olatosi 2015 [47]	Nigeria	Hospital	Urban	Cross-sectional study	Children aged 6–71 months were selected from four paediatric outpatient clinics in Lagos, Nigeria	302
Alade 2021 [50]	Nigeria	Other	Urban	Cross-sectional study	The sample recruited children 6–71 months old who were living with their biological parents or legal guardians at Ife Central Local Government Area of Osun State, Nigeria and who were both at home at the time the data was collected	1549
Folayan 2008 [52]	Nigeria	Hospital	Urban/rural	Cross-sectional study	Children	269
Sowole 2007 [55]	Nigeria	School/crèche/ preschool	Urban/rural	Cross-sectional study	Children between the ages of 6 and 71 month	389
Tobin 2017 [59]	Nigeria	School/crèche/ preschool	Urban/rural	Cross-sectional study	The study was carried out on several sites in Ilorin West (urban) and Irepodun (rural) local government areas (LGAs) of Kwara State	50
Folayan et al. 2015 [80]	Nigeria	Other	Urban/rural	Cross-sectional study	Children aged 6 months to 71 months	497

Study ID	Country	Setting	Urban/rural	Study design	Population description	*n*
Onyejaka 2021 [61]	Nigeria	School/crèche/ preschool	Urban	Cross-sectional study	The study population consisted of children attending private and public primary schools in Enugu East Local Government Area of Enugu metropolis	48
Folayan et al. 2019 [133]	Nigeria	Other	Urban/rural	Cross-sectional study	Children 6 months to 71 Months	370
Olatosi 2022 [67]	Nigeria	School/crèche/ preschool	Urban/rural	Cross-sectional study	1 public school and 1 private school were selected from each of the random LGAs using simple random sampling from the list of government-registered nursery and primary schools	273
Daouda 2016 [77]	Senegal	School/crèche/ preschool	Urban/rural	Cohort study	Children residing in developing countries	171
Mndzebele 2014 [74]	South Africa	Hospital	Urban/rural	Cross-sectional study	The population in the study constituted of children, males and females less than 6 years attending Paediatric Out-Patient Department (POPD) at Tembisa hospital	245
MacKeown 2000 [27]	South Africa	School/crèche/ preschool	Urban	Cohort study	The subject sample reported in this paper consisted of all urban black children participating in the BTT Study that had both nutrition and dental information from the 1991 and/or 1995 interceptions ($n = 1639$)	1639
Brindle 2000 [28]	South Africa	Community-based survey (School and household groups)	Rural	Cross-sectional study	Children 5 years	100
Toi 2005 [29]	South Africa	Hospital	Urban			
du Plessis 2000 [78]	South Africa	School/crèche/ preschool	Urban/rural	Cross-sectional study	4-year-old school children	54
Cleaton-Jones 2000 [31]	South Africa	School/crèche/ preschool	Urban	Cross-sectional study		6843
van Wyk 2004 [35]	South Africa	School/crèche/ preschool	Urban/rural	Cross-sectional study	All nine provinces of south Africa. 4 to 5, 6 to 12- and 15-year-old south African school children.	7555
Wanjau 2006 [37]	South Africa	School/crèche/ preschool	Urban/rural	Cross-sectional study	269 children between 3 and 5 years	409
Cleaton-Jones 2008 [39]	South Africa	School/crèche/ preschool	Urban	Cross-sectional study	Nursery school children 7185 2- to 5-year-old children whose parents had given informed consent	7185
MacKeown 2003 [134]	South Africa	School/crèche/ preschool	Urban	Cohort study	Urban black South African children	259
Mothupi 2016 [135]	South Africa	School/crèche/ preschool	Urban	Cross-sectional study	This was a cross-sectional descriptive study with a population of 4–6-year-old children attending preschools in Gauteng province, South Africa	459

Study ID	Country	Setting	Urban/rural	Study design	Population description	*n*
Molete 2018 [25]	South Africa	Hospital	Urban	Cross-sectional study	Mother and child pairs who attended the Diepsloot and Vanderbijlpark clinics Mother and Child programmes in 2015. The ages of the children ranged between 6 months and 6 years	446
Elidrissi 2016 [136]	Sudan	School/crèche/ preschool	Urban/rural	Cross-sectional study	3- to 5-year-old pre-school children in Khartoum State, Sudan	553
Mziray, 2006 [16]	Tanzania	Hospital	Urban	Cross-sectional study	Children aged 6–36 months, where parents guardian 16–55 years old attending the reproductive and child health clinic, Mnazi Mmoja dispensary, Dar es Salam. 127 participant was required. a total 159 mothers/ guardian aged 16–55 years and their 159 children aged 6–36 month participated	159
Maro 2007 [17]	Tanzania	School/crèche/ preschool	Urban/rural	Cross-sectional study	2–6-year-old underprivileged and privileged	333
Gideon 2018 [18]	Tanzania	School/crèche/ preschool	Urban/rural	Cross-sectional study	Preschool children aged 36–72 months attending informal schools in Tandale Ward and their caregivers were eligible to take part in the study	297
Savani 2008 [20]	Tanzania	Hospital	Urban	Cross-sectional study		300
Rwakatema 2010 [32]	Tanzania	School/crèche/ preschool	Urban	Cross-sectional study	A total of 372 children selected agreed to participate for clinical examination. Based on a previous report of ECC in a Tanzanian population, this number constituted a representative sample. This sample constituted about 4% of all 3–5-year olds in Moshi municipality. The subjects were randomly selected from all 57 pre-primary nursery schools in Moshi municipality to increase chances of ample representativeness. Moshi municipality had about 10 000 children aged 3–5 years. In each pre-primary nursery school subjects aged 3–5 year	372
Ndekero 2021 [57]	Tanzania	School/crèche/ preschool	Urban/rural	Cross-sectional study	831 children registered in public preschools in Kisarawe District, one of the 6 districts in the Pwani Region of Tanzania.	831
Elelmi 2021 [63]	Tunisia	School/crèche/ preschool	Urban/rural	Cross-sectional study	3–5-year-old children	393
Chouchene 2022 [65]	Tunisia	School/crèche/ preschool	Urban/rural	Cross-sectional study		381
Birungi 2016 [34]	Uganda	Other	Urban/rural	Cohort study	Caretaker-children	417
Birungi 2015 [36]	Uganda	Villages	Urban/rural	Randomised controlled trial	Mother and infant breastfeeding pairs	417

Study ID	Country	Setting	Urban/rural	Study design	Population description	*n*
Masumo 2014 [41]	Uganda/ Tanzania	Hospital	Urban/rural	Cross-sectional study	6–36-month olds in Uganda arrived at the RCH Kibuli and Naguru clinics	816
Kiwanuka 2004 [43]	Uganda	School/crèche/ preschool	Urban	Cross-sectional study	3–5 years old children and their caregivers	589
Musinguzi 2019 [137]	Uganda	School/crèche/ preschool	Rural	Cross-sectional study	The study population was drawn from the 25 primary schools in Nyakagyeme Sub-county each with pre-primary/nursery section.	432
Muhoozi 2018 [68]	Uganda	Household survey	Rural	Randomised controlled trial	Low-resource settings including rural sub-Saharan Africa. trial was conducted in Kabale and Kisoro districts in South-Western Uganda because of the high levels of child stunting reported in that region	382
Masumo 2012 [33]	Tanzania	Hospital	Urban/rural	Cross-sectional study	Children under the age of 5 from urban and rural settings	1221
Adugna 2024 [69]	Ethiopia	School	Urban	Cross-sectional study	Children under the age of 5 from urban and rural settings	816
Tesfay 2024 [70]	Ethiopia	Hospital	Urban	Cross-sectional study	Preschool children and parents	354
Attia 2024 [71]	Egypt	School/crèche/ preschool	Rural	Case control study (not in meta-analysis only)	Children between 12 and 36 months with 2 teeth	380
Ligali 2024 [72]	Nigeria	School/crèche/ preschool	Urban/rural	Cross-sectional study	Children between 3 and 5 years old	186
Bhayat 2024 [73]	South Africa	School/crèche/ preschool	Rural	Cross-sectional study	Children between 2 and 5 years old	239

Abbreviations: *n*, total number of participants; study ID, study identification.

Author Contributions

N.S., A.B. and F.K.-D.: conceived the ideas; N.S., A.B., H.A., Z.N. and F.K.-D.: collected the data; F.K.-D. and A.B. analysed the data; and N.S., A.B., H.A., Z.N. and F.K.-D.: led the writing.

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Ethics Statement

Approval number: BM 23/5/2.

Conflicts of Interest

The authors declare no conflicts of interest.

Data Availability Statement

The data that support the findings of this study are available on request from the corresponding author. The data are not publicly available due to privacy or ethical restrictions.

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