UNIVERSITÄT BERN

Graduate School for Health Sciences

University of Bern

Oral Health, Nudge Theory and Migrants

PhD Thesis submitted by

Seyed Ahmad Banihashem Rad

for the degree of

PhD in Health Sciences (Dentistry)

Thesis advisor
Prof. Dr. Guglielmo Campus
Department of Restorative, Preventive and Pediatric Dentistry
School of Dental Medicine, University of Bern

Co-thesis advisor
Prof. Dr. Marcella Esteves-Oliveira
Department of Restorative, Preventive and Pediatric Dentistry
School of Dental Medicine, University of Bern

Co-referee
Prof. Dr. Gail V A Douglas
Department of Dental Public Health
School of Dentistry, University of Leeds

Accepted by the Faculty of Medicine and the Faculty of Human Sciences of the University of Bern

Bern, Dean of the Faculty of Medicine

Bern, Dean of the Faculty of Human Sciences

For the Children.

Abstract

Background and Aims: Oral health significantly impacts overall well-being but remains one of the most neglected aspects of health, especially among marginalized populations. This PhD thesis had three primary aims: first, to assess the global prevalence of oral diseases among immigrants and refugees (Publications 1 and 2); second, to explore the potential applications of Nudge theory in oral health promotion (Publication 3); and third, to evaluate the effectiveness of Nudge theory-based interventions in improving oral self-care among schoolchildren with refugee and immigrant backgrounds through a field trial (Publication 4).

Methods: The first two studies (Study 1 and 2) were scoping reviews conducted following PRISMA guidelines to evaluate the global prevalence of dental caries and periodontal diseases among immigrants and refugees. Study 3 was a critical review utilizing Daly and Carnwell's framework. The reviews used, data from specific online databases (i.e., Scopus, Embase, and PubMed). Study 4 was a quasi-experimental field trial involving 309 schoolchildren, approximately 9 years old. Interventions using motivational video clips were randomly assigned across three schools: one received messages based on Social Norms (MSN), another on messages of Fear of Negative Outcomes (MFNO), and a control group (C). Baseline plaque index (PI) and caries experience in primary and permanent dentition (dmft/DMFT) were recorded. PI was reassessed at two weeks, two months, and six months post-intervention.

Results: This thesis comprises four published studies with the main findings summarized as follows:

- **Publications 1 and 2:** High prevalence of dental caries and gingivitis was consistently observed among immigrants and refugees, with caries rates varying from 4.6% to 98.7% and gingivitis from 5.7% to 100% across all demographic groups showing high heterogeneity in their oral health, moreover, the data showed a low level of access to dental health services for these population groups.
- **Publication 3:** There is a dearth of studies on behavioral economics, particularly those involving reward and reminder techniques. Despite this, several successful nudge interventions in sectors such as nutrition, tobacco and alcohol cessation, and medication compliance suggest the potential for oral health to benefit from the same cognitive mechanisms as these interventions. These nudges vary significantly in effectiveness depending on the delivery method and the characteristics of the population.
- **Publication 4:** There was a significant reduction in the mean PI across all groups at the two-week follow-up ($p < 0.01$). However, these improvements diminished over six months, with significant long-term benefits observed only in the MSN and MFNO groups ($p < 0.01$). The average decayed, missing, and filled teeth (dmft/DMFT) scores were 4.24 ± 2.11 and 1.70 ± 1.24, respectively, with Afghan children showing significantly higher dmft scores compared to Iranian children ($p = 0.01$). Using the Nudge theory via visual aids was more effective in promoting oral self-care than traditional Oral Health Instruction (OHI), with MSN showing better immediate effects and MFNO demonstrating more long-lasting impacts.

Conclusions: This thesis underscores the urgent need for targeted interventions to address significant oral health disparities among refugees and immigrants, highlighting the necessity for comprehensive studies in diverse

socioeconomic contexts. Nudge theory emerges as a promising strategy to improve oral health behaviors, yet its long-term effectiveness requires further exploration and testing across different populations. To enhance access and outcomes in oral health care for marginalized groups, it is crucial to develop adaptive policies and strategies, to improve oral health of marginalized populations.

Publication 1: Banihashem Rad SA, Esteves Oliveira M, Maklennan A, Castiglia P, Campus G (2023). "Higher prevalence of dental caries and periodontal problems among refugees: A scoping review". *Journal of Global Health, 13:04111*. DOI: 10.7189/jogh.13.04111. PMID: 37712847; PMCID: PMC10503462.

Publication 2: Banihashem Rad SA, Esteves-Oliveira M, Maklennan A, Douglas GV, Castiglia P, Campus G (2024). "Oral health inequalities in immigrant populations worldwide: a scoping review of dental caries and periodontal disease prevalence". *BMC public health*, 24(1):1968. DOI: 10.1186/s12889-024-19354-4.

Publication 3: Kazemian A, Hoseinzadeh M, Banihashem Rad SA, Jouya A, Tahani B (2023). "Nudging oral habits; application of behavioral economics in oral health promotion: a critical review". *Frontiers in Public Health*, 11:1243246. DOI: 10.3389/fpubh.2023.1243246. PMID: 38145077; PMCID: PMC10739307.

Publication 4: Banihashem Rad SA, Esteves-Oliveira M, Kazemian A, Azami N, Khorshid M, Sohrabi A, Attaran Khorasani A, Campus G (2024). "Evaluating the Effectiveness of the Nudge Theory in Improving the Oral Self-Care of Schoolchildren with Refugee and Immigrant Backgrounds in Mashhad, Iran". *Dentistry Journal*, 12(7):228. DOI: 10.3390/dj12070228. PMID: 39057015; PMCID: PMC11276547.

Abbreviations

C	Control
DMFT	Caries Experience in the Permanent Dentition
dmft	Caries Experience in the Primary Dentition
DT	Decayed Teeth in the Permanent Dentition
dt	Decayed Teeth in the Primary Dentition
FDI	World Dental Federation
FT	Filled Teeth in the Permanent Dentition
ft	Filled Teeth in the Primary Dentition
JBI SUMARI	Joanna Briggs Institute System for the Unified Management of the Assessment and Review of Information
MFNO	Messages based on Fear of Negative Outcome
MSN	Messages based on Social Norms
MT	Missing Teeth in the Permanent Dentition
mt	Missing Teeth in the Primary Dentition
NR	Not Reported
OSF	Open Science Framework
OHI	Oral Hygiene Instruction
PI	Plaque Index
PRISMA	Preferred Reporting Items for Systematic Reviews and Meta-Analyses
SD	Standard Deviation
SPIDER	Sample, Phenomenon of interest, Design, Evaluation, and Research type
WHO	World Health Organization

Table of Contents

1. Introduction

1.1 Oral Health: A Critical Component of Global Public Health

Oral health is a fundamental aspect of overall well-being, as it is not only essential for basic functions like eating, speaking, and socializing, but also vital for systemic health. Despite the aforementioned importance, oral health is often neglected in public health policies, particularly among marginalized communities such as immigrants and refugees. It has been documented that poor oral health is associated with systemic diseases such as diabetes, cardiovascular disease, and respiratory infection. (Sabbah et al., 2019). Furthermore, oral conditions often cause pain and disability leading to reduced dietary intake with detrimental consequences on mental status (Skolov et al., 2023), thereby it has a strong bearing on an individual's quality of life. In addition, poor oral health can negatively affect self-confidence and social interaction, further isolating the affected individuals (General, Dental, & Research, 2000).

1.2 Disparities in Global Oral Health

Oral diseases, namely dental caries, periodontal diseases and oral cancer, are the most common non-communicable diseases worldwide. The World Health Organization (WHO) reports that nearly 3.5 billion people—approximately half of the global population—suffer from oral diseases, with a disproportionate 75% of affected individuals living in middle-income countries (WHO, 2023). It has been reported that socioeconomic disparities significantly affect accessibility to oral health services, with low-income countries experiencing accessibility rates of 35%, lower-middle-income countries reaching 60%,

upper-middle-income countries reaching 75%, and high-income countries reaching 82% (Hosseinpoor et al., 2012). Higher prevalence rates particularly among low-and middle-income countries have been reported for dental caries and periodontal diseases (Cherian et al., 2023). Notably, regional disparities are evident, as Asia reports a higher prevalence of untreated dental caries compared to Europe (WHO, 2023).

1.3 Impact and Challenges of Global Migration

According to the International Organization for Migration (IOM), a refugee is an individual outside the country of his/her nationality and unable to benefit from its protection (Perruchoud et al. 2004). All refugees were once asylum seekers; although the two terms were often used interchangeably, they are not synonymous. Asylum-seekers are people seeking international protection but have not yet been legally recognized as refugees. On the other hand, an immigrant is someone who voluntarily moves to a new country, whereas a refugee is an individual who is compelled to leave the country of origin. There is a profound impact of migration on societies, economies, and cultures across the globe, and it is emerging as a key factor in global dynamics (Wouters et al., 2022). In recent years, international migration has been increasing significantly; according to the World Migration Report, the global population of international migrants reached 281 million in 2020 which indicates an increase of 60 million since 2010 (McAuliffe et al., 2021). Additionally, the UNHCR states that the number of refugees has risen from 70.8 million in 2018 to 100 million by 2022 (Sampson et al., 2013).

There are numerous intricate challenges that face both migrants and host societies during the migration process. Newcomers usually face language

barriers, unfamiliar laws, and other customary practices that affect their integration hence limiting them rightfully (Grant et al., 2005). Based on a systematic review conducted in 2020 (Blackmore R et al., 2020), approximately one-third of refugees suffer from depression, demonstrating the profound health impacts of migration and emphasizing the necessity of comprehensive social and health support systems in host countries.

1.4 Oral health in marginalized populations

In healthcare policies affecting marginalized populations such as migrants and refugees, oral health continues to be an important, but often overlooked component (Fisher-Owens et al., 2008).

Oral diseases are among the most prevalent health issues among refugees who often face significant barriers to receiving dental care (WHO, 2018). There are a number of barriers to oral health, including language difficulties, institutional discrimination, and limited access to dental services (Asfari et al., 2024; Keboa et al., 2016). As refugees may prioritize immediate survival needs upon arriving in host countries before considering oral health, financial constraints further compound these challenges (Davidson et al., 2007).

Recent reviews have demonstrated that migrants experience a higher prevalence of dental caries and poorer periodontal health compared to non-migrant populations, with disparities primarily affecting ethnicity, economic status, and social grade (Publications 1 and 2), (Lauritano et al., 2021). Additionally, cultural differences, a lack of health insurance, and insufficient financial resources limit the accessibility of dental care to these individuals. Moreover, unfamiliarity with the healthcare systems in new host countries often leaves many refugees with untreated dental issues, leading to pain and

further health complications (Asfari et al., 2024). As a result, these groups are less likely to benefit from advancements in prevention and treatment, resulting in a disproportionate burden of oral diseases (Fisher-Owens et al., 2008).

1.5 Efforts to Enhance Oral Health in Immigrant and Refugee Populations

Different initiatives have been developed to improve oral health of migrants (Glick et al., 2016). Most of these programs have a dual approach: improving oral health through oral health education and increasing access to dental care (Keboa et al., 2016).

Educational Programs: Raising awareness about oral health among these populations requires culturally appropriate oral health education (Adekunle et al., 2023). A significant contribution to oral health literacy is evident in programs aimed at improving oral hygiene practices, such as brushing and flossing techniques (Muller et al., 2024; Ponce-Gonzalez et al., 2020, 2019; Gibbs et al., 2015; Geltman et al., 2014). Similarly, it has been suggested that oral health education can be integrated into primary care for young migrant mothers through a model (e.g., drawings and images to describe the dangers of poor oral hygiene during pregnancy related to the health of mothers and babies, low-cariogenic diet practice and home oral hygiene care) to deliver preventive oral health services (Esimekara et al. 2022).

Service Provision: Several successful service models, including free dental treatments, basic oral health care packages, and mobile dental units, have been highlighted by the World Dental Federation. A wide range of dental procedures are performed using these mobile dental units, from routine cleanings to more complex procedures such as extractions and restorative

work (Bala et al., 2023; FDI, 2020). Furthermore, essential dental services are frequently provided by vans in these communities, sometimes accompanied by emergency services and support such as telephone interpretation, with the assistance of local organizations, such as government and university dental clinics and hospitals, which helps reduce costs and improve accessibility (Paisi et al., 2020; Keboa et al., 2019, 2016; Sypek et al., 2008; Zinah et al., 2021).

Policy Recommendations: The integration of oral health services into primary healthcare systems has been recommended at the policy level in order to facilitate easier access to oral health care for immigrants and refugees. This integration helps remove possible barriers to providing comprehensive care that includes oral health as a component of overall health strategies (Karnaki et al., 2022).

1.6 Nudge theory in Health and Oral health

Behavioral economics is a new field of social study that seeks to incorporate insights from psychology into economics. The awarding of Nobel Prizes in Economics to Daniel Kahneman in 2002 and Richard Thaler in 2017 significantly elevated behavioral economics to particular academic attention in different disciplines. Thaler's theory, known as Nudge Theory, addresses cheap and easy interventions that effectively alter individuals' behavior. Nudge theory focuses on Easy, Attractive, Social, and Timely interventions (EAST) to promote healthy behaviors.

It may appear logical to assume that people would make the best health decisions; however, many continue to prioritize short-term pleasures despite being aware of the long-term consequences for their health (Hofmann et al., 2008). Nudge theory recognizes behavioral complexity and rejects the idea

that humans would make optimum decisions when given the appropriate information (Hansen et al., 2013). Instead, nudges are used as interventions that do not limit choices, but are like gentle pushes that help people make better choices without forcing them or taking away their freedom of choice.

Evidence indicates that nudges can effectively affect various health policy areas, particularly in preventive healthcare. The World Health Organization (WHO) suggested that concentrating on more affordable and practical methods of preventing and managing noncommunicable diseases in low-and-middle income countries has the potential to save around 7 billion lives by 2030 (WHO, 2021). Noncontagious diseases, including type 2 diabetes, have been examined as potential targets for nudge interventions (kullgren et al., 2017). Research has also indicated that nudges can positively influence patients' lifestyle choices, such as diet, medication adherence, physical activity, and the consumption of tobacco and alcohol (Angellotti et al., 2019; Ruggeri et al., 2020; Reddy et al., 2017). Prior systematic reviews revealed that the most of the existing nudge studies were conducted in nutritional sciences, which are essential for other health topics, such as oral health (Gondivkar et al., 2019; Arno et al., 2016; Hollands et al., 2013).

In healthcare, Nudge Theory has been mainly applied to promote healthier dietary and nutritional choices. According to a recent systematic review (Almeida et al., 2024), 81% of interventions that aimed to increase fruit and vegetable consumption were effective due primarily to strategies that modified salience and accessibility of these food items, coupled with informative health claims and reinforcing social norms. Further, changes in the choice architecture, such as altering the physical or social environment, emotional priming, adjusting food availability, or providing clear labels, have

resulted in a 15.3% increase in healthier dietary choices (Arno et al., 2016).

Nudging has also proven effective in reducing unhealthy behaviors. It has been shown that strategies such as highlighting health risks and providing feedback have significantly reduced alcohol and tobacco consumption, and warning labels on alcoholic beverages have enhanced awareness of the associated risks through negative emotional stimuli (Nurchis et al., 2023). On the topic of patient safety, six nudge interventions were effective in improving the acceptability of strategies aimed at reducing medication errors in healthcare settings (Chew et al. 2023).

Technology has further broadened the impact of Nudge Theory. Text reminders and interactive chatbots have improved medication adherence and physician visits (Glasgow et al., 2021; Fukuma et al., 2021).

Similarly, notification systems on devices like the Apple Watch have substantially increased user physical activity, demonstrating the power of timely nudges in encouraging physical activity (Nazaret et al., 2023; Forberger et al., 2019).

Despite the limited research in this area, Nudge Theory has been effectively utilized to foster positive oral health behaviors. Various strategies have been employed, each tailored to encourage adherence to good practices.

A review of the potential applications of Nudge theory in oral health promotion is outlined in Publication 3. The application of Nudge Theory in promoting better oral self-care among children was rigorously evaluated and implemented as a field trial in Publication 4.

2. Aims

This PhD thesis is structured around three primary objectives:

1. **Evaluate the Global Prevalence of Oral Health Diseases among Immigrants and Refugees:**

   This objective focuses on assessing the prevalence of dental caries and periodontal diseases within immigrant and refugee populations. The findings from this investigation are detailed in Publications 1 and 2.

2. **Explore the Application of Nudge Theory in Oral Health Promotion:**

   The second aim examines how Nudge Theory can be utilized to enhance oral health practices. The methodologies and outcomes of this exploration are discussed in Publication 3.

3. **Assess the Effectiveness of Nudge Theory in Promoting Better Oral Self-Care among Schoolchildren:**

   The final objective evaluates the impact of Nudge Theory interventions on improving oral self-care among schoolchildren from refugee and immigrant backgrounds in Mashhad, Iran. The results of this field trial are described in Publication 4.

Collectively, these aims advance our understanding of oral health challenges and intervention strategies within vulnerable populations, with a particular emphasis on behavioral economics as a health promotion tool.

3. Methods

- **Publications 1 and 2 - Global Prevalence of Oral Health Diseases:**

  Conducted as scoping reviews, these studies utilized PRISMA guidelines to systematically collect and analyze data from Scopus, Embase, and PubMed on dental caries and periodontal diseases among immigrants and refugees.

- **Publication 3 - Application of Nudge Theory in Oral Health Promotion:**

  This study was a critical review that utilized Daly and Carnwell's framework to evaluate existing applications of Nudge Theory in health behavior changes, focusing on oral health initiatives.

- **Publication 4 - Effectiveness of Nudge Theory in Schoolchildren:**

  A quasi-experimental field trial was conducted involving 309 schoolchildren to test the efficacy of Nudge-based interventions in enhancing oral self-care, with interventions being randomly assigned to different groups within schools in Mashhad, Iran.

4. Results

The results of this PhD Thesis are derived from the following four Publications.

4.1 Results: Journal Article #1

Higher prevalence of dental caries and periodontal problems among refugees: A scoping review

Published in:
Journal of Global Health - 2023

Banihashem Rad SA[*], Esteves-Oliveira M[*], Maklennan A, Castiglia P, Campus G.

[*] Joint first-authorship

Own contribution:
Study design, data acquisition, analysis and interpretation, manuscript drafting and revising.

Electronic supplementary material:
The online version of this article contains supplementary material.

journal of global health

Cite as: Banihashem Rad SA, Esteves Oliveira M, Maklennan A, Castiglia P, Campus G. Higher prevalence of dental caries and periodontal problems among refugees: A scoping review. J Glob Health 2023;13:04111.

Higher prevalence of dental caries and periodontal problems among refugees: A scoping review

Seyed Ahmad Banihashem Rad[1,2*], Marcella Esteves Oliveira[1,3*], Anastasia Maklennan[1], Paolo Castiglia[4], Guglielmo Campus[1,5]

[1]Department of Restorative, Preventive and Pediatric Dentistry, University of Bern, Bern, Switzerland
[2]Graduate School for Health Sciences, University of Bern, Bern, Switzerland
[3]Department of Restorative Dentistry and Endodontology, Justus-Liebig-University Giessen, Giessen, Germany
[4]Department of Medicine, Surgery and Pharmacy, University of Sassari, Italy
[5]School of Dentistry, University of Sassari, Italy
*Joint first authorship.

Correspondence to:
Guglielmo Campus
Department of Restorative, Preventive and Pediatric Dentistry, University of Bern
Freiburgstrasse 7, 3012 Bern
Switzerland
guglielmo.campus@unibe.ch

Background We assessed the prevalence data on oral health diseases, namely dental caries and periodontitis, among refugees and asylum seekers worldwide.

Methods A systematic search of Scopus, Embase, and PubMed retrieved 1225 records; following title and abstract screening, 58 studies remained for full-text eligibility screening based on pre-defined inclusion criteria. Twenty-six studies were included in the review.

Results Dental caries and tooth loss due to caries were high in refugee populations, regardless of their age, gender, or nationality. The adult population had a mean decayed, missing, and filled teeth (DMFT) index score of 9.2 (standard deviation (SD)=2.3); children had a score of 3.1 (SD=1.1) for deciduous teeth and 2.5 (SD=1.1) for permanents. Caries prevalence among refugees ranged from 4.6% to 98.7%, and gingivitis from 5.7% to 100%, indicating a high heterogeneity in their oral health. Regarding oral health accessibility, 17% to 72% of refugees had never been to a dentist, showing a very low level of accessibility to dental health services.

Conclusions Interventions and policies need to be designed to reduce oral health inequalities among refugee populations and asylum seekers, and host countries must implement strategies to increase their access to oral health care. Existing data should be used to set priorities for improving the oral health of refugees.

Registration: Open Science Framework: https://doi.org/10.17605/OSF.IO/SU59K.

According to the International Organization for Migration (IOM), a refugee is an individual outside the country of his/her nationality and unable to benefit from its protection [1]. All refugees were once asylum seekers; although used interchangeably, these terms are not synonymous. Asylum-seekers seek international protection but have not yet been legally recognized as refugees.

According to the United Nations High Commissioner for Refugees (UNHCR), the number of displaced people worldwide has risen from 70.8 million in 2018 to a 100 million by 2022 [2,3], likely due to the situation in Afghanistan following withdrawal of the USA and new conflicts in Ukraine, Ethiopia, and Myanmar [4].

Refugee populations are at increased risk of developing a range of physical, psychological, and social health problems due to traumatic experiences and settlement pressures [5,6], as well as specific health problems [7], as many refugees come from countries where health systems have been damaged by conflict or civil unrest. Consequently, the prevalence of oral health problems is expected to be high among refugees [8], yet there is limited data and research to inform policymakers about their oral health needs and those of asylum seekers [9,10].

Oral diseases (i.e. dental caries and periodontitis) are a major contributor to the global burden of chronic disease [11,12]. Poor oral health negatively impacts quality of life and can increase the risk of developing chronic diseases [13]. For example, prolonged discomfort from an infected tooth can affect food intake and therefore nutrition. Additionally, bacteria associated with chronic periodontitis have been linked to diabetes and cardiovascular disease [14,15].

Refugee children are more likely to have poor oral health, impacting their overall health and well-being [16,17] and possibly causing malnutrition due to dietary changes and phonation difficulties, not only in children [18], but also in the elderly population [19]. Additionally, poor oral health might lead to an increase in body dissatisfaction [20] and negatively influence simple actions such as smiling, speaking, and eating [21]. Thus, oral health influences both overall health and mental health.

In summary, oral health diseases are among the most neglected aspects of health, regardless of location, culture, education, or economic standing, particularly in low- and middle-income countries. Thus, gaining a holistic overview of the prevalence of oral health problems among refugees and asylum seekers might assist policymakers in defining treatment needs and treatment strategies, as well as the best ways to adapt them to the host countries' health systems, which are frequently overloaded when many refugees suddenly entering the country.

We aimed to conduct the first review on dental caries and periodontal problems in the refugee population on a global scale. Our main goals were to synthesize the evidence of the prevalence of dental caries among refugees and asylum seekers by evaluating the Decayed, Missing, and Filled Teeth in permanent and primary dentition (DMFT/dmft) index and to evaluate the prevalence of periodontal problems. We also aimed to appraise the dental care services provided to refugees and their needs and deficiencies.

METHODS

We registered the scoping review at the Open Science Framework (OSF) registries (https://doi.org/10.17605/OSF.IO/SU59K). We conducted and reported the review following the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) 2020 statement [22].

Search strategy and selection criteria

Research question

Our research question was "What is the prevalence of dental caries and periodontal diseases among refugees and asylum seekers worldwide, and do they have an increased prevalence of these diseases than the general population of the host country?", outlined based on the sample, phenomenon of interest, design, evaluation, and research type (SPIDER) [23] tool. We searched Scopus, Embase, and PubMed using a pre-designed search strategy; a representative search string for PubMed is presented here, while the remaining ones can be found in the **Online Supplementary Document**).

Sample (S): (("Emigrants AND Immigrants"[MeSH Terms] OR "Undocumented Immigrants"[MeSH Terms] OR ("Refugees"[MeSH Terms] OR "Refugee Camps"[MeSH Terms]) OR "Ethnicity"[MeSH Terms] OR "Ethnic and Racial Minorities"[MeSH Terms] OR "asylum seeker*"[Title/Abstract] OR "displaced person*"[Title/Abstract] OR "refugee*"[Title/Abstract])

Phenomenon (P) of Interest (I): All the articles that related to either dental caries or periodontal problems.

Design (D): not restricted.

Evaluation (E): (("Dental Caries"[MeSH Terms] OR "Root Caries"[MeSH Terms] OR "Dental Caries Susceptibility"[MeSH Terms] OR "Periodontal Pocket"[MeSH Terms] OR "Periodontal Index"[MeSH Terms] OR "Gingivitis"[MeSH Terms] OR "DMF Index"[MeSH Terms] OR "dmf index*"[Title/Abstract] OR "dental decay*"[Title/Abstract] OR "carious lesion*"[Title/Abstract] OR "Carious white spot*"[Title/Abstract] OR "periodontal pocket*"[Title/Abstract] OR "dmft s*"[Title/Abstract] OR "gingival index*"[Title/Abstract] OR "dmft*"[Title/Abstract] OR "dmft index*"[Title/Abstract] OR "bleeding on probing*"[Title/Abstract] OR "probing pocket depth*"[Title/Abstract] OR "clinical attachment loss*"[Title/Abstract])

Research type (R): not restricted.

Eligibility criteria

We included all quantitative and qualitative studies on dental caries or periodontal problems of refugees and asylum seeker populations published from 2011 to December 2022. We excluded non-peer-reviewed papers and unpublished research (e.g. theses, abstracts, and preprints).

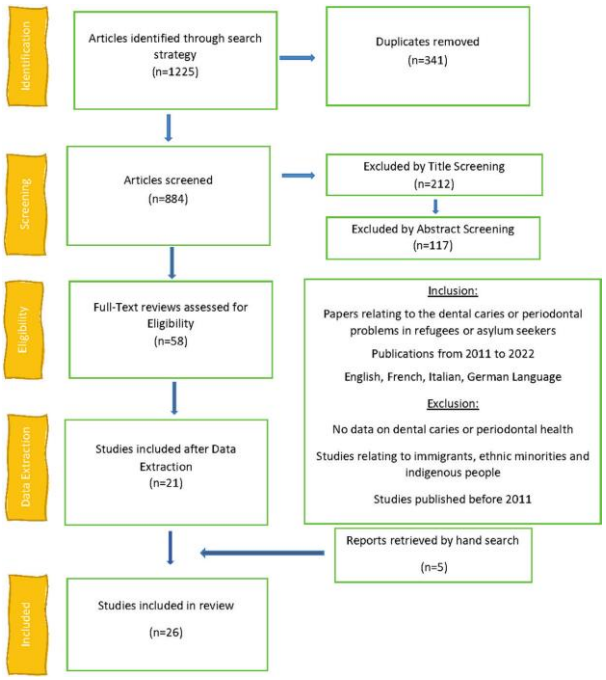


Figure 1. PRISMA flow diagram of papers selection.

Search strategy

Authors extracted text words and index keywords from relevant papers' titles and abstracts to identify relevant articles, developing search strings the selected keywords and synonyms in conjunction with the Boolean operators "AND" and "OR". We only considered papers published in English, Italian, German, Spanish, and French. All age groups were included. The inclusion and exclusion criteria are displayed in **Figure 1**.

Study selection

Following deduplication, two independent reviewers (SABR and AM) screened the retrieved titles and abstracts (n = 884) to determine their relevance against pre-defined eligibility criteria, after which they examined the full texts of the selected studies (n = 58) for inclusion. If discrepancies between the two reviewers could not be resolved through discussion, a third reviewer (GC) was consulted.

Risk of bias

After excluding ineligible papers, two reviewers (SABR and AM) independently critically rated all eligible full texts using a critical appraisal instruments for prevalence studies in the Joanna Briggs Institute (JBI) System for the Unified Management of the Assessment and Review of Information (SUMARI) software (Joanna Briggs Institute, Adelaide, Australia) (**Online Supplementary Document**). Disagreements were resolved through discussion or the assistance of a third reviewer (GC). The appraisal instrument comprised nine questions to which the answers were "yes", "no", and "unclear."

Data extraction and data synthesis

One author (SABR) extracted the following information using a pre-designed data collection form in Excel (Microsoft Corporation, Washington, USA): study characteristics – first author's last name, year of publication, country of study, study design, sampling procedures, calculation of sample size, and methods of data collection, participant characteristics and outcome measure – number of participants, sex, age, prevalence of dental caries and periodontal problems, oral health accessibility, and other findings from the original papers. The data was checked by a co-author (GC).

Parameters measured in the review

We excluded immigrants and ethnic minorities, as we focused on summarising data on oral health diseases (ie, dental caries and periodontitis) among refugee and asylum seeker populations.

In line with the World Health Organization (WHO) methodology [24,25], we applied the DMFT index score to evaluate dental caries [25], calculating the mean and standard deviation (SD) of the prevalence and range of dental caries scores where relevant. We considered both studies with prevalence (% of DMFT>0) and severity (mean DMFT) data on either permanent or deciduous dentition or periodontal problems (e.g. gingivitis, periodontitis).

RESULTS

Study selection

We retrieved 850 studies from Scopus, 98 from Embase, and 277 from PubMed. Following deduplication (n = 341), two reviewers (SABR, AM) screened the study titles, followed by their abstract (n = 212), after which 58 studies remained for full-text review (**Figure 1** and **Online Supplementary Document**). We then extracted data from 21 articles on refugees' and asylum seekers' oral health. We further retrieved five studies [26-30] through additional manual searches. Finally, we included 26 studies in the analysis [26-52] (**Table 1** and **Online Supplementary Document**).

Quality assessment

We did not exclude any study based on methodological quality assessment. The frame and adequacy of the sample size of the included studies received the lowest scores: five in two studies [44,50] and six in four studies [33,41,42,49] because there was no description of the sampling frame, participant selection procedures, and sample size calculation. Only 11 studies reported procedures for calculating sample size or its acceptability for the target group. Twenty studies provided a detailed description of the study setting and participants. Seven studies [38,41,42,44,48-50] failed to indicate the confidence interval (CI) for the mean value.

Table 1. List of studies included in review, ordered alphabetically by country where the study was conducted

	Year of study	Study type	Country of study	Country of origin of study participants	Number of participants	Age range in years
Nicol et al. [31]	2012	Cross-sectional	Australia	Afghanistan, Burma, Iran, Iraq, and Sri Lanka	105	0.7-6.7
Marwaha et al. [32]	2017	Cross-sectional	Australia	Afghanistan, Burma, Iran, Pakistan, and Sri Lanka.	201	18-74
van Berlaer et al. [26]	2015	Cross-sectional:	Belgium	Afghanistan, Iraq, Morocco	3907	0-75+
Hoover et al. [33]	2012	Pilot Study	Canada	The Indian subcontinent, other parts of Asia, and the rest of the world	89	3-15
Moreau et al. [34]	2013	Retrospective study	Canada	Africa, Europe, Middle East, North America, and South America,	120	1-14
Azrak et al. [35]	2017	Cross-sectional	Canada	Africa, Eastern Mediterranean, and South East Asia	211	1-5.9
Goetz et al. [36]	2016	Cross-sectional:	Germany	Afghanistan, Armenia, Chechnya, Eritrea, Iran, Iraq, Somalia, Syria, and Yemen	102	16-64
Solyman et al [37]	2016	Cross-sectional	Germany	Iraq and Syria	386	18-60
Takriti et al. [38]	2016	Cross-sectional	Germany	Afghanistan, Iraq, and Syria	288	18-75
Al-Ani et al. [39]	2016	Cross-sectional	Germany	Mainly from Syria, Afghanistan, Iraq, Eastern Europe, and from Asia (Iran, Pakistan, Thailand, Azerbaijan, Tajikistan, Russia,) as well as from African countries (Eritrea, Ghana, Nigeria, Ethiopia, and Somalia)	544	3-75+
Freiberg et al. [27]	2019	Retrospective Study	Germany	Afghanistan, Iran, Somalia, and Syria	568	20-34
Pavlopoulou et al. [28]	2010	Cross-sectional:	Greece	Afghanistan, Bangladesh, DR Congo, Eritrea, Iran, Kenya, Lebanon, Pakistan, Somalia, and Sudan	300	0-14
Kakalou et al. [29]	2015	Cross-sectional:	Greece	Afghanistan, Iraq, and Syria; other regions: Africa, Asia, and the Middle East	6688	0-75+
Bhatt et al. [40]	2017	Cross-sectional	India	Tibet	254	6-18
Noaman et al. [41]	2017	Cross-sectional	Iraq	Syria	79	4-5
Hamid et al. [42]	2020	Cross-sectional	Iraq	Syria	200	25-65
Biscaglia et al. [43]	2016	Cross-sectional	Palestine	Palestine (UNRWA Schools) Jordan, Lebanon, Syria, Gaza Strip, and West Bank	1550	6-18
Makan et al. [44]	2017	Cross-sectional	Jordan	Syria	125	6-12
Salim et al. [45]	2019	Cross-sectional	Jordan	Syria	606	7-19
Salim et al. [46]	2019	Cross-sectional	Jordan	Syria	547	18-50*
Joury et al. [47]	2017	Cross-sectional	Lebanon	Syria	823	4-23
Høyvik et al. [48]	2013	Cross-sectional	Norway	Middle East and Africa (Syria, Iran, Iraq, Afghanistan, Eritrea, Somalia, Sudan, Nigeria)	132	18*
Riatto et al. [49]	2015	Cross-sectional	Spain	Syria	156	5-13
Hjern et al. [30]	2015	Cross-sectional	Sweden	Afghanistan and Syria	639	6-15
Kazwini et al. [50]	2019	Cross-sectional	Syria	Syria	118	4-60
Flynn et al. [51]	2020	Cross-sectional	USA	Somalia	366	0.5-60

Characteristics of included studies

Seven studies had a control group [28,30,33,34,38,39,50], primarily the host country's local population, except for two studies [28,33] which had the immigrant population as a control group. Four included studies [33,38,44,48] assessed the treatment need of refugees, seven [33-35,38,40,41,46] reported on the utilisation of oral health services, two [41,43] investigated dietary factors, and two [41,51] investigated the mother-child caries rates, with one [51] showing a positive correlation between mother-child caries experience. Five studies [26,27,30,32,38] also included asylum seekers as participants. Three of these studies used the terms "refugee" and "asylum seeker" interchangeably [17,32,38]. None of the included studies had access to the oral health status of the sample group prior to their arrival.

Children were the study populations in 11 studies [28,30,31,33-35,40,41,43,44,49], children and adults in eight [26,29,36,39,45,47,50,51], and only adults in seven [27,32,37,38,42,46,48]. All study samples consisted of more men than women, except for three studies [29,46,50]. Only three studies [38,39,43] had a multicenter clinical design. The main host countries were Germany, Canada, Australia, Jordan, and Iraq, while refugees originated from a wide range of countries, with most coming from Syria, Afghanistan, and Iraq (**Table 1**, **Figure 2**).

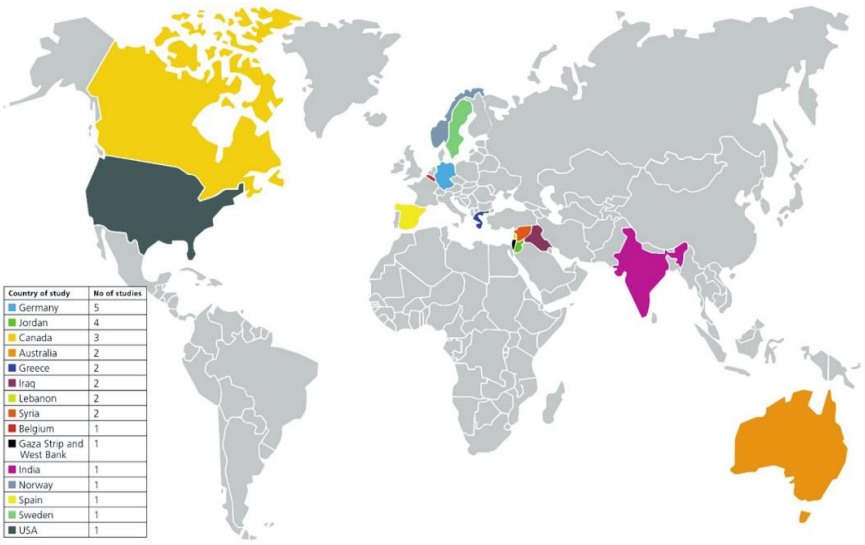


Figure 2. World map showing the countries, where studies regarding the oral health of refugees have been performed. A table at the left side shows additionally the number of studies per country, with the countries sorted by number of studies (from the highest to the lowest), where it is clearly observable the highest number of studies on refugees have been conducted in Germany. Some studies were conducted in more than one Country. Countries in which no studies could be found are marked in gray.

Age was directly correlated with caries prevalence [31,34,37]. In another study, the same trend was observed just for permanent dentition and an opposite relationship was shown for deciduous teeth. Meaning caries was inversely related to the age of the deciduous dentition [49] (**Online Supplementary Document**). Three studies [37,46,50] indicated that men had a lower oral health status (decayed and missing tooth) compared to women. This difference was significant in two studies [37,46] and not significant in one [50]. No substantial significant gender differences in dental status were found in five studies [31,41,48-50].

Country of origin was described a significant determinant for caries [33]. Refugees from the Middle East had more decayed teeth (DT) and a higher DMFT sum compared to refugees from Africa [48]. Refugees that had been displaced for more than five years were significantly more susceptible to caries than those who had been displaced for less than five years [47].

Dental caries in refugees

Regarding caries in adults, four of the seven studies [38,39,42,46] indicated a very high DMFT severity (mean DMFT>10), while also showing an expanded version of the DMFT index with individual components (Table 2).

Table 2. Caries distribution in refugees in included studies*

	Sample size	DMFT	DT	MT	FT	dmft	dt	mt	ft	DMFT/ dmft	DT/dt
Adults											
Solyman et al [37]	386	6.3 (5.0)	4 (3.3)	1.4 (3.3)	0.9 (1.6)	NA	NA	NA	NA	NA	NA
Goetz et al. [36]	102	6.89 (5.5)	2.9 (2.0)	3.8 (2.9)	3.7 (2.9)	NA	NA	NA	NA	NA	NA
Høyvik et al. [48]	132	7.4 (5.8)	4.3 (3.5)	1.4 (2.4)	1.7 (3.4)	NA	NA	NA	NA	NA	NA
Hamid et al. [42]	200	10.7 (3.3)	NA	NA	NA	NA	NA	NA	NA	NA	NA
Takriti et al. [38]	288	10.9 (3.7)	3.4 (0.3)	4.1 (3.1)	3.3 (1.0)	NA	NA	NA	NA	NA	NA
Al-Ani et al. [39]	544	10.9 (3.7)	3.4 (0.3)	4.1 (3.1)	3.3 (1.0)	NA	NA	NA	NA	NA	NA
Salim et al. [46]	547	11.8 (1.7)	5.4 (0.3)	3.5 (1.2)	3.4 (0.6)	NA	NA	NA	NA	NA	NA
Overall	2199	9.2 (2.3)	3.9 (0.8)	3(1.2)	2.7 (1.1)	NA	NA	NA	NA	NA	NA
Children											
Nicol et al. [31]	105	NA	NA	NA	NA	5.2 (4.1)	NA	NA	NA	NA	NA
Hoover et al. [33]	89	NA	NA	NA	NA	NA	NA	NA	1.5 (2.3)	5.8 (4.2)	3.0 (3.4)
Moreau et al. [34]	120	NA	NA	NA	NA	NA	NA	NA	NA	7.2 (5.1)	6.7 (5.0)
Azrak et al. [35]	211	NA	NA	NA	NA	2.2 (3.8)	1.7 (3.0)	0.2 (0.8)	0.3 (1.6)	NA	NA
Al-Ani et al. [39]	544	1.4 (1.2)	0.8 (0.8)	0.0.1 (0.1)	0.4 (0.3)	3.0 (1.8)	2.4 (1.4)	0.2 (0.2)	0.3 (0.2)	NA	NA
Bhatt et al. [40]	254	2.8 (2.4)	NA	NA	NA	3.5 (4.1)	NA	NA	NA	NA	NA
Noaman et al. [41]	79	NA	NA	NA	NA	2.9 (0.8)	NA	NA	NA	4.4 (5.0)	3.2 (4.3)
Salim et al. [45]	606	4.3	NA	NA	NA	NA	NA	NA	NA	NA	NA
Makan et al. [44]	125	3.6 (9.8)	NA	NA	NA	2.9 (4.7)	NA	NA	NA	NA	NA
Biscaglia et al. [43]	1550	2.5 (2.5)	NA	NA	NA	NA	NA	NA	NA	NA	NA
Joury et al. [47]	823	NA	2.0 (2.3)	NA	NA	NA	3.2 (3.0)	NA	NA	NA	5.3
Riatto et al. [49]	156	0.8 (1.8)	0.7 (1.79	0 (0.1)	0.1 (0.4)	2.2 (2.9)	NA	NA	NA	NA	NA
Kazwini et al. [50]	118	2.4 (2.3)	NA	0.8 (1.3)	0.7 (1)	NA	NA	NA	NA	2.48	NA
Overall	4780	2.5 (1.1)	0.7 (0.07)	0.4 (0.4)	0.4 (0.3)	3.1 (1.1)	2.4 (0.7)	0.2	0.7 (0.6)	5.8 (1.4)	4.3 (2.0)

DMFT – decaying, missing and filled index score in permanent dentition, dmft – caries index in primary dentition, DT – decaying teeth in permanent dentition, MT – missing teeth in permanent dentition, FT – filled teeth in permanent dentition, dt – decaying teeth in primary dentition, mt – missing teeth in primary dentition, ft – filled teeth in primary dentition, NA – not applicable, SD – standard deviation
*Data presented as mean (SD) unless otherwise specified.

DT was high in all but one study [49] in which the authors suggest that the high to moderate socioeconomic status of the sample population is the reason for lower DT. The overall DMFT mean SD obtained in our systematic search was 9.2 (SD = 2.3) for the adult population. The DT accounted for the highest proportion in the DMFT index, while the least proportion belonged to filled teeth (FT).

Regarding caries in children, two studies [31,34] reported very high decayed, missing, and filled teeth in primary dentition (dmft) of >5, with an overall mean dmft of 3.1 (SD = 1.1) for deciduous teeth and a DMFT of 2.5 (SD = 1.1) for permanent teeth. DT and dt in children/primary dentition (dt) also accounted for the highest proportion of caries in children's primary and permanent dentition. Overall, the mean DT among children, regardless of dentition stage, was 4.3 (SD = 2.0), which is relatively high (Table 2).

Only one study reported a higher prevalence of caries in local population compared to refugees [39], reporting that the German resident population had a slightly higher caries experience (11.2 vs 10.9), but a significantly lower treatment need compared to refugees.

Caries prevalence and further detail of included papers

Most studies focused on oral health, except for four [26,28-30] which involved also general health. The prevalence of dental caries was higher in studies that focused on oral health. Only one study [49] revealed a low prevalence of caries, which was attributed to the fact that children were from wealthy households. The caries prevalence in primary dentition ranged from 55.8% to 84.0%, and in permanent dentition from 27.6% to 94.1%. Overall, the caries prevalence regardless of dentition stage ranged from 4.6% to 98.7% among the refugee population (Table 3).

Table 3. Further detail of included studies and caries prevalence

	Focus GH or OH	Dentist involved	Instruments mentioned	Reliability tested†	Caries detection method	Caries prevalence in %
Primary dentition						
Riatto et al. [49]	OH	Yes	Yes	Yes	WHO	55.8
Nicol et al. [31]	OH	Yes	NA	NA	NA	62
Noaman et al. [41]	OH	NA	Yes	Yes	WHO	64.5
Bhatt et al. [40]	OH	NA	Yes	Yes	WHO	84
Permanent dentition						
Riatto et al. [49]	OH	Yes	Yes	Yes	WHO	27.6
Takriti et al. [38]	OH	Yes	Yes	NA	WHO	53
Biscaglia et al. [43]	OH	NA	Yes	Yes	WHO	72.8
Bhatt et al. [40]	OH	NA	Yes	Yes	WHO	79.5
Marwaha et al. [32]	OH	Yes	Yes	Yes	ICDAS II	82
Solyman et al. [37]	OH	Yes	Yes	1Dentist	WHO	87.5
Høyvik et al. [48]	OH	Yes	Yes	Yes	astdd	89.4
Salim et al. [45]	OH	Yes	Yes	Yes	WHO	92.4
Salim et al. [46]	OH	NA	Yes	Yes	WHO	94.1
Unspecified dentition						
Kakalou et al. [29]	GH	NA	NA	NA	ICD-10	4.6
van Berlaer et al. [26]	GH	NA	NA	NA	ICD-10	8.1
Pavlopoulou et al. [28]	GH	NA	NA	NA	NA	24.7
Azrak et al. [35]	OH	Yes	Yes	NA	WHO	48.8
Hjern et al. [30]	GH	NA	Yes	NA	NA	48.1
Hoover et al. [33]	OH	Yes	Yes	NA	NA	67.4
Al-Ani et al. [39]	OH	Yes	Yes	Yes	WHO	79.5
Joury et al. [47]	OH	Yes	NA	NA	NA	90.2
Freiberg et al. [27]	OH	Yes	NA	NA	NA (BEMA)*	98.7
Moreau et al. [34]	OH	NA	Yes	NA	WHO	NA
Goetz et al. [36]	OH	Yes	Yes	1 dentist	ICDAS (STROBE)	NA
Hamid et al. [42]	OH	NA	Yes	NA	NR	NA
Makan et al. [44]	OH	Yes	NA	NA	WHO	NA
Kazwini et al. [50]	OH	Yes	Yes	NA	WHO	NA
Flynn et al. [51]	OH	NA	NA	NA	WHO	NA

GH – general health, OH – oral health, NA – not applicable, WHO – World Health Organization, ICD-10 – International Classification of Diseases 10th revision, astdd – Association of State and Territorial Dental Directors, ICDAS – International Caries Detection and Assessment System, BEMA – Einheitliche Bewertungsmaßstab für zahnärztliche Leistungen [Scale of Evaluation for Medical Services in the Statutory Health Insurance Sector]

*BEMA is the standard of evaluation of dental services and forms within the statutory health insurance in Germany (dentist recorded caries in BEMA forms).

†Reliability tested: If the studies gave information about inter or intra reliability of dental examination, it is showed as Yes or NA. The studies that did not report the caries prevalence, reported caries in other forms DMFT/S.

Other indices to report caries: Decayed-Missing-Filled Surfaces and International Caries Detection and Assessment System

Four studies [32,35,43,51] reported caries prevalence in other forms using Decayed-Missing-Filled Surfaces (DMFS) or International Caries Detection and Assessment System (ICDAS). Two studies [35,43] reported caries using DMFS, while one used ICDAS [53] (**Table 4**). Analysis of tooth surfaces found that white spot lesions were especially frequent in age groups 18-29 (mean = 4.45 (SD = 4.95)) and 30-39 (mean = 3.49 (SD = 4.74)) [32].

Periodontal health in refugees

Seven studies [27,31,33,34,42,44,49] examined periodontal health; all focussed on children, except two [27,42] which addressed periodontal health in adults. Regarding periodontal health in children, the prevalence of gingivitis ranged from 5.7% to 100%, indicating high asymmetry. The prevalence of gingivitis was reported as very high in three studies [33,34,44], with one study reporting that almost all children had chronic gingivitis [44] and two reporting a prevalence of two thirds [33,34]. Although gingival inflammation was apparently high [33,34,44], two studies reported a prevalence of gingivitis of 5.7% [31] and 14% [49].

Table 4. Caries distribution in refugees*

	Age in years	DMFS	Decayed surfaces	Missing surfaces	Filled surfaces
Azrak et al. [35]	1-5.9	4.8 (11.0)	3.0 (6.7)	0.7 (3.5)	1.1 (6.2)
Biscaglia et al. [43]	6-18	3.99 (4.59)	3.29 (3.99)	0.22 (1.12)	0.48 (1.34)
Flynn et al. [51]	<2	0 (0)	0 (0)	NA	0 (0)
	2-5	2.3 (6.1)	0.8 (1.5)	NA	1.6 (6.0)
	6-11	4.2 (8.2)	1.0 (2.9)	NA	3.3 (7.9)
	12	0.8 (1.2)	0 (0)	NA	0.8 (1.2)
	<35	20.1 (19.6)	5.2 (7.2)	9.8 (15.5)	5.1 (6.9)
	>35	22.8 (18.3)	5.9 (9.3)	9.7 (13.0)	7.2 (9.1)
ICDAS study	**Age in years**	**ICDAS**	**ICDAS codes 1-2**	**ICDAS codes 3-4**	**ICDAS codes 5-6**
Marwaha et al. [32]	18-29	7.40 (6.59)	4.45 (4.95)	1.80 (2.94)	1.27 (2.59)
	30-39	6.27 (6.55)	3.49 (4.74)	1.73 (2.16)	0.87 (2.08)
	40-49	5.78 (6.25)	2.88 (4.58)	1.47 (2.06)	0.92 (3.42)
	≥50	4.47 (5.19)	2.24 (4.01)	0.76 (1.22)	1.47 (3.58)

NA – not applicable, DMFS – decaying, missing, and filled surfaces, ICDAS – International Caries Detection and Assessment System
*Caries value is reported as mean (SD) unless otherwise specified.

Regarding periodontal health in adults, the prevalence of periodontitis was present in 2.8% of the observed population [27], with most cases diagnosed with apical periodontitis and a prevalence of gingivitis at 0.9%. The mean Gingival Index [54] was 0.8 (SD = 0.7) and ranged from 0 to 2.7 in the Iraq refugees [42].

All studies except one [35], reported that the prevalence of gingivitis in refugees was higher compared to the local population.

Oral health accessibility

Access to oral health care is an important determinant of oral health status. Unfamiliarity with the health care system can make obtaining oral care difficult. Moreover, in some refugee-receiving countries, dental treatment can be financially unfeasible.

Studies indicate that refugees in the transition phase mainly receive emergency treatment. Once refugee status is granted, refugees often have better access to dental care [26,28,37,52]. According to three studies, general referral systems appeared to be in place [26,28,36]. None of these studies went into specifics about the utility of referral systems.

When asking adult refugees about the history of their last dentist visit, the percentage of individuals who never visited a dentist in their life ranged from 17% to 33% (**Online Supplementary Document**), increasing to between 42% and 72% among children, indicating very low levels of accessibility to dental health services in the country of origin and the low socio-economic level of many refugees.

DISCUSSION

The included studies indicated that the prevalence of oral health problems among refugee populations was relatively high compared with the general population of host countries. Even though the perceived need for treatment varied between studies, dental caries and periodontal disease were most commonly perceived as urgent problems for refugees.

The high prevalence of dental caries and periodontal disease in this population, as well as limited access to oral health care, low utilisation of preventive oral health services, and the high cost of dental care, were the most common explanations for refugees having their teeth extracted when they could have been preserved under "conventional" conditions. Oral screening is not usually available as standard in host countries; consequently, detectable oral health problems remain undetected, increasing the likelihood of more invasive treatment at subsequent dental visits. An additional challenge is the lack of information on pre-arrival oral conditions, which makes difficult to compare and assess the progression of oral health conditions.

Oral health can be neglected due to pressing resettlement issues, as shown in almost all studies. Additionally, access to dental services and language barriers had been significant barriers to dental care for refugees [37,49]. Access to essential dental services can also be affected by language, cultural and economic barriers, social isolation, unfamiliarity with the local health system, laws, regulations and other constraints.

Refugees tend to be less motivated by and focused on oral health treatment and prevention than the native community [37] as they might prioritise resettlement [48].

Kakalou et al. [29] reported the lowest caries prevalence value among all included studies; however, this study focused on general rather than oral health, and the oral examinations were performed by medical clinicians and not dentists, which may have led to an underestimation of the prevalence of oral disorders.

Some studies [36,48] examined the effects of oral health on the general health of refugees. For example, Høyvik et al. [48] argued that dental disorders considerably impact social, physical, and mental health of this population. In this context, missing teeth have been reported to have a significant impact on refugees' self-confidence and ability to learn a new language. Moreover, dental anomalies in Western cultures can have a substantial effect on self-esteem, social conduct, employment, housing, and social impressions of others [55]. Reduced social and psychological well-being can delay the process of acceptance and integration, leading to social isolation and mental health problems that exacerbate general health problems [36].

Although the refugees have poor oral status, there is variation among subgroups, and children of African ancestry reported better oral health conditions than other refugee groups [16,48]. The proportion of caries-free children aged five to six years and 12 years was more than 80% [56]. The low levels of caries in the Ethiopian children may be due to most of the food consumed by Ethiopian refugees in their culture being produced without refined sugar. East African countries typically have low caries prevalence compared to industrialised countries, with rural areas having lower prevalence than urban areas. Furthermore, differences in caries prevalence between high and low socioeconomic categories have been reported, with caries prevalence and severity generally higher among wealthier Africans living in urban areas where sugar consumption is higher and considered a luxury [57].

Oral health problems are magnified when refugees begin their journey. Their pre-existing health conditions worsen during the journey and while waiting for official recognition of refugee status by the host country [37]. An important reason for the worsening of oral health is due to their diet changing in the host country [27,30]. Increased sugar consumption among refugees upon arrival in Europe has been observed [27], affecting their dental health. Children are particularly vulnerable, as their families traditionally promote caries-related dietary habits [30], Moreover, the lack of preventive measures adds up to the burden of oral problems to refugee children. One study reported that parents were unwilling to adopt preventive approaches to oral health [48] and only took their children to the dentist when they had pain.

Refugees' prior dental care experiences in their home countries and their beliefs could impact their dental hygiene practices in the host countries. Dental pain and fear of dental procedures reduced the likelihood of going to the dentist [39], which was exacerbated by linguistic barriers and the inability to express their emotions appropriately. This highlights the need of enhancing communication between physicians and refugees through the use of interpreters, when necessary, and the provision of informational pamphlets in the refugees' native language, particularly about diet and the effects of sugar on oral health [37].

Oral examination of refugees at the point of entry or registration for further dental screening could be a useful approach [48]. Communication in the native languages can also prevent miscommunication and delays [37]. Additionally, all refugee-hosting countries are called upon to enhance their dental care capacity, as the need for refugee dental services is likely to increase steadily in the near future. Despite all the developments and resources available in host countries, especially in European countries with developed health care system, the inclusion and integration of refugees and asylum seekers remains a challenge [36,48]. More studies are needed to understand the oral health perspectives of refugees and asylum seekers. Future research should focus on identifying specific characteristics and beliefs in order to develop targeted and efficient interventions to improve oral health status in displaced people.

One of the limitations of this study is that some information could have been missed, as the studies retrieved in the systematic database search showed huge differences in the characterization and reported data of the refugee population. We also observed significant differences in the sampling procedure, power calculation, and geographical location among the included studies; several [41,42,44,50] did not describe sample size calculation, and refugee populations were usually smaller than the general population. Moreover, refugee status dynamics and interactions could have affected the result.

We did not conduct a meta-analysis due to the lack of comparability among the studies and high heterogenicity. The limited number of publications on this topic, particularly from developing and underdeveloped countries, and the inclusion of studies published exclusively after 2011, reduces the generalisability of our findings. Human mistakes and bias, which may have led to losing some information or biasing the results, are also possible.

Despite these limitations, this study is, to the best of our knowledge, the first systematic global evaluation of dental caries and periodontal diseases, including from a quantitative perspective, in refugee populations. It adds to the limited existing knowledge on special needs and associations necessary for future planning to improve refugees' oral health. Our findings have substantial implications for professionals working in the field of oral health as well as for oral public health efforts. Refugee populations constitute a small proportion of the population in the host countries, and inequalities in refugee oral health care are often masked in population-level data. The studies we examined here successfully addressed the reality of refugee oral health in their respective countries, and future studies should use identical comparative approaches to provide an accurate depiction of population oral health.

CONCLUSIONS

There is more available data on refugees' general health needs and problems than regarding refugees oral health. The prevalence and severity of dental caries are higher among refugees and asylum seekers than among the local population in each host country, regardless of age, sex, or country. Rates of untreated dental caries (i.e. DT) and tooth loss (i.e. missing teeth) due to caries are higher in this population. A high prevalence of dental caries and limited access to dental care are major challenges faced by refugees and asylum seekers worldwide. Interventions and policies need to be designed to reduce oral health inequalities in this population, and host countries need to implement strategies to significantly increase access to oral health care for refugees and asylum seekers. Future studies need to add to real-world knowledge about refugee oral health, as they can help host-countries policy makers improve refugee oral health and develop a more cost-effective preventive approach to oral health care. There is an urgent need to use existing data to set priorities for improving the oral health of refugees.

Ackowledgements: The authors would like to thank Bernadette Rawyler and Ines Badertscher from the graphic Department of School of Dental Medicine, University of Bern, Switzerland for the help to create the figures.

Funding: The research presented in the manuscript received funding from Swiss Government Excellence Scholarship Grants: #2021.0876/Iran/OP.

Authorship contributions: SABR, GC, and MEO contributed to design, data acquisition, analysis and interpretation, drafted and critically revised the manuscript; SABR and AM contributed to critically appraising the papers included in the review at the eligibility stage. PC provided critical insights and revised the manuscript at various stages. All authors gave their final approval and agree to be accountable for all aspects of the work.

Disclosure of interest: The authors completed the ICMJE Disclosure of Interest Form (available upon request from the corresponding author) and disclose no relevant interests.

Additional material
Online Supplementary Document

REFERENCES

1 Perruchoud R, Redpath-Cross J. Glossary on migration. Geneva: International Organization for Migration; 2004.
2 Sampson R, Mitchell G. Global trends in immigration detention and alternatives to detention: practical, political and symbolic rationales. J Migr Hum Secur. 2013;1:97-121. doi:10.1177/233150241300100302
3 Blair CW, Grossman G, Weinstein JM. Forced Displacement and Asylum Policy in the Developing World. Int Organ. 2022;76:337-78. doi:10.1017/S0020818321000369
4 The Lancet Global Health. Refugees and migrants: overexposed yet unseen. Lancet Glob Health. 2022;10:e1209. Medline:35961328 doi:10.1016/S2214-109X(22)00329-1
5 Riggs E, Yelland J, Shankumar R, Kilpatrick N. 'We are all scared for the baby': promoting access to dental services for refugee background women during pregnancy. BMC Pregnancy Childbirth. 2016;16:12. Medline:26794243 doi:10.1186/s12884-015-0787-6
6 Sutradhar I, Zaman MH. One Health approaches to improve refugee health. Lancet Glob Health. 2021;9:e1646-7. Medline:34798016 doi:10.1016/S2214-109X(21)00416-2
7 Efird JT, Bith-Melander P. Refugee health: an ongoing commitment and challenge. Int J Environ Res Public Health. 2018;15:131. Medline:29342831 doi:10.3390/ijerph15010131
8 Armfield JM, Spencer AJ, Slade GD. Changing inequalities in the distribution of caries associated with improving child oral health in Australia. J Public Health Dent. 2009;69:125-34. Medline:19192105 doi:10.1111/j.1752-7325.2008.00110.x
9 Keboa MT, Hiles N, Macdonald ME. The oral health of refugees and asylum seekers: a scoping review. Global Health. 2016;12:59. Medline:27717391 doi:10.1186/s12992-016-0200-x

REFERENCES

10 Riggs E, Gibbs L, Kilpatrick N, Gussy M, van Gemert C, Ali S, et al. Breaking down the barriers: a qualitative study to understand child oral health in refugee and migrant communities in Australia. Ethn Health. 2015;20:241-57. Medline:24739019 doi:10.1080/13557858.2014.907391

11 Bernabe E, Marcenes W, Hernandez CR, Bailey J, Abreu LG, Alipour V, et al. Global, Regional, and National Levels and Trends in Burden of Oral Conditions from 1990 to 2017: A Systematic Analysis for the Global Burden of Disease 2017 Study. J Dent Res. 2020;99:362-73. Medline:32122215 doi:10.1177/0022034520908533

12 Wen PYF, Chen MX, Zhong YJ, Dong QQ, Wong HM. Global Burden and Inequality of Dental Caries, 1990 to 2019. J Dent Res. 2022;101:392-9. Medline:34852668 doi:10.1177/00220345211056247

13 Linden GJ, Lyons A, Scannapieco FA. Periodontal systemic associations: review of the evidence. J Periodontol. 2013;84:S8-19. Medline:23631586 doi:10.1902/jop.2013.1340010

14 Carramolino-Cuéllar E, Tomás I, Jiménez-Soriano Y. Relationship between the oral cavity and cardiovascular diseases and metabolic syndrome. Med Oral Patol Oral Cir Bucal. 2014;19:e289. Medline:24121926 doi:10.4317/medoral.19563

15 Cronin A. Periodontal disease is a risk marker for coronary heart disease? Evid Based Dent. 2009;10:22. Medline:19322227 doi:10.1038/sj.ebd.6400634

16 Cote S, Geltman P, Nunn M, Lituri K, Henshaw M, Garcia RI. Dental caries of refugee children compared with US children. Pediatrics. 2004;114:e733-40. Medline:15574605 doi:10.1542/peds.2004-0496

17 Hjern A, Koçtürk-Runefors T, Jeppson O, Tegelman R, Höjer B, Adlercreutz H. Health and nutrition in newly resettled refugee children from Chile and the Middle East. Acta paediatrica Scandinavica. 1991;80:859-67. Medline:1957607 doi:10.1111/j.1651-2227.1991.tb11961.x

18 Riggs E, Rajan S, Casey S, Kilpatrick N. Refugee child oral health. Oral Dis. 2017;23:292-9. Medline:27385659 doi:10.1111/odi.12530

19 Maamari A. Odontologie gériatrique. Rev Med Brux. 2018;39:322-4. Medline:30320995

20 Banu A, Şerban C, Pricop M, Urechescu H, Vlaicu B. Dental health between self-perception, clinical evaluation and body image dissatisfaction–a cross-sectional study in mixed dentition pre-pubertal children. BMC Oral Health. 2018;18:74. Medline:29724206 doi:10.1186/s12903-018-0542-2

21 Petersen P. Oral health. In: Cockerham WC. International Encyclopedia of Public Health. Cambridge: Academic Press; 2008. pp. 677-85.

22 Page MJ, McKenzie JE, Bossuyt PM, Boutron I, Hoffmann TC, Mulrow CD, et al. The PRISMA 2020 statement: an updated guideline for reporting systematic reviews. Syst Rev. 2021;10:89. Medline:33781348 doi:10.1186/s13643-021-01626-4

23 Cooke A, Smith D, Booth A. Beyond PICO: the SPIDER tool for qualitative evidence synthesis. Qual Health Res. 2012;22:1435-43. Medline:22829486 doi:10.1177/1049732312452938

24 World Health Organization. Oral health surveys: basic methods. Geneva: World Health Organization; 2013.

25 Anaise JZ. Measurement of dental caries experience modification of the DMFT index. Community Dentistry and Oral Epidemiology. 1994;12:43-46. doi:10.1111/j.1600-0528.1984.tb01408.x

26 van Berlaer G, Carbonell FB, Manantsoa S, de Béthune X, Buyl R, Debacker M, et al. A refugee camp in the centre of Europe: clinical characteristics of asylum seekers arriving in Brussels. BMJ Open. 2016;6:e013963. Medline:27884856 doi:10.1136/bmjopen-2016-013963

27 Freiberg A, Wienke A, Bauer L, Niedermaier A, Führer A. Dental Care for Asylum-Seekers in Germany: A Retrospective Hospital-Based Study. Int J Environ Res Public Health. 2020;17:2672. Medline:32295091 doi:10.3390/ijerph17082672

28 Pavlopoulou ID, Tanaka M, Dikalioti S, Samoli E, Nisianakis P, Boleti OD, et al. Clinical and laboratory evaluation of new immigrant and refugee children arriving in Greece. BMC Pediatr. 2017;17:132. Medline:28549451 doi:10.1186/s12887-017-0888-7

29 Kakalou E, Riza E, Chalikias M, Voudouri N, Vetsika A, Tsiamis C, et al. Demographic and clinical characteristics of refugees seeking primary healthcare services in Greece in the period 2015–2016: A descriptive study. Int Health. 2018;10:421-9. Medline:29992276 doi:10.1093/inthealth/ihy042

30 Hjern A, Kling S. Health care needs in school-age refugee children. Int J Environ Res Public Health. 2019;16:4255. Medline:31683963 doi:10.3390/ijerph16214255

31 Nicol P, Anthonappa R, King N, Slack-Smith L, Cirillo G, Cherian S. Caries burden and efficacy of a referral pathway in a cohort of preschool refugee children. Aust Dent J. 2015;60:73-9. Medline:25721281 doi:10.1111/adj.12269

32 Marwaha P, Ghanim A, Shankumar R. Risk indicators of dental caries among refugee patients attending a public dental service in Victoria. Aust Dent J. 2022;67:21-9. Medline:34499752 doi:10.1111/adj.12873

33 Hoover J, Vatanparast H, Uswak G. Risk determinants of dental caries and oral hygiene status in 3-15 year-old recent immigrant and refugee children in Saskatchewan, Canada: a pilot study. J Immigr Minor Health. 2017;19:1315-21. Medline:27349936 doi:10.1007/s10903-016-0452-9

34 Moreau A-M, Hennous F, Dabbagh B, Ferraz dos Santos B. Oral health status of refugee children in Montreal. J Immigr Minor Health. 2019;21:693-8. Medline:30406328 doi:10.1007/s10903-018-0835-1

35 El Azrak M, Huang A, Hai-Santiago K, Bertone MF, DeMaré D, Schroth RJ. The oral health of preschool children of refugee and immigrant families in Manitoba. J Can Dent Assoc. 2017;83 h9:1488-2159.

36 Goetz K, Winkelmann W, Steinhäuser J. Assessment of oral health and cost of care for a group of refugees in Germany: a cross-sectional study. BMC Oral Health. 2018;18:69. Medline:29699553 doi:10.1186/s12903-018-0535-1

37 Solyman M, Schmidt-Westhausen A-M. Oral health status among newly arrived refugees in Germany: a cross-sectional study. BMC Oral Health. 2018;18:132. Medline:30075766 doi:10.1186/s12903-018-0600-9

38 Takriti M, Al-Ani A, Walter M, Alkilzy M, Splieth CH. Dental status and prosthetic treatment needs among adult refugees in Germany. Quintessence Int. 2021;52:764-71. Medline:34269038

REFERENCES

39 Al-Ani A, Takriti M, Schmoeckel J, Alkilzy M, Splieth C. National oral health survey on refugees in Germany 2016/2017: caries and subsequent complications. Clin Oral Investig. 2021;25:2399-405. Medline:33011846 doi:10.1007/s00784-020-03563-3
40 Bhatt S, Gaur A. Dental caries experience and utilization of Oral Health services among Tibetan refugee-background children in Paonta sahib, Himachal Pradesh, India. J Immigr Minor Health. 2019;21:461-5. Medline:29869194 doi:10.1007/s10903-018-0769-7
41 Noaman BR, Khalid RF, Fattah LD. Maternal Dental Health Knowledge and Its Relation to the Dental Caries Experience of Their Children in Mamyzawa Camp of Refugees in Erbil, Iraq. Acta Med Acad. 2019;48:294-302. Medline:32124628 doi:10.5644/ama2006-124.270
42 Hamid RN, Mudher SH, Ali SM. Caries Index, Root Caries Index and Gingival Index in Immigrants at the Camp of Arbat in Sulaimaniya Governorate, Iraq. Intern Med J. 2020;27:357-9.
43 Biscaglia L, di Caccamo P, Terrenato I, Arrica MA, Seita A, Campus G. Oral health status and caries trend among 12-year old Palestine refugee students: results from the UNRWA's oral health surveys 2011 and 2016. BMC Oral Health. 2019;19:157. Medline:31319840 doi:10.1186/s12903-019-0844-z
44 Makan R, Gara M, Awwad MA, Hassona Y. The oral health status of Syrian refugee children in Jordan: An exploratory study. Spec Care Dentist. 2019;39:306-9. Medline:30985010 doi:10.1111/scd.12377
45 Salim NA, Alamoush RA, Al-Abdallah MM, Al-Asmar AA, Satterthwaite JD. Relationship between dental caries, oral hygiene and malocclusion among Syrian refugee children and adolescents: a cross-sectional study. BMC Oral Health. 2021;21:629. Medline:34876100 doi:10.1186/s12903-021-01993-3
46 Salim NA, Sawair FA, Satterthwaite JD, Al-Zubi Z. Oral Hygiene Awareness, Practices and Attitudes among Syrian Refugees in Zaatari Camp and Their Impact on Oral Health Status. Oral Health Prev Dent. 2021;19:689-98. Medline:34918503
47 Joury E, Meer R, Chedid JCA, Shibly O. Burden of oral diseases and impact of protracted displacement: a cross-sectional study on Syrian refugee children in Lebanon. Br Dent J. 2021. Medline:33986480 doi:10.1038/s41415-021-2960-9
48 Høyvik AC, Lie B, Grjibovski AM, Willumsen T. Oral health challenges in refugees from the Middle East and Africa: a comparative study. J Immigr Minor Health. 2019;21:443-50. Medline:29961163 doi:10.1007/s10903-018-0781-y
49 Riatto SG, Montero J, Pérez DR, Castaño-Séiquer A, Dib A. Oral health status of Syrian children in the refugee center of Melilla, Spain. Int J Dent. 2018;2018:2637508. Medline:29743889 doi:10.1155/2018/2637508
50 Kazwini R, Kasem T, Alhuda NEA, Albarshah M, Subeh D, Alhaffar M. Oral health assessment in a sample of displaced people as a result of the war in Syria in Damascus city: results of non-profit initiative. BMC Oral Health. 2021;21:532. Medline:34654422 doi:10.1186/s12903-021-01874-9
51 Flynn PM, Petersen A, Entinger J, Shire A. The Association of Social Determinants of Health with Somali Refugee Mother–Child Caries. J Immigr Minor Health. 2021;23:615-23. Medline:32592025 doi:10.1007/s10903-020-01040-3
52 Williams B, Cassar C, Siggers G, Taylor S. Medical and social issues of child refugees in Europe. Arch Dis Child. 2016;101:839-42. Medline:27470163 doi:10.1136/archdischild-2016-310657
53 Pitts NB, Ekstrand KR. ICDAS Foundation. International Caries Detection and Assessment System (ICDAS) and its International Caries Classification and Management System (ICCMS)-methods for staging of the caries process and enabling dentists to manage caries. Community Dent Oral Epidemiol. 2013;41:e41-52. Medline:24916677 doi:10.1111/cdoe.12025
54 Löe H, Silness J. Periodontal disease in pregnancy I. Prevalence and severity. Acta Odontol Scand. 1963;21:533-51. Medline:14121956 doi:10.3109/00016356309011240
55 Cortes MI, Marcenes W, Sheiham A. Impact of traumatic injuries to the permanent teeth on the oral health-related quality of life in 12–14-year-old children. Community Dent Oral Epidemiol. 2002;30:193-8. Medline:12000342 doi:10.1034/j.1600-0528.2002.300305.x
56 Sgan-Cohen HD, Steinberg D, Zusman SP, Sela MN. Dental caries and its determinants among recent immigrants from rural Ethiopia. Community Dent Oral Epidemiol. 1992;20:338-42. Medline:1464228 doi:10.1111/j.1600-0528.1992.tb00694.x
57 Holm A-K. Diet and caries in high-risk groups in developed and developing countries. Caries Res. 1990;24 Suppl. 1:44-52. Medline:2249228 doi:10.1159/000261325

Supplementary Materials for

"Higher prevalence of dental caries and periodontal problems among refugees: A scoping review"

Appendix 1. Detailed search procedure in databases

Pubmed (n=277)	((("Emigrants AND Immigrants"[MeSH Terms] OR "Undocumented Immigrants"[MeSH Terms] OR ("Refugees"[MeSH Terms] OR "Refugee Camps"[MeSH Terms]) OR "Ethnicity"[MeSH Terms] OR "Ethnic and Racial Minorities"[MeSH Terms] OR "asylum seeker*"[Title/Abstract] OR "displaced person*"[Title/Abstract] OR "refugee*"[Title/Abstract]) AND (("Dental Caries"[MeSH Terms] OR "Root Caries"[MeSH Terms] OR "Dental Caries Susceptibility"[MeSH Terms] OR "Periodontal Pocket"[MeSH Terms] OR "Periodontal Index"[MeSH Terms] OR "Gingivitis"[MeSH Terms] OR "DMF Index"[MeSH Terms] OR "dmf index*"[Title/Abstract] OR "dental decay*"[Title/Abstract] OR "carious lesion*"[Title/Abstract] OR "Carious white spot*"[Title/Abstract] OR "periodontal pocket*"[Title/Abstract] OR "dmft s*"[Title/Abstract] OR "gingival index*"[Title/Abstract] OR "dmft*"[Title/Abstract] OR "dmft index*"[Title/Abstract] OR "bleeding on probing*"[Title/Abstract] OR "probing pocket depth*"[Title/Abstract] OR "clinical attachment loss*"[Title/Abstract]) AND ("english"[Language] OR "french"[Language] OR "german"[Language] OR "italian"[Language]))) AND ((english[Filter] OR french[Filter] OR german[Filter] OR italian[Filter]) AND (2011:2022[pdat]))
EMBASE (n=98)	Sources Embase, MEDLINE Query('immigrant':ti,ab OR 'immigrants':ti,ab OR 'refugee':ti,ab OR 'refugee camp':ab OR 'asylum seeker':ti,ab OR 'ethnic group':ti,ab) AND ('dental caries':ti,ab OR 'dmf index':ti,ab OR 'dmft index':ti,ab OR 'dmfs index':ti,ab OR 'caries assessment':ti,ab OR 'periodontal disease':ti,ab OR 'gingiva disease':ti,ab OR 'gingivitis':ti,ab OR 'periodontal pocket depth':ti,ab OR 'pocket depth':ti,ab OR 'gingival index':ti,ab OR 'bleeding on probing':ti,ab OR 'clinical attachment level':ti,ab OR 'decay rate':ti,ab) AND ([embase]/lim OR [medline]/lim OR [pubmed-not-medline]/lim) AND ([english]/lim OR [french]/lim OR [german]/lim OR [italian]/lim) AND [2011-2022]/
Scopus (n=850)	((immigrant* OR refugee* OR "refugee camp" OR "asylum seeker" OR "ethnic group")) AND (("dental caries" OR "DMF index" OR "DMFT index" OR "DMFS index" OR "caries" OR "periodontal disease" OR "gingiva disease" OR "gingivitis" OR "periodontal pocket depth" OR "pocket depth" OR "gingival index" OR "bleeding on probing" OR "clinical attachment level" OR "decay rate")) AND (LIMIT-TO (PUBYEAR , 2022) OR LIMIT-TO (PUBYEAR , 2021) OR LIMIT-TO (PUBYEAR , 2020) OR LIMIT-TO (PUBYEAR , 2019) OR LIMIT-TO (PUBYEAR , 2018) OR LIMIT-TO (PUBYEAR , 2017) OR LIMIT-TO (PUBYEAR , 2016) OR LIMIT-TO (PUBYEAR , 2015) OR LIMIT-TO (PUBYEAR , 2014) OR LIMIT-TO (PUBYEAR , 2013) OR LIMIT-TO (PUBYEAR , 2012) OR LIMIT-TO (PUBYEAR , 2011)) AND (LIMIT-TO (LANGUAGE , "English") OR LIMIT-TO (LANGUAGE , "German") OR LIMIT-TO (LANGUAGE , "French") OR LIMIT-TO (LANGUAGE , "Italian")) AND (LIMIT-TO (EXACTKEYWORD , "Oral Health") OR LIMIT-TO (EXACTKEYWORD , "Health"))

Appendix 2: Quality assessment (JBI SUMARI)

Citation	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Total score
Nicol et al.(26)	Y	Y	N	Y	Y	Y	Y	Y	Y	8
Marwaha et al. (27)	U	Y	U	Y	Y	Y	Y	Y	Y	7
van Berlaer et al.(28)	U	Y	Y	Y	Y	U	Y	Y	Y	7
Hoover et al.(29)	U	Y	N	Y	Y	Y	Y	Y	N	6
Moreau et al.(30)	Y	Y	N	Y	Y	Y	Y	Y	Y	8
Azrak et al. (31)	Y	Y	N	Y	Y	Y	U	Y	Y	7
Goetz et al.(32)	Y	Y	N	Y	Y	Y	Y	Y	Y	8
Solyman et al.(33)	Y	Y	Y	Y	Y	Y	Y	U	Y	8
Takriti et al.(34)	Y	Y	U	Y	Y	Y	U	Y	Y	7
Al-Ani et al. (35)	Y	Y	Y	Y	Y	Y	Y	Y	Y	9
Freiberg et al.(36)	U	Y	Y	Y	Y	Y	Y	Y	Y	8
Pavlopoulou et al.(37)	U	Y	Y	Y	Y	Y	Y	Y	Y	8
Kakalou et al.(38)	U	Y	Y	Y	Y	Y	Y	Y	Y	8
Bhatt et al. (39)	U	Y	N	Y	Y	Y	Y	Y	Y	7
Noaman et al. (40)	Y	Y	N	Y	U	Y	Y	Y	N	6
Hamid et al.(41)	Y	U	U	Y	U	Y	Y	Y	Y	6
Biscaglia et al.(42)	Y	Y	Y	U	Y	Y	Y	Y	Y	8
Makan et al.(43)	U	Y	N	U	Y	Y	Y	Y	U	5
Salim et al. (44)	U	Y	Y	Y	Y	Y	Y	Y	Y	8
Salim et al.(45)	U	Y	Y	Y	Y	Y	Y	Y	Y	8
Joury et al.(46)	Y	Y	Y	U	Y	U	Y	Y	Y	7
Høyvik et al.(47)	Y	Y	U	Y	Y	Y	Y	U	Y	7
Riatto et al.(48)	N	Y	U	Y	Y	Y	Y	U	Y	6
Hjern and Kling (49)	N	Y	Y	Y	Y	Y	Y	Y	U	7
Kazwini et al.(50)	U	Y	N	Y	U	Y	Y	U	Y	5
Flynn et al.(51)	Y	Y	N	Y	Y	Y	Y	Y	Y	8
Total (%) yes	50	96.1	42.3	88.4	88.4	92.3	92.3	84.6	84.6	

Critical appraisal questions: Q1. Was the frame appropriate to address the target population? Q2. Were study participants sampled in an appropriate way? Q3. Was the sample size adequate? Q4. Were the study subjects and the setting described in detail? Q5. Was data analysis conducted with sufficient coverage of the identified sample? Q6. Were valid methods used for identification of the condition? Q7. Was the condition measured in a standard, reliable way for all participants? Q8. Was there appropriate statistical analysis? Q9. Was the response rate adequate and, if not, was the low response rate managed appropriately? Y, yes; U, unclear; N, no

Appendix 3: Excluded papers

Excluded Studies	REASON FOR EXCLUSION
Amin et al. (2015)	The study participants were immigrants.
Christian . (2015)	The study participants were immigrants.
Ferrazzano et al. (2019)	The study participants were immigrants.
Gibbs et al. (2016)	The study participants were immigrants.
Hamid et al. (2020)	The study participants were immigrants.
Hashizume et al. (2011)	The study participants were immigrants.
Lin et al.(2019)	The study participants were immigrants.
Lin et al.(2014)	The study participants were immigrants.
Liu C et al. (2016)	The study participants were immigrants.
Olerud et al (2016)	The study participants were immigrants.
Sivakumar et al.(2016)	The study participants were immigrants.
Stecksén-Blicks et al.(2014)	The study participants were immigrants.
Wilson et al. (2018)	The study participants were immigrants.
Dahlan et al. (2021).	The study participants were immigrants.
Diamanti et al. (2022)	The study participants were immigrants.
Gómez- et al. (2021)	The study participants were immigrants.
Kabani et al. (2020)	The study participants were immigrants.
Sanders et al. (2020)	The study participants were immigrants.
Thorbert-Mros et al. (2021)	The study participants were immigrants.
Traisuwan et al. (2021)	The study participants were immigrants.
Zhang et al. (2013)	The study participants were ethnic minorities.
Caplin et al. (2015)	The study participants were immigrants.
Chen et al. (2021)	The study participants were ethnic minorities.
Premaraj et al. (2020)	The study participants were ethnic minorities.
Sgan-Cohen et al. (2014)	The study participants were ethnic minorities.
Shi et al. (2018)	The study participants were ethnic minorities.
Van Der Tas et al. (2016)	The study participants were ethnic minorities.
Wu et al. (2021)	The study participants were ethnic minorities.
Wulaerhan et al. (2014)	The study participants were ethnic minorities.
Zhang et al. (2014)	The study participants were ethnic minorities.
Zhang et al (2015)	The study participants were ethnic minorities.
Hermans et al. (2017)	No information about DMFT or Caries prevalence.
Williams et al. (2016)	No information about DMFT or Caries prevalence.
Mattila et al. (2016)	No separate information about DMFT or Caries prevalence.
Vega-López et al.(2018)	No information about DMFT or Caries prevalence.
Ogawa et al. (2019)	No information on prevalence and only indicating the caries risk.
Alrashdi et al. (2021)	No information about DMFT or Caries prevalence.

Appendix 4: Oral health status of refugee children within the distinct age groups. .

According to the data obtained from Riatto et al.[48]

Variables	Age groups (years)		
	5–7	8–10	11–13
Global caries prevalence (DMFT or dft > 1) (% of subjects)	74.5	74.2	59.0
Caries prevalence in permanent dentition (% of subjects)	7.8	34.8	41.0
Caries prevalence in deciduous dentition (% of subjects)	72.5	60.6	25.6

History of dental visits

Author	Azrak et al.[31]	Moreau et al.[31]	Bhatt et al.[39]	Noaman et al. [40]	Salim et al.[44]	Høyvik et al.[47]
	Children				*Adults*	
Never visited a dentist (%)	*72.7*	*60*	*60*	*42*	*17*	*33.3*

Appendix 5: History of dental visit

Appendix 6: Reference list of excluded studies

1. Amin MS, Perez A, Nyachhyon P. Parental awareness and dental attendance of children among African immigrants. J Immigr Minor Health. 2015;17(1):132-8.
2. Christian B, Young D, Gibbs L, De Silva A, Gold L, Riggs E, et al. Exploring child dental service use among migrant families in metropolitan Melbourne, Australia. Australian Dental Journal. 2015;60(2):200-
3. Ferrazzano GF, Cantile T, Sangianantoni G, Ingenito A, Rengo S, Alcidi B, et al. Oral health status and Unmet Restorative Treatment Needs (UTN) in disadvantaged migrant and not migrant children in Italy. European Journal of Paediatric Dentistry. 2019;20(1):10-4.
4. Gibbs L, de Silva AM, Christian B, Gold L, Gussy M, Moore L, et al. Child oral health in migrant families: A cross-sectional study of caries in 1-4 year old children from migrant backgrounds residing in Melbourne, Australia. Community Dental Health. 2016;33(2):100-6.
5. Hamid RN, Mudher SH, Ali SM. Caries index, root caries index and gingival index in immigrants at the camp of arbat in sulaimaniya governorate, iraq. International Medical Journal. 2020;27(3):357-9.
6. Hashizume LN, Shinada K, Kawaguchi Y. Factors associated with prevalence of dental caries in Brazilian schoolchildren residing in Japan. J Oral Sci. 2011;53(3):307-12.
7. Lin YC, Chang CS, Ho PS, Lee CH, Chen JH, Huang HL. Immigrant–Native Differences in Sugar-Sweetened Beverage and Snack Consumption and Preventive Behaviors Associated with Severe Early Childhood Caries: A Large-Scale Survey in Taiwan. Int J Environ Res Public Health. 2019;16(6).
8. Lin YC, Yen YY, Chang CS, Ting CC, Chen PH, Chen CC, et al. Oral health disparities of children among Southeast Asian immigrant women in arranged transnational marriages in Taiwan. Caries Res. 2014;48(6):575-83.
9. Liu CJ, Zhou W, Feng XS. Dental caries status of students from migrant primary schools in Shanghai Pudong New Area. BMC Oral Health. 2016;16(1).
10. Olerud E, Hagman-Gustavsson ML, Gabre P. Oral health status in older immigrants in a medium-sized Swedish city. Special Care in Dentistry. 2016;36(6):328-34.

11. Sivakumar V, Jain J, Haridas R, Paliayal S, Rodrigues S, Jose M. Oral health status of tibetan and local school children: A comparative study. Journal of Clinical and Diagnostic Research. 2016;10(11):ZC29-ZC33.
12. Stecksén-Blicks C, Hasslöf P, Kieri C, Widman K. Caries and background factors in Swedish 4-year-old children with special reference to immigrant status. Acta Odontol Scand. 2014;72(8):852-8.
13. Wilson FA, Wang Y, Borrell LN, Bae S, Stimpson JP. Disparities in oral health by immigration status in the United States. Journal of the American Dental Association (1939). 2018;149(6):414-21.
14. Dahlan R, Bohlouli B, Salami B, Saltaji H, Amin M. Parental acculturation and oral health of children among immigrants. Journal of public health dentistry. 2021.
15. Diamanti I, Berdouses ED, Kavvadia K, Arapostathis KN, Polychronopoulou A, Oulis CJ. Dental caries prevalence and experience (Icdas ii criteria) of 5-, 12-and 15-year-old children and adolescents with an immigrant background in greece, compared with the host population: A cross-sectional study. International Journal of Environmental Research and Public Health. 2022;19(1).
16. Gómez-Costa D, San-Roman-Montero J, Rojo R, Gil Á, Gómez de Diego R, López-Sánchez AF. Self-reported prevalence of periodontal disease among the Spanish population and immigrants: 2006, 2011/12 and 2017: a population-based study. BMC Oral Health. 2021;21(1).
17. Kabani FA, Stockbridge EL, Berly Varghese B, Loethen AD. Acculturation and the oral health of a nationally representative sample of Hispanic children in the United States: an analysis of 2011-2012 National Survey of Children's Health data. BMC Public Health. 2020;20(1):111.
18. Sanders A, Cardel M, Laniado N, Kaste L, Finlayson T, Perreira K, et al. Diet quality and dental caries in the Hispanic Community Health Study/Study of Latinos. J Public Health Dent. 2020;80(2):140-9.
19. Thorbert-Mros S, Ali N, Ali M, Ayas M, Trullenque-Eriksson A, Dahlén G. A comparative study on periodontitis and periodontitis-associated bacteria in Somali and non-Somali children and adolescents living in Trollhättan, Sweden. European journal of oral sciences. 2021:e12843.
20. Traisuwan W. Oral health status and behaviors of pregnant migrant workers in Bangkok, Thailand: a cross-sectional study. BMC oral health. 2021;21(1):379.
21. Zhang S, Liu J, Lo ECM, Chu CH. Dental caries status of dai preschool children in yunnan province, china. BMC Oral Health. 2013;13(1).
22. Caplin JL, Evans CA, Begole EA. The Relationship between Caries and Malocclusion in Chinese Migrant Workers' Children in Shanghai. Chin J Dent Res. 2015;18(2):103-10.
23. Chen KJ, Liu J, Xu B, Li Y, Li Y, Zhang S, et al. Oral health status of 12-year-old children in Lisu minority ethnic group in China: a cross-sectional study. BMC Oral Health. 2021;21(1):27.
24. Premaraj TS, Vella R, Chung J, Lin Q, Panier H, Underwood K, et al. Ethnic variation of oral microbiota in children. Sci Rep. 2020;10(1):14788.
25. Sgan-Cohen HD, Margvelashvili V, Bilder L, Kalandadze M, Gordon M, Margvelashvili M, et al. Dental caries among children in Georgia by age, gender, residence location and ethnic group. Community Dent Health. 2014;31(3):163-6.
26. Shi C, Faris P, McNeil DA, Patterson S, Potestio ML, Thawer S, et al. Ethnic disparities in children's oral health: findings from a population-based survey of grade 1 and 2 schoolchildren in Alberta, Canada. BMC Oral Health. 2018;18(1):1.
27. Van Der Tas JT, Kragt L, Veerkamp JJS, Jaddoe VWV, Moll HA, Ongkosuwito EM, et al. Ethnic Disparities in Dental Caries among Six-Year-Old Children in the Netherlands. Caries Research. 2016;50(5):489-97.
28. Wu SC, Ma XX, Zhang ZY, Lo ECM, Wang X, Wang B, et al. Ethnic Disparities in Dental Caries among Adolescents in China. J Dent Res. 2021;100(5):496-506.
29. Wulaerhan J, Abudureyimu A, Bao XL, Zhao J. Risk determinants associated with early childhood caries in Uygur children: a preschool-based cross-sectional study. BMC Oral Health. 2014;14:136.
30. Zhang S, Liu J, Lo ECM, Chu CH. Dental and periodontal status of 12-year-old Bulang children in China. BMC Oral Health. 2014;14(1).
31. Zhang S, Xu B, Liu J, Lo ECM, Chu CH. Dental and periodontal status of 12-yearold Dai school children in Yunnan Province, China: A cross-sectional study. BMC Oral Health. 2015;15(1).
32. Hermans MP, Kooistra J, Cannegieter SC, Rosendaal FR, Mook-Kanamori DO, Nemeth B. Healthcare and disease burden among refugees in long-stay refugee camps at Lesbos, Greece. European journal of epidemiology. 2017 Sep;32(9):851-4. (NO DATA ON CARIES PREVELANCE)
33. Williams B, Cassar C, Siggers G, Taylor S. Medical and social issues of child refugees in Europe. Archives of Disease in Childhood. 2016 Sep 1;101(9):839-42.

34. Mattila A, Ghaderi P, Tervonen L, Niskanen L, Pesonen P, Anttonen V, Laitala ML. Self-reported oral health and use of dental services among asylum seekers and immigrants in Finland—a pilot study. The European Journal of Public Health. 2016 Dec 1;26(6):1006-10. Did not divide between participants ref immig all togethrt
35. Vega-López S, Lindberg NM, Eckert GJ, Nicholson EL, Maupome G. Association of added sugar intake and caries-related experiences among individuals of Mexican origin. Community dentistry and oral epidemiology. 2018 Aug;46(4):376-84.
36. Ogawa JT, Kiang J, Watts DJ, Hirway P, Lewis C. Oral health and dental clinic attendance in pediatric refugees. Pediatric dentistry. 2019 Jan 15;41(1):31-4.
37. Alrashdi M, Cervantes Mendez MJ, Farokhi MR. A Randomized Clinical Trial Preventive Outreach Targeting Dental Caries and Oral-Health-Related Quality of Life for Refugee Children. International Journal of Environmental Research and Public Health. 2021 Feb;18(4):1686.

4.2 Results: Journal Article #2

Oral Health Inequalities in Immigrant Populations Worldwide:
A Scoping Review of Dental Caries and Periodontal Disease Prevalence

Published in:
Journal of BMC Public Health -2024

Banihashem Rad SA[*†], Esteves-Oliveira M[*], Maklennan A, Douglas GV, Castiglia P, Campus G.

[*] Joint first-authorship

[†] Corresponding author

Own contribution:
Study design, data acquisition, analysis and interpretation, manuscript drafting and revising.

BMC Public Health

RESEARCH Open Access

Oral health inequalities in immigrant populations worldwide: a scoping review of dental caries and periodontal disease prevalence

Seyed Ahmad Banihashem Rad[1,2*†], Marcella Esteves-Oliveira[1,3,4†], Anastasia Maklennan[1,2], Gail V. A. Douglas[5], Paolo Castiglia[6] and Guglielmo Campus[1,6,7]

Abstract

Background Inequalities in immigrants' oral health are often masked in population-level data. Therefore, this paper was planned to assess the prevalence data on oral health diseases, namely dental caries, and periodontitis, among immigrants worldwide.

Methods Following a systematic search in Scopus, Embase, and PubMed for studies published between 2011 and 2023, 1342 records were identified. Following title and abstract screening, 76 studies remained for full-text eligibility-screening based on predefined inclusion criteria. Thirty-two studies were included in the review.

Results Dental caries figures were higher in immigrant populations compared to the local population, regardless of host countries, age, gender, or nationality. In children, the overall mean and standard deviation (SD) for decayed, missing, and filled teeth in the primary dentition ($d_3$mft) was 3.63(2.47), and for D_3MFT (permanent dentition), it was 1.7(1.2).

Upon comparing overall mean caries counts in children and adults with their control groups in the included studies, untreated dental caries (D_3T and d_3t) constituted the dominant share of caries experience (D_3MFT and $d_3$mft) in immigrant children. For the local population, the highest proportion of caries experience was attributed to filled teeth (FT and ft).

Dentin caries prevalence among immigrants ranged from 22% to 88.7% in the primary dentition and 5.6% to 90.9% in the permanent dentition. Gingivitis ranged from 5.1% to 100%. Oral health varied greatly between studies. Regarding oral health accessibility, 52% to 88% of immigrant children had never been to a dentist, suggesting a very limited level of accessibility to dental health services.

Conclusion It is imperative to develop interventions and policies that have been customized to address the oral health disparities experienced by immigrant populations. Additionally, host countries should actively implement

†Seyed Ahmad Banihashem Rad and Marcella Esteves-Oliveira are joint first authors.

*Correspondence:
Seyed Ahmad Banihashem Rad
seyedahmad.banihashemrad@unibe.ch
Full list of author information is available at the end of the article

measures aimed at enhancing the accessibility of oral health care services for these individuals. The utilization of available data is crucial in establishing a hierarchy of objectives aimed at enhancing the oral health of immigrant populations.

Trial registration The Scoping review protocol was registered at OSF Registries with registration number (https://doi.org/10.17605/OSF.IO/MYXS4).

Keywords Global burden of oral disease, Emigrants and Immigrants, Oral health, Dental caries, Periodontal diseases, Gingivitis, DMFT, Dmft, Caries lesion

Introduction

In recent years, international migration has dramatically increased, becoming a significant worldwide phenomenon. According to the World Migration Report, there were 281 million international migrants in 2020 globally, an increase of 60 million from 2010. This number includes individuals of all ages who have crossed international borders to reside in countries other than their birthplace [1].

The health and oral health of immigrants may be adversely affected by a number of challenges, such as linguistic and cultural barriers, socioeconomic changes, limited access to healthcare facilities, lack of medical and dental insurance, and loss of social networks [2, 3]. These challenges can often result in poor oral health outcomes among immigrant populations. In this context, the prevalence of oral health problems is expected to be high among immigrants [4]. However, data on the extent of oral health issues and research to inform policymakers about the oral health needs of immigrants are still very limited [5]. There is an urgent need to study oral health in this population due to the growing number of immigrants.

Oral health is an important component of overall health and well-being; however, it is often overlooked in public health discussions. Oral diseases (*i.e.*, dental caries and periodontitis) contribute significantly to the global burden of chronic disease [6, 7]. These oral health conditions can cause significant pain, discomfort, tooth loss, malnutrition, and impair a person's ability to eat, communicate, and smile confidently [8, 9]. These conditions can have adverse impacts on a person's overall health and quality of life [10]. Furthermore, untreated dental caries and periodontal disease can be involved in more serious health complications, such as cardiovascular disease, respiratory infections, and even diabetes [11, 12].

With the increasing globalization and migration of people, it is important to understand the prevalence and risk factors of dental caries and periodontal problems among immigrant populations worldwide. Research has also shown that the prevalence of these oral health diseases in immigrant populations varies depending on their country of origin, level of acculturation, and length of stay in the host country [13, 14].

In summary, oral health diseases are among the most neglected aspects of health, regardless of location, culture, education, or economic standing, and particularly in low- and middle-income countries. Thus, gaining a holistic overview of the prevalence of oral health problems among immigrants might assist policymakers in defining treatment needs and treatment strategies as well as the best ways to adapt them to the health systems of the host countries. Furthermore, oral health disparities between immigrants and non-immigrants can exacerbate existing health inequities and contribute to broader health disparities.

In a previous paper, dental caries and periodontal issues in refugees were described and discussed [15]. In the present review, the focus was put on immigrant populations and compare their data with those of local population of the host country. An immigrant is someone who voluntarily relocates to a different country, whereas a refugee is an individual who is compelled to leave the country of origin.

To the best of authors' knowledge, this is the first review that addresses dental caries and periodontal problems in the immigrant populations on a global quantitative scale. The main goals were to synthesize the evidence of the prevalence of dental caries among immigrants using the Decayed Missing and Filled index (D_3MFT/d_3mft) and to evaluate the prevalence of periodontal disease. Further, the dental care services provided to immigrants and their needs and deficiencies were appraised.

Materials and methods

The Scoping review protocol was registered at OSF Registries with registration number (https://doi.org/10.17605/OSF.IO/MYXS4). The review was completed and reported in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) 2020 statement [16].

Research question and search strategy

What is the prevalence of dental caries and periodontal diseases among immigrants worldwide, and is this higher than those of the general population of the host country?

The research question for this scoping review was outlined based on sample, phenomenon of interest, design, evaluation, and research type (SPIDER) [17] tool. Three electronic databases, Scopus, Embase, and PubMed were searched using the following search strategy. Search strings were created using the keywords and synonyms in conjunction with the Boolean operators "AND" and "OR". In addition to electronic database searches, a comprehensive hand search was conducted to ensure that relevant literature was included in the review. An example of a search string used for PubMed is included here, and the others can be found in Appendix (page 2).

S (Sample): (("Emigrants AND Immigrants"[MeSH Terms] OR "Undocumented Immigrants"[MeSH Terms] OR ("Refugees"[MeSH Terms] OR "Refugee Camps"[MeSH Terms]) OR "Ethnicity"[MeSH Terms] OR "Ethnic and Racial Minorities"[MeSH Terms] OR "asylum seeker*"[Title/Abstract] OR "displaced person*"[Title/Abstract] OR "refugee*"[Title/Abstract]).

P (Phenomenon) of ***I*** (Interest): All the articles that related to either dental caries or periodontal problems.

D (Design): not restricted.

E (Evaluation): (("Dental Caries"[MeSH Terms] OR "Root Caries"[MeSH Terms] OR "Dental Caries Susceptibility"[MeSH Terms] OR "Periodontal Pocket"[MeSH Terms] OR "Periodontal Index"[MeSH Terms] OR "Gingivitis"[MeSH Terms] OR "DMF Index"[MeSH Terms] OR "dmf index*"[Title/Abstract] OR "dental decay*"[Title/Abstract] OR "carious lesion*"[Title/Abstract] OR "Carious white spot*"[Title/Abstract] OR "periodontal pocket*"[Title/Abstract] OR "dmft s*"[Title/Abstract] OR "gingival index*"[Title/Abstract] OR "dmft*"[Title/Abstract] OR "dmft index*"[Title/Abstract] OR "bleeding on probing*"[Title/Abstract] OR "probing pocket depth*"[Title/Abstract] OR "clinical attachment loss*"[Title/Abstract]).

R (Research type): not restricted.

Eligibility criteria

This scoping review included all quantitative and qualitative studies on dental caries or periodontal problems of immigrant populations of any age published from 2011 to August 2023. This timeframe was selected specifically to ensure the review is current and relevant. The review was conducted as part of a Ph.D. project addressing oral health disparities in marginalized communities. Therefore, the search population included terms like refugees and ethnic minorities, while the present review focused only on the immigrant population.

Studies with insufficient oral health data about dental caries or periodontal disease, as well as those involving refugees, asylum seekers, ethnic minorities, or indigenous populations, were excluded. Non-peer-reviewed papers and unpublished research (*e.g.*, theses, abstracts, and preprints) were excluded. Only papers published in English, Italian, German, and French were considered.

Study selection

The selection was conducted using structured procedures. After removing duplicates, the titles and abstracts of search results were examined by two independent reviewers (SABR, AM) to determine their relevance and whether they matched the planned inclusion criteria. Any uncertainties regarding the inclusion of a study were discussed with a third reviewer (GC).

Risk of bias

After excluding ineligible papers, two independent reviewers (SABR, AM) critically rated all eligible full texts using critical appraisal instruments for prevalence studies in the Joanna Briggs Institute (JBI) System for the Unified Management of the Assessment and Review of Information (SUMARI) software (Joanna Briggs Institute, Adelaide, Australia) (appendix page 3). There were nine questions to which the answers were "yes," "no," and "unclear." Uncertainties were resolved through discussion or the assistance of a third reviewer (GC).

Data extraction and data synthesis

One author (SABR) extracted the data using an ad hoc designed excel file for data collection, which was then checked by a second author (GC).

The following information was provided on the data extraction form:

1. Study characteristics: first author's last name, year of publication, journal, country of study, study design, sampling procedures, calculation of sample size, and methods of data collection
2. Participant characteristics and outcome measure: number of participants, sex, age, prevalence of dental caries and periodontal problems, oral health accessibility, and some other findings from the original papers.

Parameters measured in the review

In line with the WHO methodology [18], the decayed (d_3/D_3), missing (m/M), and filled (f/F) teeth ($d_3$mft/D_3MFT) index score (*e.g.* DMF, DMFT, dmft, DMFS,

deft, dft) was applied to evaluate oral health status [19]. Where this index is reported in this review, it refers to caries measured at the dentinal caries threshold (D_3MF/d_3mf) and excludes enamel caries, unless otherwise specified [20]. As we aimed to report on caries prevalence comprehensively, we included studies that utilized both WHO and ICDAS criteria. The D3/d3 level, representing caries lesions in dentine (open and closed), was chosen as a common metric. We acknowledged the differences in diagnostic thresholds between the WHO criteria, which typically focus on cavitated lesions, and the ICDAS criteria, which offer a more detailed assessment of caries progression, including non-cavitated stages. By reporting on both indices, we aimed to present a more complete picture of caries prevalence as reported in the included studies.

The mean and standard deviation (SD) of the prevalence of dental caries and range were calculated where relevant. Studies with prevalence (% $d_3mft/D_3MFT > 0$) or caries count (mean d_3mft/D_3MFT) data on either primary or permanent dentition or periodontal problems (*e.g.*, gingivitis, periodontitis) were taken into consideration.

Periodontal health in children and adults was evaluated using criteria such as gingivitis (Gingival Index and Community Periodontal Index), clinical attachment loss, periodontal pocket depth, bleeding on probing, and radiographic bone loss if reported by the included studies.

Results

Study selection

The initial search with the keywords resulted in 928 papers in Scopus, 116 results in Embase, and 298 results in PubMed (Fig. 1). The authors (SABR and AM) screened the studies by title after the removal of duplicates ($n = 379$). After the title and abstract screening, 76 studies were left for full-text screening. Data extraction was then performed on 30 articles that met the inclusion criteria. In addition, two papers [21, 22] were retrieved by hand search, so overall 32 studies were included. The studies excluded after the full-text review are listed in appendix (page 4). The list of the included studies sorted by country of study is reported in Table 1.

Quality assessment

No papers were excluded solely based on methodological quality assessment. Despite aiming for high methodological quality studies, we recognized that excluding moderate quality studies could potentially miss valuable insights. Studies with a quality assessment score of 5,or 6 were included, even if they weren't of the highest quality. Incorporating a broader range of evidence allowed us to gain a more comprehensive understanding of oral health disparities. Studies of moderate quality contribute valuable data and perspectives, and their inclusion helps mitigate publication bias.

Only two studies [34, 51] out of a total of 32 studies, had all the questions of the critical appraisal answered with a "yes", gaining a score of 9 out of 9. The least favorable scores were given to questions regarding the frame and adequacy of the sample size. The lowest score was five [32, 44, 45] and four studies [25, 29, 38, 43] scored six because there was no description of the sampling frame, participant selection procedures, and sample size calculation. Only thirteen studies reported procedures for calculating sample size or if the sample size was acceptable for the target group. Nineteen studies provided a detailed description of the study's setting and participants. Four studies [35, 38, 44, 45] failed to indicate the confidence interval (CI) for the mean value. The detailed quality assessment can be found in Appendix (page 3).

Characteristics of included studies

Seventeen studies had a control group [21, 22, 31–37, 39, 40, 42, 45, 47–50]. The control groups were the local population of the host country, except for three papers [21, 25, 32] which had a refugee population as a control group.

Among the included papers, three papers [25, 29, 47] assessed the treatment need of immigrants. Ten papers [2, 23, 26–29, 33, 38, 49, 50] reported the utilization of oral health services. Four papers [27, 30, 38, 48] investigated the dietary factors and two papers measured the household acculturation rate [28, 52]. Two papers studied the oral health status of pregnant immigrant women [40, 49] and two papers [33, 44] only included elderly population. None of the included studies had access to the oral health status of the sample group prior to their immigration.

The study participants were children in twenty-four studies, in two studies both children and adults [40, 41] and in six studies only adults [32, 33, 39, 44, 49, 51] were involved. Immigrants originated from a wide range of countries, with a majority coming from South Asia, Africa, Eastern Europe and Central and South America as listed in Table 1. The frequency and distribution of the geographical location of countries of study are shown in Fig. 2, where it is clearly observable the highest number of studies on immigrants have been conducted in Canada and Spain.

Dental caries in immigrants

Regarding dentin caries in children, two papers [47, 48] reported higher d_3mft counts compared to other studies included in the review (mean $d_3mft > 5$), both studies were conducted in Taiwan. The overall d_3mft count

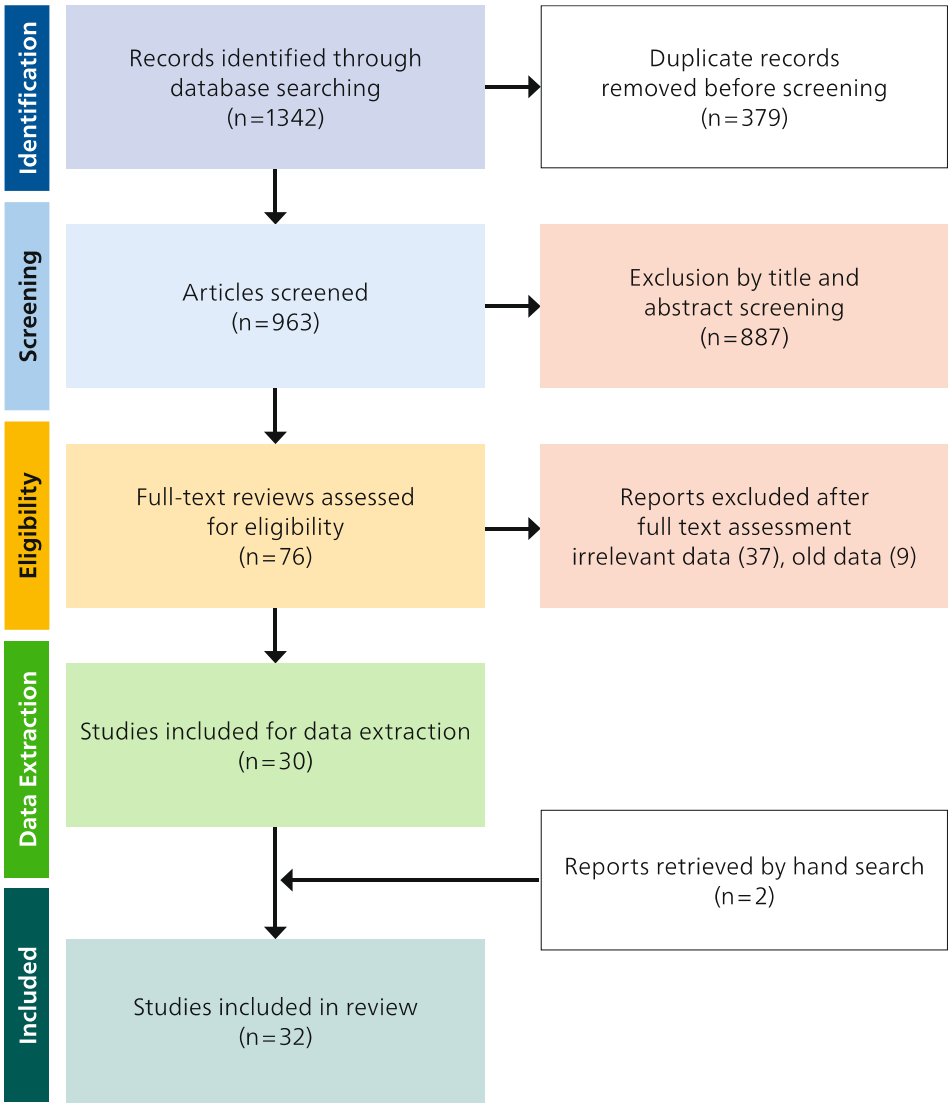


Fig. 1 PRISMA flow diagram of study selection

(primary dentition) of studies identified was 3.63 (2.47) and for D_3MFT (permanent teeth), it was 1.7 (1.2). Four papers [28, 35, 36, 42] also showed an expanded version of the decayed missing filled teeth (D_3MFT) index with individual components, as seen in Table 2.

Upon comparing the overall caries means of the included studies, untreated dental Caries (D_3T and d_3t) constituted the dominant share of the caries experience (D_3MFT and $d_3$mft) in immigrant children. While, within their respective control groups, the highest

Table 1 List of all included papers in the review ordered alphabetically by country where the study was conducted

	Year of study	Study type	Country of study	Country of origin of study participants	Participants (n)	Age Range (years)
Christian B et al., [23]	2012	exploratory trial	Australia	Iraq, Pakistan, and Lebanon	625	1–4
Gibbs et al., [24]	2012	Cross-sectional	Australia	Iraq, Pakistan, and Lebanon	630	1–4
Hoover et al., [25]	2012	Pilot Study	Canada	The Indian subcontinent, other parts of Asia, and the rest of the world	133	3–15
Amin et al., [26]	2013	Cross-sectional	Canada	Africa	125	1.7–6
Elyasi et al., [27]	2015	Cross-sectional	Canada	South Asia, East Asia, Africa,and East Europe	274	1–12
Dahlan et al., [28]	2017	Cross-sectional	Canada	South Asia, South East and East Asia, Arabs, Africans, East Europeans, and Hispanics	336	2–12
Azrak et al., [29]	2017	Cross-sectional	Canada	Africa, Eastern Mediterranean, and South East Asia	211	1–5.9
Liu et al., [30]	2012	Cross-sectional:	China	NR	1323	7–12
Zhang et al., [31]	2013	Cross-sectional	China	NR	10,150	5–15
Mattila et al., [32]	2012	pilot study	Finland	Iraq, Afghanistan, Iran, Russia, Thailand, Somalia, Turkey, Hungary, Slovakia, China, Vietnam, South Sudan, Syria, Sweden and Morocco	38	18–53
Aarabi et al., [33]	2012	Cross-sectional	Germany	Austria, Croatia, Italy, Turkey, Iran, Tunisia, Vietnam, Israel, Poland, Russia and Jamaica	112	60^{+}
Pavlopoulou et al., [21]	2010	Cross-sectional:	Greece	Albania,Meldova,Egypt,Afghanistan, Bangladesh, India, Iran, Kenya, Lebanon, Pakistan, Ukraine,China	300	1–14
Diamanti et al., [34]	2013	Cross-sectional	Greece	Mostly Albania,Eastern European countries (such as Georgia, Romania, Bulgaria and Russia)	4409	5–15
Sivakumar et al., [35]	2016	Cross-sectional	India	Tibet	865	11–13
Ferrazzano et al., [36]	2014	Retrospective Study	Italy	NR	553	12–14
Campus et al., [37]	2017	Cross-sectional	Italy	NR	6,825	3–4
Hashizume et al., [38]	2011	Cross-sectional	Japan	Brazil	378	6–14
Lee et al., [39]	2016	Cross-sectional	South Korea	North Korea, Vietnam, China, Japan, Philippine, Thailand, Cambodia, Mongolia, and Uzbekistan	6,931	19–80
García-Pola et al., [40]	2010	prospective case–control	Spain	South America, Africa, Europe and Asia	90	6–41
Gómez-Costa et al., [41]	2011	Cross-sectional	Spain	NR	115,123	15– 64
Soria et al., [22]	2014	Cross-sectional	Spain	Morocco, Ecuador, Eastern Europe	333	6–17
Rodriguez-Alvarez et al., [42]	2016	Cross-sectional	Spain	NR	1388	4–9
Duran et al., [43]	2018	Cross-sectional	Spain	Asia, South America,Africa,Central America, North America, Euroupe	1400	3–14

Table 1 (continued)

	Year of study	Study type	Country of study	Country of origin of study participants	Participants (n)	Age Range (years)
Olerud et al., [44]	2014	Cross-sectional	Sweden	Iran and the Horn of Africa,Balkans,Central Asia	42	60^{+}
Thorbert-Mros et al., [45]	2021	Cross-sectional	Sweden	Somalia	179	10–17
Baggio et al., [46]	2011	Cross-sectional	Switzerland	NR	856	3–6
Y.C.Lin et al., [47]	2011	Cross-sectional	Taiwan	Vietnam and Indonesia	590	4–6
Ying-Chun Lin et al., [48]	2015	Cross-sectional:	Taiwan	NR	32,611	3–5
Traisuwan et al., [49]	2016	Cross-sectional	Thailand	Myanmar,Republic of Lao,Cambodia,	418	20^{+}
Meva Altas et al., [50]	2022	descriptive and retrospective study	Turkey	Syria	549	6–12
Wilson et al., [51]	2013	Cross-sectional	USA	Mexico	4520	$20–65^{+}$
Kabani et al., [52]	2011	Cross-sectional:	USA	Central and South America	9143	1–17

NR Not reported

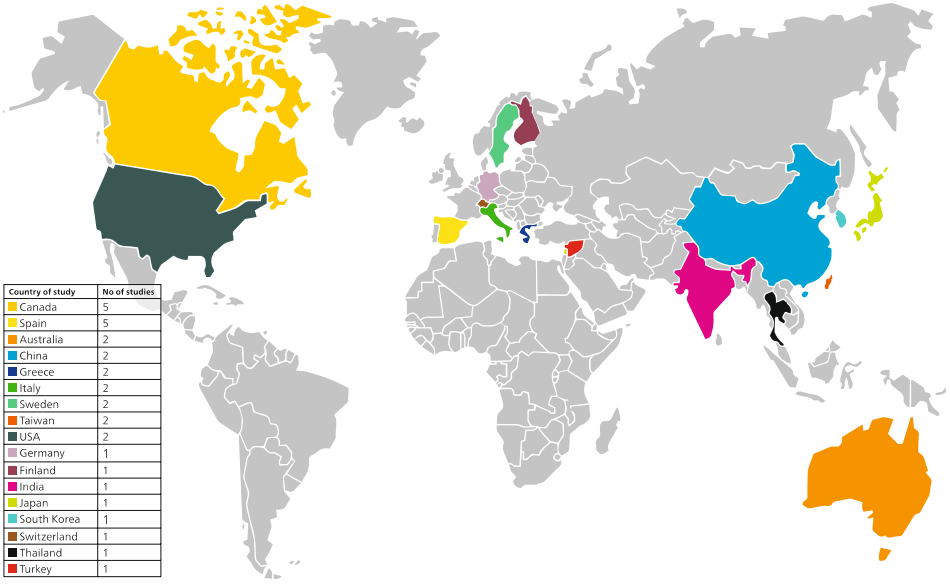


Fig. 2 World map showing the host countries, where the studies on the oral health of immigrants have been conducted. The key on the left shows the number of studies per country, with the countries sorted by number of studies (from the highest to the lowest). Countries in which no studies could be found are marked in grey

proportion of caries experience was attributed to Filled Teeth (FT and ft).

Among the papers that had the local population as control group, the immigrant children had a higher mean D_3MFT/d_3mft (SD) compared to local children. This difference was significant except for two papers [31, 42], which only showed a significant difference for primary dentition and not the permanent dentition.

There were only three studies [33, 40, 49] reported caries using D_3MFT in adults, suggesting that there is a lack

Table 2 Caries distribution in immigrants and control groups in included studies[a]

	Sample size	D_3MFT	D_3t	Mt	Ft	D_3mft	d_3t	mt	ft	D_3MFT/d_3mft	D_3t/d_3t
Immigrant group											
Adults											
Traisuwan et al., [49]	208	5.8 (4.4)	5.5 (3.6)	1.5 (1)	3.2 (2.5)	NR	NR	NR	NR	NR	NR
García-Pola et al., [37]	45	8.33 (6.66)	NR	NR	NR	NR	NR	NR	NR	NR	NR
Aarabi et al., [33]	61	24.8 (3.9)	5.3 (4.6)	14.4 (8.8)	5 (4.6)	NR	NR	NR	NR	NR	NR
Children											
Hashizume et al., [38]	378	1.28 (2.22)	NR	NR	NR	NR	NR	NR	NR	NR	NR
Ferrazzano et al., [36]	183	3.92 (2.92)	2.49 (1.98)	0.88 (1.24)	0.56 (1.1)	NR	NR	NR	NR	NR	NR
Y.C. Lin et al., [47]	150	NR	NR	NR	NR	6.05	4.5	0.39	1.16	NR	NR
Liu et al., [30]	1323	2.74 (3.02)	0.01	0	NR	3.17 (3.12)	2.71	0.01	0.01	NR	NR
Sivakumar et al., [35]	431	1.14 (1.04)	1.13 (1.07)	0.04 (0.25)	0	0.18 (0.5)	0.12 (0.4)	0.04 (0.26)	0.02 (0.15)	NR	NR
Ying-Chun Lin et al., [48]	1046	NR	NR	NR	NR	8.47	5.38	0.3	2.79	NR	NR
Zhang et al., [31]	3412	1.05 (0.34)	NR	NR	NR	3.18 (0.57)	NR	NR	NR	NR	NR
Dahlan et al., [28]	336	NR	NR	NR	NR	NR	NR	NR	NR	3.7	NR
Diamanti et al., [34]	707	2.5 (0.14)	1.75 (0.07)	00 (0.1)	0.75 (0.21)	3 (3.8)	2.7 (3.9)	0.0 (0.4)	0.3 (1.1)	NR	NR
Rodriguez-Alvarez et al., [42]	413	0.1 (0.42)	0.1 (0.4)	NR	NR	1.7 (2.6)	1.5 (2.5)	NR	NR	NR	NR
Soria et al., [22]	177	NR	NR	NR	NR	NR	NR	NR	NR	7.8	NR
Azrak et al., [29]	211	NR	NR	NR	NR	2.2 (3.8)	1.7 (3)	0.2 (0.8)	0.3 (1.6)	NR	NR

Table 2 (continued)

	Sample size	D_3MFT	D_3t	Mt	Ft	D_3mft	d_3t	mt	ft	D_3MFT/d_3mft	D_3t/d_3t
Hoover et al., [25, 53]	44	NR	NR	0.64 (1.12)	0.48 (1.52)	NR	NR	NR	NR	3.52 (3.78)	2.41 (3.44)
Meva Altas et al., [50]	549	0.94 (0.18)	NR	NR	NR	4.8 (1.6)	NR	NR	NR	NR	NR
Elyasi et al., [27]	274	NR	NR	NR	NR	NR	NR	NR	NR	3.28 (3.76)	NR
García-Pola et al., [37]	45	NR	NR	NR	NR	NR	3.5 (3.4)	NR	NR	NR	NR
Overall	9679	1.7 (1-2)	1.36 (1.01)	0.52 (0.43)	0.59 (0.13)	3.63 (2.47)	2.76 (1.69)	0.18 (0.16)	0.76 (1.07)	4.57 (2.15)	2.41
Control group											
Adults											
Traisuwan et al., [49]	210	4.8 (4)	3.8 (2.9)	2 (1.5)	3.1 (2.5)	NR	NR	NR	NR	NR	NR
García-Pola et al., [37]	45	8.07 (6.05)	NR	NR	NR	NR	NR	NR	NR	NR	NR
Aarabi et al., [33]	51	23.4 (4.6)	2.1 (2.8)	12.6 (9.5)	8.6 (6.2)	NR	NR	NR	NR	NR	NR
Children											
Y.C.Lin et al., [47]	440	NR	NR	NR	NR	3.88	1.57	0.17	2.13	NR	NR
Ferrazzano et al., [36]	370	3.29 (3.21)	1.16 (1.35)	0.71 (1.43)	1.38 (1.98)	NR	NR	NR	NR	NR	NR
Sivakumar et al., [35]	434	0.45 (0.8)	0.32 (0.69)	0.02 (0.16)	0.1 (0.36)	0.58 (0.98)	0.3 (0.72)	0.23 (0.65)	0.04 (0.21)	NR	NR
Ying-Chun Lin et al., [48]	31,565	NR	NR	NR	NR	8.10	4.37	0.23	3.5	NR	NR
Zhang et al., [31]	6738	1 (0.31)	NR	NR	NR	2.61 (0.66)	NR	NR	NR	NR	NR
Rodriguez-Alvarez et al., [42]	839	0.0 (0.28)	0.0 (0.2)	NR	NR	0.7 (1.5)	0.6 (1.4)	NR	NR	NR	NR

Table 2 (continued)

	Sample size	D_3MFT	D_3t	Mt	Ft	D_3mft	d_3t	mt	ft	D_3MFT/d_3mft	D_3t/d_3t
Soria et al., [22]	136	NR	NR	NR	NR	NR	NR	NR	NR	6.6	7.3 (4.4)
Hoover et al., [25]	89	NR	NR	1.25 (2.2)	1.55 (2.36)	NR	NR	NR	NR	5.8 (4.2)	3 (3.4)
García-Pola et al., [37]	45	NR	NR	NR	NR	NR	0.24 (0.6)	NR	NR	NR	NR
Overall	40,656	1.58 (1.5)	0.74 (0.59)	0.66 (0.61)	1.01 (0.79)	2.68 (3)	1.71 (1.85)	0.21 (0.03)	1.89 (1.74)	6.2 (0.56)	5.15 (3.04)

D_3MFT – caries experience in the permanent dentition, d_3mft – caries experience in the primary dentition, D_3T – decayed teeth in the permanent dentition, MT – missing teeth in the permanent dentition, FT – filled teeth in the permanent dentition, d_3t – decayed teeth in the primary dentition, mt – missing teeth in the primary dentition, ft – filled teeth in the primary dentition, *NR* Not reported, *SD* Standard deviation

[a] Data presented as mean (SD) unless otherwise specified

of caries data in immigrant adults. The mean D_3MFT count among immigrant adults was higher than that of the local population. This difference was significant except for two studies [33, 40]. It is important to emphasize that we only reported the statistics generated by the included studies. As regards caries experience, due to the limited number of studies and heterogeneity of study participants in the adult population, the overall mean for caries experience was not calculated.

Caries prevalence and further detail of included papers

The main focus of all included studies was oral health (OH) except for two [21, 25], which also involved general health (GH). Only three studies [21, 42] reported a caries prevalence of below 20% for immigrant children. Caries prevalence in the primary dentition ranged from 22% to 88.7%, and in the permanent dentition from 5.6% to 90.9%. Overall, the caries prevalence, regardless of dentition stage, ranged from 17% to 97.3% among the immigrant population (Table 3).

When comparing the caries prevalence to the local population, the immigrants always had a higher prevalence. Only one study [21] reported a lower caries prevalence than in the control group however, in this instance the control group was a refugee population. Visual comparison of caries prevalence between immigrant groups and their corresponding control groups via bar charts can be found in the appendix (page 5).

Other indices to report caries: DMFS and ICDAS

Five papers [24, 26, 29, 34, 37] reported caries prevalence in other forms using D_3MF at the surface level (D_3MFS) or International Caries Detection and Assessment System *(*ICDAS). Two papers [26, 29] reported caries using D_3MFS (Table 4). Two papers [24, 34] used the dmfs index derived from the full range of ICDAS scores [53], as a result, their count of caries experience included both enamel and dentine caries since both are recorded by the ICDAS index [54]. Analysis of tooth surfaces found that early caries lesions were especially frequent in age groups 12 and 15, with respective mean values of 1.9(2.1) and 2.4(3.0) [34].

Periodontal Health in immigrants

Nine papers [25, 32, 33, 41, 44, 45, 49–51] examined the periodontal health. Four of them [25, 32, 45, 50] focused on children and five [33, 41, 44, 49, 51] on adults. Two paper [33, 44] only included an elderly population and one paper included only pregnant migrant women [49].

Regarding periodontal health in children, the prevalence of gingivitis ranged from 5.1% to 100%, indicating a high variation. In particular, the prevalence of gingivitis was reported as very high in three studies [25, 32, 45], with one paper reporting that almost all children had chronic gingivitis [45] and two papers reporting a prevalence of two thirds [25, 32]. Although gingival inflammation was apparently high from the aforementioned studies, one paper [50] reported a prevalence of gingivitis of 5.1%. Another paper showed a higher prevalence of gingivitis in immigrant children compared to the local population with a margin of 25% [45].

Regarding periodontal health in adults, the prevalence of periodontitis was present in half of the population observed [51], similar was observed in another study [44] which reported two-thirds of participants had periodontitis and a quarter of them were diagnosed with severe periodontitis (gingival pockets of 6 mm or deeper). Based on the Papillary Bleeding Index, a study [33] conducted on elderly immigrants showed a greater prevalence of papillary bleeding compared to their peers (46.3% *vs* 30.5%).

The one paper that included only pregnant Immigrant women, reported almost all participants had gingivitis, the periodontitis was three times more prevalent in immigrant pregnant women compared to local pregnant women (74.5% vs 22.4%). Moreover, 11% were diagnosed with severe periodontitis compared to only 0.5% in the host population, which showed a huge difference in periodontal health between pregnant migrant women and local pregnant ones [49].

Oral health accessibility

Access to oral health care is an important determinant of oral health status [55]. Unfamiliarity with the dental care delivery system, lack of proper insurance (where relevant) and high costs of dental treatment might make obtaining proper oral care difficult [26].

Eight papers [23, 26–29, 33, 49, 50] explored the history of dental visits in immigrants, all papers addressed children except for two [33, 49]. Four papers [27, 28, 33, 49] reported, whether the participants have had a dental visit in the last year while others asked about history of dental visit in their lifetime.

When asking immigrants' children about the history of their last dentist visit, the percentage of children who never visited a dentist in their life, ranged from 52 to 88% (appendix page 6). For adults, there was a significant difference in dental visits between migrants and local women, with 61.1% of migrants never having visited the dentist or visiting less frequently than once a year [49]. Regarding last year dental visit, 88.2% of non-migrant Germans had at least one dental examination, compared to 68.9% of immigrants.

Table 3 Further detail of included papers and caries prevalence

	Focus GH or OH	Dentist involved	Instruments mentioned	Reliability tested†	Caries detection method	Caries prevalence (%)	Caries prevalence in control group (%)
Primary Dentition							
Christian B et al., [23]	OH	NR	NR	NR	ICDAS II	22	NR
Gibbs et al., [24]	OH	Yes	Yes	Yes	ICDAS/ WHO	34	NR
Baggio et al., [46]	OH	Yes	Yes	Yes	WHO	38.6	12.1
Rodriguez-Alvarez et al., [42]	OH	One dentist	Yes	No	WHO	42.6	24.1
Azrak et al., [29]	OH	Yes	Yes	NR	WHO	45.5	NR
Amin et al., [26]	OH	Yes	Yes	Yes	WHO	56	NR
Duran et al., [43]	OH	Yes	Yes	Yes	NR	62.3	42.6
Diamanti et al., [34]	OH	Yes	Yes	Yes	ICDAS II	64.2	NR
Liu et al., [30]	OH	Yes	Yes	Yes	WHO	65.7	NR
García-Pola et al., [37]	OH	Yes	Yes	NR	WHO	66.6	15.5
Ying-Chun Lin et al., [48]	OH	Yes	Yes	NR	WHO	68.1	56.7
Zhang et al., [31]	OH	Yes	Yes	Yes	WHO	71.4	64.5
Campus et al., [37]	OH	Yes	Yes	Yes	ICDAS	72.6	41.6
Y.C. Lin et al., [47]	OH	NR	Yes	Yes	WHO	88.7	NR
Permanent Dentition							
Rodriguez-Alvarez et al., [42]	OH	One dentist	Yes	No	WHO	5.6	2.4
Duran et al., [43]	OH	Yes	Yes	Yes	NR	16.4	12.2
Liu et al., [30]	OH	Yes	Yes	Yes	WHO	28.1	NR
Wilson et al., [51]	OH	Yes	NR	NR	NS	38	34.4
Hashizume et al., [38]	OH	Yes	Yes	NR	WHO	38.1	NR
Zhang et al., [31]	OH	Yes	Yes	Yes	WHO	42.5	39.6
Lee et al., [39]	OH	Yes	Yes	NR	WHO	54.8	24.9
Mattila et al., [32]	OH	Yes	NR	NR	NR	65	57
Diamanti et al., [34]	OH	Yes	Yes	Yes	WHO	67.1,	NR
Sivakumar et al., [35]	OH	NR	Yes	Yes	WHO	71	53.9
Olerud et al., [44]	OH	One dentist	Yes	NR	NR	75	NR
Ferrazzano et al., [36]	OH	Yes	Yes	Yes	WHO	77.5	55.9
García-Pola et al., [37]	OH	Yes	Yes	NR	WHO	88.9	80
Traisuwan et al., [49]	OH	Yes	NR	Yes	WHO	90.9	85.2
Aarabi et al., [33]	OH	Yes	Yes	Yes	WHO	NR	NR
Unspecified dentition							
Pavlopoulou et al., [21]	GH	NR	NR	NR	NR	17.4	24.7
Kabani et al., [52]	OH	NR	NR	NR	WHO	24.9	NR
Elyasi et al., [27]	OH	Yes	Yes	NR	WHO	52	NR
Soria et al., [22]	OH	Yes	NR	NR	NR	92.3	NR
Meva Altas et al., [50]	OH	One dentist	Yes	NR	NR	97.3	NR
Dahlan et al., [28]	OH	Yes	Yes	NR	WHO	NR	NR
Gómez-Costa et al., [41]	OH	Yes	NR	NR	WHO	NR	NR
Thorbert-Mros et al., [45]	OH	Yes	Yes	NR	WHO	NR	NR
Hoover et al., [25]	GH	Yes	Yes	NR	NR	NR	NR

GH General health, *OH* Oral health, *NR* Not reported, *WHO* World health organization, *ICDAS* International Caries Detection and Assessment System

†Reliability tested: If the studies gave information about inter or intra reliability of dental examination, it is showed as Yes or NR. The studies that did not report the caries prevalence, reported caries in other forms DMFT/S

Discussion

Based on the included studies, it was evident that immigrants were more likely to suffer from oral health problems than the local population in their host country. The perceived treatment needs varied between studies, still dental caries and periodontal disease were

Table 4 Caries distribution in immigrants in studies using DMFS and ICDAS as caries indices[a]

	Sample size	Age in years	dmfs	Decayed surfaces	Missing surfaces	Filled surfaces
Amin et al., [26]	125	1.7–6	7.2 (11.6)	4.2 (7.4)	NR	NR
Azrak et al., [29]	211	1–5.9	4.8 (11)	3 (6.7)	0.7 (3.5)	1.1 (6.2)
ICDAS Study	**Sample size**	**Age in years**	**DMFS/dmfs $_{ICDAS\ 1–6}$**	**DFMS/dmfs $_{ICDAS1•3}$**		**DMFS/dmfs $_{ICDAS\ 4–6}$**
Diamanti et al., [34]	707	5	4.1 (9.1)	1.1 (1.6)		5 (7.9)
		12	3.6 (4.4)	1.9 (2.1)		3.6 (4.4)
		15	3.7 (4.8)	2.4 (3)		3.7 (4.8)
Gibbs et al., [24]	630	1–4	1.9 (4.62)	NA		0.91 (3.47)

NR Not reported, *DMFS* Decayed, missing, and filled surfaces, *ICDAS* International Caries Detection and Assessment System

[a] Caries value is reported as mean (SD) unless otherwise specified

most commonly regarded as urgent problems among immigrants.

A variety of factors have been identified as influencing dental caries prevalence among immigrant children, including family socioeconomic status, household acculturation, oral health accessibility, child's age, gingival inflammation, fluoride exposure,country of origin, and generational status [22, 25, 46, 52]. These factors collectively contribute to caries development, highlighting the complex interaction between diverse influences on dental health outcomes within different demographic contexts.

Acculturation and oral health have a dynamic relationship [3]. Oral health might be affected by acculturation, which has been defined as "lifestyle and behavioral changes as a result of moving from one culture to another, usually as a result of immigration" [56]. According to one study [52], household acculturation was a significant predictor of dental caries in children, whereas another study [28] found no association between parental acculturation and children's dmft/DMFT level.

Lower age was directly correlated to higher caries prevalence [34, 50]. In another study, the same was observed but just for the primary dentition [31]. The disparity in caries between immigrant children and their peers in older age groups was less, which it has been suggested indicates that the dental health of migrants children was better in older children [31, 34, 50]. The decrease in caries disparity among older immigrant children might be due to improved socioeconomic status of parents [34], increased access to oral health services, local peers' influences at schools [31], and ultimately development of better oral health habits, such as proper oral hygiene practices(frequent and adequate brushing and flossing) and healthier nutritional choices. It might be hypothesized that the older children are more mature and generally more familiarized with the new language and therefore adopt easier to dental health habits of their host country, while younger children usually continue to follow their parents' traditional practices. According to a study conducted in Spain, the second generation of immigrant children had lower caries prevalence than first-generation and they were almost similar to Spanish-born children after adjustment for confounders (social class, marital status, and maternal education) [22]. However, there are many confounding variables at play, as well as methodological limitations, which limits confidence in any conclusions about age-related disparities drawn from cross-sectional studies.

All studies, except one [41], reported that the prevalence of periodontitis in immigrants was higher compared to the local population. According to one study [41], there was a similar proportion of gum bleeding among immigrants (16 to 23%) and Spanish nationals (17 to 21%). immigrant women, as well as immigrants between the ages of 25–64, were less likely to experience gum bleeding than their local peers.

The socio-demographic characteristics of immigrant children significantly impacted their use of dental care. These factors included parental education [28], income level [28], dental coverage [23, 26–28], child's age [26], mother's age [26, 28], the duration of parental residence in the host country [26], household structure [28] (whether living with both parents or with a single parent), frequency of parent's dental visits [23] (characterized by infrequent attendance), primary reasons for dentist visits (primarily for treatment rather than preventive care) [23], parental perception of the child's dental care needs [23], and parental assimilation scores [28]. Among the various factors considered by the studies, requiring insurance coverage was identified as the most common and significant factor affecting children's dental visits [23, 26–28]. One paper [23] specifically explores reasons related to the immigrant child's non-utilization of dental services and their parents/guardians reported cost, long waiting periods for treatment, language barriers and "no need for

child to visit" were the main barriers for accessing to oral health services for their children.

Oral health disparities are not limited to immigrant groups and are widespread in numerous nations, reflecting the present global tendency to emphasize specialized treatments rather than ensuring equal access to care [57, 58]. It is evident that a number of global factors might be contributing to the weaker oral health of immigrants compared to native people in host countries. Firstly, there are disparities in oral health across the world that are impacted by socioeconomic, cultural, and environmental variables. Second, these difficulties could also be exacerbated by obstacles such as language barriers, inadequate insurance, and unfamiliarity with the healthcare systems in the host countries. Oral health disparities across immigrant populations can be made exacerbated by differences in income, education, and healthcare facilities between the countries of origin and the host countries. To address these global factors contributing to oral health inequalities, multi-level interventions aimed at providing equitable access to dental healthcare services are needed [57, 59].

Our search strategy was unable to find any studies conducted in South America or Africa. This might be attributed to a lack of scientific research on immigrant dental caries or periodontal problems after 2011 in these regions or to the fact that these studies have not yet been published in indexed journals. In our review, the majority of studies employed cross-sectional designs and had a pure descriptive scope, indicating that this issue is still in its exploratory phase.

This scoping review has some limitations, including the possibility that some information could have been overlooked, as the studies retrieved in the systematic database search showed considerable differences in the characterization and reported data of the immigrant population. Additionally, we observed significant differences in sampling procedures, power calculations, and geographic location among the included studies; some studies [25, 29, 38, 43] did not specify sample size calculation, and immigrant populations were generally smaller than the control groups. There are also existing intra-immigrant disparities, which might be due to variations in socioeconomic status, healthcare access, cultural practices, and health literacy which was not discussed in detail in our review.

Due to a lack of comparability and high heterogeneity among the studies, we did not conduct a meta-analysis. Since we included studies published exclusively after 2011, our findings are less generalizable due to the limited number of publications on this topic, especially from developing and underdeveloped countries. Moreover, including only articles published in English, Italian, German, and French might have introduced a language bias, excluding studies published in other languages. In addition, human errors and bias may have contributed to the loss of information or bias of the results.

In spite of these limitations, to our knowledge, the present review was the first to summarize oral health diseases of immigrants in a quantitative manner on a global scale. The study provides additional information on special needs and associations that can be used to improve oral health in immigrants.

The findings of our study have significant implications for professionals in oral health as well as public health efforts. Inequalities in immigrants' oral health care are often masked by population-level data since immigrants constitute a small proportion of populations in host countries. Our findings successfully addressed the reality of immigrant oral health in their respective countries.

Conclusion

There is a higher prevalence of dental caries among immigrants than among the local population in each host country, regardless of age, gender, or country. Untreated dental caries (D_3T, d3t) were more prevalent in this population. The existing data can be used to set priorities for improving immigrants' oral health worldwide. Immigrants worldwide face major oral health challenges, including dental caries, periodontal diseases and limited access to oral health services.

Efforts must be made to reduce oral health disparities among immigrants. Host countries must implement strategies to significantly increase access to dental care for immigrants such as Providing oral health insurance to immigrant children, developing community healthcare centers, expanding financial assistance, and integrating dental services into primary healthcare.. Further studies are needed to contribute to real-world knowledge about immigrants' oral health, as they can assist host-country policymakers in improving immigrants' oral health and developing more cost-effective preventative measures.

Abbreviations

OSF	Open science framework
PRISMA	Preferred Reporting Items for Systematic Reviews and Meta-Analyses
SPIDER	Sample phenomenon of interest, design, evaluation, and research type
JBI SUMARI	Joanna Briggs Institute System for the Unified Management of the Assessment and Review of Information
WHO	World health organization
D_3MFT	Caries experience in the permanent dentition
d_3mft	Caries experience in the primary dentition
D_3T	Decayed teeth in the permanent dentition
MT	Missing teeth in the permanent dentition
FT	Filled teeth in the permanent dentition
d_3t	Decayed teeth in the primary dentition
mt	Missing teeth in the primary dentition
ft	Filled teeth in the primary dentition
NR	Not reported

SD	Standard deviation
GH	General health
OH	Oral health
ICDAS	International Caries Detection and Assessment System
DMFS	Decayed, missing, and filled surfaces

Supplementary Information

The online version contains supplementary material available at https://doi.org/10.1186/s12889-024-19354-4.

Supplementary Material 1.

Acknowledgements
The authors would like to thank Bernadette Rawyler and Ines Badertscher from the graphic Department of School of Dental Medicine, University of Bern, Switzerland for the help to create the figures.

Authors' contributions
S.A.B.R, G.C, and M.E.O contributed to design, data acquisition, analysis, and interpretation, drafted and critically revised the manuscript; G.VA.D, A.M, and P.C provided critical insights and revised the manuscript at various stages. All authors gave their final approval and agreed to be accountable for all aspects of the work.

Funding
The research presented in the manuscript received funding from Swiss Government Excellence Scholarship Grants: #2021.0876.

Availability of data and materials
Any data that support the findings of this study are available from the corresponding author, upon reasonable request.

Declarations

Ethics approval and consent to participate
Not applicable.

Consent for publication
Not applicable.

Competing interests
The authors declare no competing interests.

Author details
[1]Department of Restorative, Preventive and Pediatric Dentistry, University of Bern, Freiburgstrasse 7, Bern 3012, Switzerland. [2]Graduate School for Health Sciences, University of Bern, Bern, Switzerland. [3]Department of Restorative Dentistry and Endodontology, Justus-Liebig-University Giessen, Giessen, Germany. [4]Department of Conservative Dentistry, Periodontology and Endodontology, Oral Medicine and Maxillofacial Surgery (UZMK), University Centre of Dentistry, University of Tübingen, Tübingen, Germany. [5]Department of Dental Public Health, University of Leeds School of Dentistry, Leeds, UK. [6]Department of Medicine, Surgery and Pharmacy, University of Sassari, Sassari, Italy. [7]Department of Cariology, Saveetha Dental College and Hospitals, SIMATS, Chennai 600077, India.

Received: 26 October 2023 Accepted: 3 July 2024
Published online: 23 July 2024

References

1. McAuliffe M, Khadria B. International Organization for Migration (2021). World Migration Report. 2022
2. Liu Y. Differentiation of self-rated oral health between American noncitizens and citizens. Int Dent J. 2016;66(6):350–5.
3. Wu B, Mao W, Qi X, Pei Y. Immigration and oral health in older adults: an integrative approach. J Dent Res. 2021;100(7):686–92.
4. Armfield JM, Spencer AJ, Slade GD. Changing inequalities in the distribution of caries associated with improving child oral health in Australia. J Public Health Dent. 2009;69(2):125–34.
5. Riggs E, Gibbs L, Kilpatrick N, Gussy M, van Gemert C, Ali S, et al. Breaking down the barriers: a qualitative study to understand child oral health in refugee and migrant communities in Australia. Ethn Health. 2015;20(3):241–57.
6. Collaborators GOD, Bernabe E, Marcenes W, Hernandez C, Bailey J, Abreu L, et al. Global, regional, and national levels and trends in burden of oral conditions from 1990 to 2017: a systematic analysis for the global burden of disease 2017 study. J Dent Res. 2020;99(4):362–73.
7. Wen P, Chen M, Zhong Y, Dong Q, Wong H. Global burden and inequality of dental caries, 1990 to 2019. J Dent Res. 2022;101(4):392–9.
8. Kisely S. No mental health without oral health. Can J Psychiatry. 2016;61(5):277–82.
9. Azzolino D, Passarelli PC, De Angelis P, Piccirillo GB, D'Addona A, Cesari M. Poor oral health as a determinant of malnutrition and sarcopenia. Nutrients. 2019;11(12):2898.
10. Fiorillo L. Oral health: the first step to well-being. MDPI; 2019. p. 676.
11. Carramolino-Cuéllar E, Tomás I, Jiménez-Soriano Y. Relationship between the oral cavity and cardiovascular diseases and metabolic syndrome. Med Oral Patol Oral Cir Bucal. 2014;19(3): e289.
12. Cronin A. Periodontal disease is a risk marker for coronary heart disease? Evidence-Based Dentistry. 2009;10(1):22.
13. Ramos-Gomez F, Kinsler JJ. Addressing social determinants of oral health, structural racism and discrimination and intersectionality among immigrant and non-English speaking Hispanics in the United States. J Public Health Dent. 2022;82:133–9.
14. Riley JL, Gilbert GH, Heft MW. Socioeconomic and demographic disparities in symptoms of orofacial pain. J Public Health Dent. 2003;63(3):166–73.
15. Banihashem Rad SA, Esteves Oliveira M, Maklennan A, Castiglia P, Campus G. Higher prevalence of dental caries and periodontal problems among refugees: A scoping review. J Glob Health. 2023;13:04111.
16. Page MJ, McKenzie JE, Bossuyt PM, Boutron I, Hoffmann TC, Mulrow CD, et al. The PRISMA 2020 statement: an updated guideline for reporting systematic reviews. Int J Surg. 2021;88: 105906.
17. Cooke A, Smith D, Booth A. Beyond PICO: the SPIDER tool for qualitative evidence synthesis. Qual Health Res. 2012;22(10):1435–43.
18. Organization WH. Oral health surveys: basic methods: World Health Organization; 2013.
19. Klein H, Palmer CE, Knutson JW. Studies on dental caries: I. Dental status and dental needs of elementary school children. Public Health Reports (1896–1970). 1938:751–65.
20. Pitts N, Fyffe H. The effect of varying diagnostic thresholds upon clinical caries data for a low prevalence group. J Dent Res. 1988;67(3):592–6.
21. Pavlopoulou ID, Tanaka M, Dikalioti S, Samoli E, Nisianakis P, Boleti OD, et al. Clinical and laboratory evaluation of new immigrant and refugee children arriving in Greece. BMC Pediatr. 2017;17(1):1–10.
22. Valcarcel Soria R, Bernabé E, Somacarrera Perez ML. Acculturation and dental caries among children in Spain. J Immigr Minor Health. 2019;21:699–705.
23. Christian B, Young D, Gibbs L, de Silva A, Gold L, Riggs E, et al. Exploring child dental service use among migrant families in metropolitan Melbourne. Aust Dental J. 2015;60(2):200–4.
24. Gibbs L, de Silva AM, Christian B, Gold L, Gussy M, Moore L, et al. Child oral health in migrant families: a cross-sectional study of caries in 1–4 year old children from migrant backgrounds residing in Melbourne. Aust Commun Dental Health. 2016;33(2):100–6.
25. Hoover J, Vatanparast H, Uswak G. Risk determinants of dental caries and oral hygiene status in 3–15 year-old recent immigrant and refugee children in Saskatchewan, Canada: a pilot study. J Immigr Minor Health. 2017;19:1315–21.
26. Amin MS, Perez A, Nyachhyon P. Parental awareness and dental attendance of children among African immigrants. J Immigr Minor Health. 2015;17:132–8.
27. Elyasi M, Abtahi M, Kornerup I, Amin M. Impact of Parents' Sense of Coherence on Children's Oral Health-Related Behaviors and Dental Caries Experience among Newcomers. J Health Care Poor Underserved. 2021;32(1):423–34.
28. Dahlan R, Bohlouli B, Salami B, Saltaji H, Amin M. Parental acculturation and oral health of children among immigrants. J Public Health Dent. 2022;82(4):426–36.

29. El Azrak M, Huang A, Hai-Santiago K, Bertone MF, DeMaré D, Schroth RJ. The oral health of preschool children of refugee and immigrant families in Manitoba. J Can Dent Assoc. 2017;83(h9):1488–2159.
30. Liu C-j, Zhou W, Feng X-s. Dental caries status of students from migrant primary schools in Shanghai Pudong New Area. BMC Oral Health. 2016;16:1–8.
31. Zhang H, Zeng X, Jiang Y, Xu W, Wang X, Li C, et al. The disparity in caries and sealants between migrant and native children in Shanghai: A cross-sectional study. Int J Dental Hygiene. 2020;18(1):84–91.
32. Mattila A, Ghaderi P, Tervonen L, Niskanen L, Pesonen P, Anttonen V, et al. Self-reported oral health and use of dental services among asylum seekers and immigrants in Finland—a pilot study. Eur J Public Health. 2016;26(6):1006–10.
33. Aarabi G, Reissmann DR, Seedorf U, Becher H, Heydecke G, Kofahl C. Oral health and access to dental care–a comparison of elderly migrants and non-migrants in Germany. Ethn Health. 2018;23(7):703–17.
34. Diamanti I, Berdouses ED, Kavvadia K, Arapostathis KN, Polychronopoulou A, Oulis CJ. Dental caries prevalence and experience (ICDAS II criteria) of 5-, 12-and 15-year-old children and adolescents with an immigrant background in Greece, compared with the host population: a cross-sectional study. Int J Environ Res Public Health. 2021;19(1):14.
35. Sivakumar V, Jain J, Haridas R, Paliayal S, Rodrigues S, Jose M. Oral health status of Tibetan and local school children: a comparative study. J Clin Diagnos Res. 2016;10(11):ZC29.
36. Ferrazzano G, Cantile T, Sangianantoni G, Ingenito A, Rengo S, Alcidi B, et al. Oral health status and Unmet Restorative Treatment Needs (UTN) in disadvantaged migrant and not migrant children in Italy. Eur J Paediatr Dent. 2019;20(1):10–4.
37. Campus G, Cocco F, Strohmenger L, Wolf TG, Balian A, Arghittu A, et al. Inequalities in caries among pre-school Italian children with different background. BMC Pediatr. 2022;22(1):1–10.
38. Hashizume LN, Shinada K, Kawaguchi Y. Factors associated with prevalence of dental caries in Brazilian schoolchildren residing in Japan. J Oral Sci. 2011;53(3):307–12.
39. Lee H, Seo S, Kang R, Kim Y, Hyun H-K. Increasing access to oral healthcare for marriage-immigrant women in South Korea: programme design to policy recommendation. Int Dent J. 2019;69(5):354–60.
40. García-Pola M, González-Díaz A, García-Martín JM. Effect of a preventive oral health program starting during pregnancy: a case-control study comparing immigrant and native women and their children. Int J Environ Res Public Health. 2021;18(8):4096.
41. Gómez-Costa D, San-Roman-Montero J, Rojo R, Gil Á, Gómez de Diego R, López-Sánchez AF. Self-reported prevalence of periodontal disease among the Spanish population and immigrants: 2006, 2011/12 and 2017: a population-based study. BMC Oral Health. 2021;21(1):1–10.
42. Rodriguez-Alvarez E, Borrell LN, Marañon E, Lanborena N. Immigrant status and ethnic inequities in dental caries in children: Bilbao, Spain. Int J Environ Res Public Health. 2022;19(8):4487.
43. Veloso Duran A, Framis-de-Mena B, Vázquez Salceda MC, Guinot JF. Evaluation and comparison of oral health status between spanish and immigrant children residing in Barcelona, Spain. Children. 2022;9(9):1354.
44. Olerud E, Hagman-Gustavsson ML, Gabre P. Oral health status in older immigrants in a medium-sized Swedish city. Spec Care Dentist. 2016;36(6):328–34.
45. Thorbert-Mros S, Ali N, Ali M, Ayas M, Trullenque-Eriksson A, Dahlén G. A comparative study on periodontitis and periodontitis-associated bacteria in Somali and non-Somali children and adolescents living in Trollhättan, Sweden. Eur J Oral Sci. 2022;130(2): e12843.
46. Baggio S, Abarca M, Bodenmann P, Gehri M, Madrid C. Early childhood caries in Switzerland: a marker of social inequalities. BMC Oral Health. 2015;15(1):1–9.
47. Lin Y, Yen Y, Chang C, Ting C, Chen P, Chen C, et al. Oral health disparities of children among Southeast Asian immigrant women in arranged transnational marriages in Taiwan. Caries Res. 2014;48(6):575–83.
48. Lin Y-C, Chang C-S, Ho P-S, Lee C-H, Chen J-H, Huang H-L. Immigrant-native differences in sugar-sweetened beverage and snack consumption and preventive behaviors associated with severe early childhood caries: a large-scale survey in Taiwan. Int J Environ Res Public Health. 2019;16(6):1047.
49. Traisuwan W. Oral health status and behaviors of pregnant migrant workers in Bangkok, Thailand: A cross-sectional study. BMC Oral Health. 2021;21:1–8.
50. Altaş ZM, Sezerol MA. Prevalence and associated factors of dental caries in syrian immigrant children aged 6–12 Years. Children. 2023;10(6):1000.
51. Wilson FA, Wang Y, Borrell LN, Bae S, Stimpson JP. Disparities in oral health by immigration status in the United States. J Am Dental Assoc. 2018;149(6):414–21. e3.
52. Kabani FA, Stockbridge EL, Berly Varghese B, Loethen AD. Acculturation and the oral health of a nationally representative sample of Hispanic children in the United States: An analysis of 2011–2012 National Survey of Children's Health data. BMC Public Health. 2020;20(1):1–12.
53. Pitts NB, Ekstrand KR, Foundation I. International Caries Detection and Assessment System (ICDAS) and its International Caries Classification and Management System (ICCMS)–methods for staging of the caries process and enabling dentists to manage caries. Commun Dent Oral Epidemiol. 2013;41(1):e41–52.
54. Ismail AI, Sohn W, Tellez M, Amaya A, Sen A, Hasson H, et al. The International Caries Detection and Assessment System (ICDAS): an integrated system for measuring dental caries. Commun Dent Oral Epidemiol. 2007;35(3):170–8.
55. Bahannan SA, Eltelety SM, Hassan MH, Ibrahim SS, Amer HA, El Meligy OA, Al-Johani KA, Kayal RA, Mokeem AA, Qutob AF, Mira AI. Oral and Dental Health Status among Adolescents with Limited Access to Dental Care Services in Jeddah. Dent J (Basel). 2018;6(2):15. https://doi.org/10.3390/dj6020015.
56. Gao X-L, McGrath C. A review on the oral health impacts of acculturation. J Immigr Minor Health. 2011;13:202–13.
57. Cohen L, Dahlen G, Escobar A, Fejerskov O, Johnson N, Manji F. Dentistry in crisis: time to change. La Cascada Declaration Australian Dental Journal. 2017;62(3):258–60.
58. Fejerskov O, Escobar G, Jøssing M, Baelum V. A functional natural dentition for all–and for life? The oral healthcare system needs revision. J Oral Rehabil. 2013;40(9):707–22.
59. Watt RG, Daly B, Allison P, Macpherson LM, Venturelli R, Listl S, et al. Ending the neglect of global oral health: time for radical action. Lancet. 2019;394(10194):261–72.

Publisher's Note

Supplementary Materials for

"Oral Health Inequalities in Immigrant Populations Worldwide:

A Scoping Review of Dental Caries and Periodontal Disease Prevalence"

Appendix 1. Detailed search procedure in databases

Pubmed (n=298)	(("Emigrants AND Immigrants"[MeSH Terms] OR "Undocumented Immigrants"[MeSH Terms] OR ("Refugees"[MeSH Terms] OR "Refugee Camps"[MeSH Terms]) OR "Ethnicity"[MeSH Terms] OR "Ethnic and Racial Minorities"[MeSH Terms] OR "asylum seeker*"[Title/Abstract] OR "displaced person*"[Title/Abstract] OR "refugee*"[Title/Abstract]) AND ("Dental Caries"[MeSH Terms] OR "Root Caries"[MeSH Terms] OR "Dental Caries Susceptibility"[MeSH Terms] OR "Periodontal Pocket"[MeSH Terms] OR "Periodontal Index"[MeSH Terms] OR "Gingivitis"[MeSH Terms] OR "DMF Index"[MeSH Terms] OR "dmf index*"[Title/Abstract] OR "dental decay*"[Title/Abstract] OR "carious lesion*"[Title/Abstract] OR "carious white spot*"[Title/Abstract] OR "periodontal pocket*"[Title/Abstract] OR "dmft s*"[Title/Abstract] OR "gingival index*"[Title/Abstract] OR "dmft*"[Title/Abstract] OR "dmft index*"[Title/Abstract] OR "bleeding on probing*"[Title/Abstract] OR "probing pocket depth*"[Title/Abstract] OR "clinical attachment loss*"[Title/Abstract]) AND (("all"[Filter] NOT "preprint"[Publication Type]) AND ("english"[Language] OR "french"[Language] OR "italian"[Language]) AND 2011/01/01:2023/12/31[Date - Publication])) AND ((excludepreprints[Filter]) AND (english[Filter] OR french[Filter] OR german[Filter] OR italian[Filter]) AND (2011:2023[pdat]))
EMBASE (n=116)	Query('immigrant':ti,ab OR 'immigrants':ti,ab OR 'refugee':ti,ab OR 'refugee camp':ab OR 'asylum seeker':ti,ab OR 'ethnic group':ti,ab) AND ('dental caries':ti,ab OR 'dmf index':ti,ab OR 'dmft index':ti,ab OR 'dmfs index':ti,ab OR 'caries assessment':ti,ab OR 'periodontal disease':ti,ab OR 'gingiva disease':ti,ab OR 'gingivitis':ti,ab OR 'periodontal pocket depth':ti,ab OR 'pocket depth':ti,ab OR 'gingival index':ti,ab OR 'bleeding on probing':ti,ab OR 'clinical attachment level':ti,ab OR 'decay rate':ti,ab) AND (2011:py OR 2012:py OR 2013:py OR 2014:py OR 2015:py OR 2016:py OR 2017:py OR 2018:py OR 2019:py OR 2020:py OR 2021:py OR 2022:py OR 2023:py) AND ([english]/lim OR [french]/lim OR [german]/lim OR [italian]/lim) AND ([embase]/lim OR [medline]/lim OR [pubmed-not-medline]/lim)
Scopus (n=928)	(TITLE-ABS-KEY (immigrant* OR refugee* OR "refugee camp" OR "asylum seeker" OR "ethnic group") AND ALL (("dental caries" OR "DMF index" OR "DMFT index" OR "DMFS index" OR "caries" OR "periodontal disease" OR "gingiva disease" OR "gingivitis" OR "periodontal pocket depth" OR "pocket depth" OR "gingival index" OR "bleeding on probing" OR "clinical attachment level" OR "decay rate"))) AND PUBYEAR > 2010 AND PUBYEAR < 2024 AND (LIMIT-TO (EXACTKEYWORD , "Human")) AND (LIMIT-TO (LANGUAGE , "English") OR LIMIT-TO (LANGUAGE , "German") OR LIMIT-TO (LANGUAGE , "French")) OR LIMIT-TO (LANGUAGE , "Italian"))

Appendix 2: Quality assessment (JBI SUMARI)

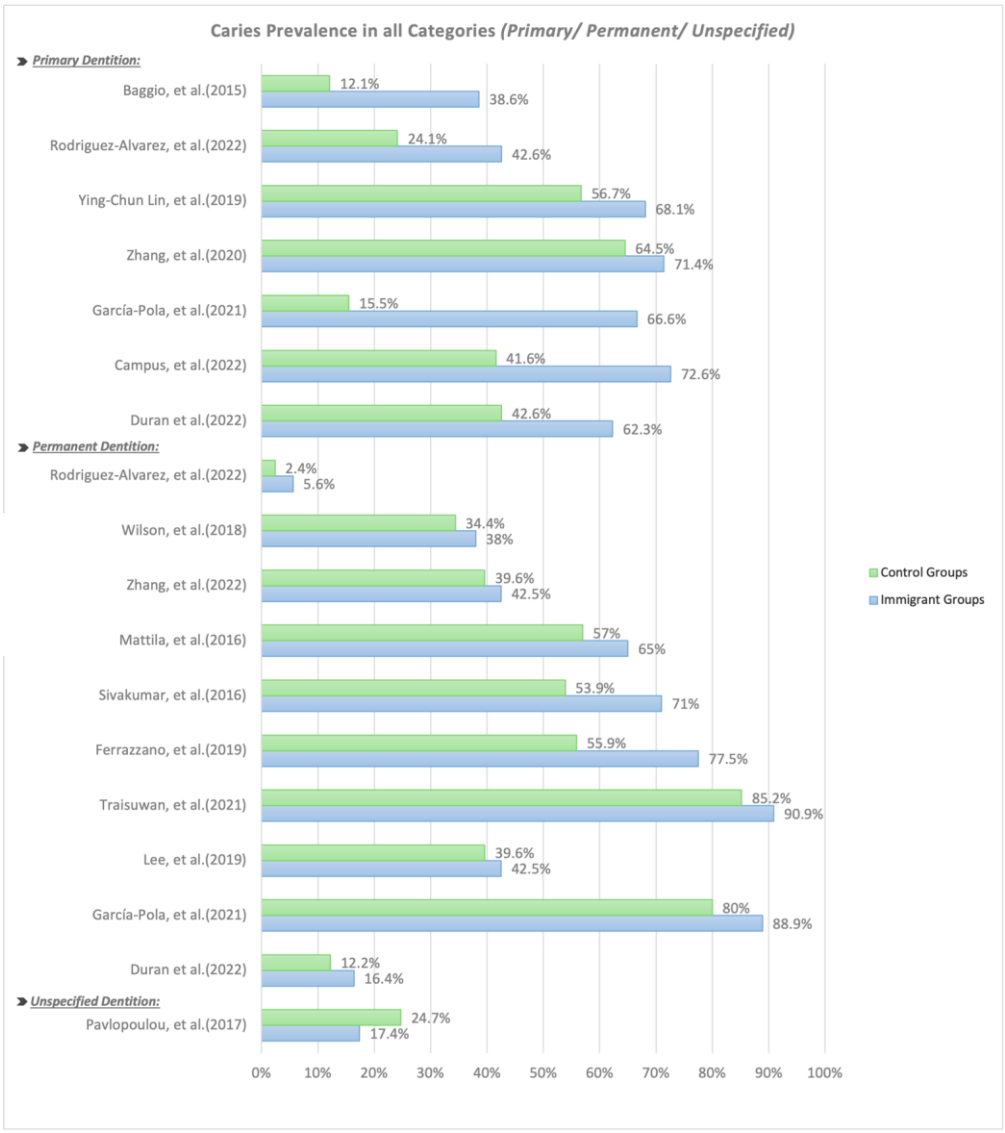
Citation	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Total score
Christian B et al,(23)	Y	U	Y	Y	Y	Y	Y	N	Y	7
Gibbs et al,(24)	Y	U	Y	Y	Y	Y	Y	Y	Y	7
Hoover et al,(25)	N	Y	N	Y	U	Y	Y	Y	Y	6
Amin et al,(26)	Y	Y	N	Y	Y	Y	Y	Y	U	7
Elyasi et al,(27)	U	Y	U	Y	Y	Y	Y	Y	Y	7
Dahlan et al,(28)	N	Y	N	Y	Y	Y	Y	Y	Y	7
Azrak et al,(29)	N	U	N	Y	Y	Y	U	Y	Y	6
Liu et al,(30)	Y	Y	Y	U	Y	Y	Y	Y	Y	8
Zhang et al,(31)	Y	Y	Y	U	Y	Y	Y	Y	Y	8
Mattila et al,(32)	N	U	N	Y	Y	Y	U	Y	Y	5
Aarabi et al,(33)	U	Y	U	Y	Y	Y	Y	Y	Y	7
Pavlopoulou et al,(21)	U	Y	U	Y	Y	Y	Y	Y	Y	8
Diamanti et al, (34)	Y	Y	Y	Y	Y	Y	Y	Y	Y	9
Sivakumar et al,(35)	U	Y	Y	Y	Y	Y	Y	U	Y	7
Ferrazzano et al,(36)	Y	Y	Y	U	Y	Y	Y	Y	Y	7
Campus et al,(37)	Y	Y	Y	U	Y	Y	Y	Y	Y	8
Hashizume et al,(38)	U	Y	N	Y	N	Y	Y	Y	Y	6
Lee et al,(39)	Y	Y	Y	U	Y	Y	Y	Y	Y	8
García-Pola et al,(40)	Y	Y	U	Y	U	Y	Y	Y	Y	7
Gómez-Costa et al,(41)	Y	Y	Y	U	Y	Y	Y	Y	Y	8
Soria et al,(22)	N	Y	N	Y	Y	Y	Y	Y	Y	7
Rodriguez-Alvarez et al,(42)	Y	Y	Y	U	Y	Y	Y	Y	Y	8
Duran et al,(43)	Y	Y	Y	Y	U	U	U	Y	Y	6
Olerud et al,(44)	N	Y	N	Y	Y	Y	Y	U	U	5
Thorbert-Mros et al,(45)	N	Y	N	Y	Y	Y	Y	U	U	5
Baggio et al,(46)	Y	Y	Y	U	Y	Y	Y	Y	Y	8
Y.C. Lin et al,(47)	Y	Y	U	Y	Y	Y	Y	Y	Y	8
Ying-Chun Lin et al,(48)	Y	Y	Y	U	Y	Y	Y	Y	Y	8
Traisuwan et al,(49)	Y	Y	U	Y	Y	Y	y	Y	Y	8
Meva Altas et al,(50)	Y	U	Y	Y	Y	Y	Y	Y	Y	8
Wilson et al,(51)	Y	Y	Y	Y	Y	Y	Y	Y	Y	9
Kabani et al,(52)	Y	Y	Y	Y	Y	U	Y	Y	Y	8
Total (%) yes	64.5	87	54.9	74.2	90.3	96.7	93.5	89	93.3	

Critical appraisal questions: Q1. Was the frame appropriate to address the target population? Q2. Were study participants sampled in an appropriate way? Q3. Was the sample size adequate? Q4. Were the study subjects and the setting described in detail? Q5. Was data analysis conducted with sufficient coverage of the identified sample? Q6. Were valid methods used for identification of the condition? Q7. Was the condition measured in a standard, reliable way for all participants? Q8. Was there appropriate statistical analysis? Q9. Was the response rate adequate and, if not, was the low response rate managed appropriately? Y, yes; U, unclear; N, no

Appendix 3: Excluded studies (n=46)

Excluded Studies	REASON FOR EXCLUSION
1. Nicol et al,(2015)	The study participants were refugees.
2. Marwaha et al(2022),	The study participants were refugees.
3. Moreau et al, (2019)	The study participants were refugees.
4. van Berlaer G, (2016)	The study participants were refugees.
5. Goetz et al,(2018)	The study participants were refugees.
6. Solyman et al,(2018)	The study participants were refugees.
7. Takriti et al, (2021)	The study participants were refugees.
8. Al-Ani et al, (2016)	The study participants were refugees.
9. Kakalou et al, (2018)	The study participants were refugees.
10. Bhatt et al, (2019)	The study participants were refugees.
11. Noaman et al,(2019)	The study participants were refugees.
12. Hamid et al, (2020)	The study participants were refugees.
13. Biscaglia et al,(2019)	The study participants were refugees.
14. Makan et al, (2019)	The study participants were refugees.
15. Salim et al, (2021)	The study participants were refugees.
16. Salim et al, (2021)	The study participants were refugees.
17. Høyvik et al, (2019)	The study participants were refugees.
18. Riatto et al, (2018)	The study participants were refugees.
19. Kazwini et al,(2021)	The study participants were refugees.
20. Flynn et al, (2021)	The study participants were refugees.
21. Zhang et al. (2013)	The study participants were ethnic minorities.
22. Chen et al. (2021)	The study participants were ethnic minorities.
23. Premaraj et al. (2020)	The study participants were ethnic minorities.
24. Sgan-Cohen et al. (2014)	The study participants were ethnic minorities.
25. Shi et al. (2018)	The study participants were ethnic minorities.
26. Van Der Tas et al. (2016)	The study participants were ethnic minorities.
27. Wu et al. (2021)	The study participants were ethnic minorities.
28. Wulaerhan et al. (2014)	The study participants were ethnic minorities.
29. Zhang et al. (2014)	The study participants were ethnic minorities.
30. Zhang et al (2015)	The study participants were ethnic minorities.
31. Matsuo et al (2015)	The study participants were ethnic minorities.
32. Mallik et al (2012)	The study participants were ethnic minorities.
33. Moss et al (2023)	The study participants were ethnic minorities.
34. Lim E et al (2020)	The study participants were ethnic minorities.
35. Jardim et al (2015)	The study participants were ethnic minorities.
36. Owens et al (2013)	The study participants were ethnic minorities.
37. Drummond et al (2015)	The study participants were ethnic minorities.
38. Stecksén-Blicks et al. (2014)	Data was collected in 2007.
39. Sanders (2020)	Data was collected in 2008.
40. Heinrich-Weltzien et al(2014)	Data was collected in 2005.
41. Cvikl et al. (2014)	Data was collected in 2007.
42. Vered Y et al. (2011)	Data was collected in 2000.
43. Delgado-Angulo et al(2017)	Data was collected in 2009.
44. Ghiabi et al (2013)	Data was collected in 2008.
45. Lau et al (2012)	Data was collected in 2003.
46. Quach et al (2015)	Data was collected in 2006.

Appendix 4: Comparison of caries prevalence between immigrant and control groups divided by dentition stage



Appendix 5: History of dental visits in immigrants.

Author	Christian et al,(23)	Azrak et al,(29)	Elyasi et al,(27)	Meva Altas et al,(50)	Amin et al,(26)	Dahlan et al,(28)	Traisuwan et al,(49)	Arabi et al,(33)
	Children						*Adults*	
Percentage of participants, not visiting a dentist within last year or in their lifetime (%)	*88**	*72.7**	*65.7*	*61.3**	*52**	*51.2*	*61.1*	*68.9*

*Not visiting a dentist in their lifetime.

Appendix 6: Reference list of excluded studies

1. Nicol P, Anthonappa R, King N, Slack-Smith L, Cirillo G, Cherian S. Caries burden and efficacy of a referral pathway in a cohort of preschool refugee children. Aust Dent J. 2015;60(1):73-9.
2. Marwaha P, Ghanim A, Shankumar R. Risk indicators of dental caries among refugee patients attending a public dental service in Victoria. Aust Dent J. 2022;67(1):21-29.
3. Moreau A-M, Hennous F, Dabbagh B, Ferraz dos Santos B. Oral health status of refugee children in Montreal. Immigr Minor Health. 2019;21(4):693-698.
4. van Berlaer G, Carbonell FB, Manantsoa S, de Béthune X, Buyl R, Debacker M, et al. A refugee camp in the centre of Europe: clinical characteristics of asylum seekers arriving in Brussels. 2016;6(11):e013963.
5. Goetz K, Winkelmann W, Steinhäuser J. Assessment of oral health and cost of care for a group of refugees in Germany: a cross-sectional study. BMC Oral Health. 2018;18(1):69.
6. Solyman M, Schmidt-Westhausen A-M. Oral health status among newly arrived refugees in Germany: a cross-sectional study. MC Oral Health. 2018;18(1):132.
7. Takriti M, Al-Ani A, Walter M, Alkilzy M, Splieth CH. Dental status and prosthetic treatment needs among adult refugees in Germany. Quintessence Int. 2021;52(9):764-771.
8. Al-Ani A, Takriti M, Schmoeckel J, Alkilzy M, Splieth C. National oral health survey on refugees in Germany 2016/2017: caries and subsequent complications. Clin Oral Investig. 2021;25(4):2399-2405.
9. Kakalou E, Riza E, Chalikias M, Voudouri N, Vetsika A, Tsiamis C, et al. Demographic and clinical characteristics of refugees seeking primary healthcare services in Greece in the period 2015–2016: A descriptive study. Int Health. 2018;10(6):421-429.
10. Bhatt S, Gaur A. Dental caries experience and utilization of Oral Health services among Tibetan refugee-background children in Paonta sahib, Himachal Pradesh, India. J Immigr Minor Health. 2019;21(3):461-465.
11. Noaman BR, Khalid RF, Fattah LD. Maternal Dental Health Knowledge and Its Relation to the Dental Caries Experience of Their Children in Mamyzawa Camp of Refugees in Erbil, Iraq. Acta Med Acad. 2019;48(3):294-302.
12. Hamid RN, Mudher SH, Ali SM. Caries Index, Root Caries Index and Gingival Index in Immigrants at the Camp of Arbat in Sulaimaniya Governorate, Iraq. Inter Med J. 2020;27(3):357-9.
13. Biscaglia L, di Caccamo P, Terrenato I, Arrica MA, Seita A, Campus G. Oral health status and caries trend among 12-year old Palestine refugee students: results from the UNRWA's oral health surveys 2011 and 2016. BMC Oral Health. 2019 ;19(1):157.
14. Makan R, Gara M, Awwad MA, Hassona Y. The oral health status of Syrian refugee children in Jordan: An exploratory study. Spec Care Dentist. 2019;39(3):306-309.
15. Salim NA, Alamoush RA, Al-Abdallah MM, Al-Asmar AA, Satterthwaite JD. Relationship between dental caries, oral hygiene and malocclusion among Syrian refugee children and adolescents: a cross-sectional study. BMC Oral Health. 2021;21(1):1-8.
16. Salim NA, Sawair FA, Satterthwaite JD, Al-Zubi Z. Oral Hygiene Awareness, Practices and Attitudes among Syrian Refugees in Zaatari Camp and Their Impact on Oral Health Status. Oral Health Prev Dent. 2021;19(1):689-698.
17. Høyvik AC, Lie B, Grjibovski AM, Willumsen T. Oral health challenges in refugees from the Middle East and Africa: a comparative study. J Immigr Minor Health. 2019;21(3):443-450.

18. Riatto SG, Montero J, Pérez DR, Castaño-Séiquer A, Dib A. Oral health status of Syrian children in the refugee center of Melilla, Spain. Int J Dent. 2018;2018:2637508.
19. Kazwini R, Kasem T, Alhuda NEA, Albarshah M, Subeh D, Alhaffar M. Oral health assessment in a sample of displaced people as a result of the war in Syria in Damascus city: results of non-profit initiative. BMC Oral Health. 2021;21(1):1-6.
20. Flynn PM, Petersen A, Entinger J, Shire A. The Association of Social Determinants of Health with Somali Refugee Mother–Child Caries. J Immigr Minor Health. 2021;23(3):615-23.
21. Zhang S, Liu J, Lo ECM, Chu CH. Dental caries status of dai preschool children in yunnan province, china. BMC Oral Health. 2013;13(1).
22. Chen KJ, Liu J, Xu B, Li Y, Li Y, Zhang S, et al. Oral health status of 12-year-old children in Lisu minority ethnic group in China: a cross-sectional study. BMC Oral Health. 2021;21(1):27.
23. Premaraj TS, Vella R, Chung J, Lin Q, Panier H, Underwood K, et al. Ethnic variation of oral microbiota in children. Sci Rep. 2020;10(1):14788.
24. Sgan-Cohen HD, Margvelashvili V, Bilder L, Kalandadze M, Gordon M, Margvelashvili M, et al. Dental caries among children in Georgia by age, gender, residence location and ethnic group. Community Dent Health. 2014;31(3):163-6.
25. Shi C, Faris P, McNeil DA, Patterson S, Potestio ML, Thawer S, et al. Ethnic disparities in children's oral health: findings from a population-based survey of grade 1 and 2 schoolchildren in Alberta, Canada. BMC Oral Health. 2018;18(1):1.
26. Van Der Tas JT, Kragt L, Veerkamp JJS, Jaddoe VWV, Moll HA, Ongkosuwito EM, et al. Ethnic Disparities in Dental Caries among Six-Year-Old Children in the Netherlands. Caries Research. 2016;50(5):489-97.
27. Wu SC, Ma XX, Zhang ZY, Lo ECM, Wang X, Wang B, et al. Ethnic Disparities in Dental Caries among Adolescents in China. J Dent Res. 2021;100(5):496-506.
28. Wulaerhan J, Abudureyimu A, Bao XL, Zhao J. Risk determinants associated with early childhood caries in Uygur children: a preschool-based cross-sectional study. BMC Oral Health. 2014;14:136.
29. Zhang S, Liu J, Lo ECM, Chu CH. Dental and periodontal status of 12-year-old Bulang children in China. BMC Oral Health. 2014;14(1).
30. Zhang S, Xu B, Liu J, Lo ECM, Chu CH. Dental and periodontal status of 12-yearold Dai school children in Yunnan Province, China: A cross-sectional study. BMC Oral Health. 2015;15(1).
31. Matsuo G, Rozier RG, Kranz AM. Dental caries: racial and ethnic disparities among North Carolina kindergarten students. American journal of public health. 2015 Dec;105(12):2503-9.
32. Mallik BK, Panda T, Padhy RN. Traditional herbal practices by the ethnic people of Kalahandi district of Odisha, India. Asian Pacific Journal of Tropical Biomedicine. 2012 Feb 1;2(2):S988-94.
33. Luo H, Moss ME, Wright W, Webb M, Pardi V, Lazorick S. Racial/ethnic disparities in preventive dental services use and dental caries among children. Journal of Public Health Dentistry. 2023 Mar 7.
34. Lim E, Davis J, Siriwardhana C, Aggarwal L, Hixon A, Chen JJ. Racial/ethnic differences in health-related quality of life among Hawaii adult population. Health and Quality of Life Outcomes. 2020 Dec;18:1-6.
35. Gaetti-Jardim Jr E, Pereira MF, Vieira EM, Schweitzer CM, Okamoto AC, Ávila-Campos MJ. Occurrence of periodontal pathogens in ethnic groups from a native Brazilian reservation. Archives of Oral Biology. 2015 Jun 1;60(6):959-65.
36. Fisher-Owens SA, Isong IA, Soobader MJ, Gansky SA, Weintraub JA, Platt LJ, Newacheck PW. An examination of racial/ethnic disparities in children's oral health in the United States. Journal of Public Health Dentistry. 2013 Mar;73(2):166-74.
37. Drummond AM, Ferreira EF, Gomes VE, Marcenes W. Inequality of experience of dental caries between different ethnic groups of Brazilians aged 15 to 19 years. PloS one. 2015 Dec 22;10(12):e0145553
38. Stecksén-Blicks C, Hasslöf P, Kieri C, Widman K. Caries and background factors in Swedish 4-year-old children with special reference to immigrant status. Acta Odontologica Scandinavica. 2014 Nov 1;72(8):852-8.
39. Sanders A, Cardel M, Laniado N, Kaste L, Finlayson T, Perreira K, Sotres-Alvarez D. Diet quality and dental caries in the Hispanic Community Health Study/Study of Latinos. Journal of public health dentistry. 2020 Jun;80(2):140-9.
40. Heinrich-Weltzien R, Walther M, Goddon I, Kühnisch J. Zahngesundheit erster Molaren bei westfälischen Migranten und deutschen Schülern. Bundesgesundheitsblatt-Gesundheitsforschung-Gesundheitsschutz. 2014;1(57):128-34.
41. Cvikl B, Haubenberger-Praml G, Drabo P, Hagmann M, Gruber R, Moritz A, Nell A. Migration background is associated with caries in Viennese school children, even if parents have received a higher education. BMC oral health. 2014 Dec;14(1):1-6.

42. Vered Y, Soskolne V, Zini A, Livny A, Sgan-Cohen HD. Psychological distress and social support are determinants of changing oral health status among an immigrant population from Ethiopia. Community dentistry and oral epidemiology. 2011 Apr;39(2):145-53.
43. Delgado-Angulo EK, Marcenes W, Harding S, Bernabé E. Ethnicity, migration status and dental caries experience among adults in East London. Community Dentistry and Oral Epidemiology. 2018 Aug;46(4):392-9.
44. Ghiabi E, Matthews DC, Brillant MS. The oral health status of recent immigrants and refugees in Nova Scotia, Canada. Journal of immigrant and minority health. 2014 Feb;16:95-101.
45. Lau M, Lin H, Flores G. Racial/ethnic disparities in health and health care among US adolescents. Health services research. 2012 Oct;47(5):2031-59.
46. Quach A, Laemmle-Ruff IL, Polizzi T, Paxton GA. Gaps in smiles and services: a cross-sectional study of dental caries in refugee-background children. BMC Oral Health. 2015 Dec;15:1-0.

4.3 Results: Journal Article #3

Nudging oral habits; application of behavioral economics in oral health promotion:
a critical review

Published in:
Journal of Frontiers in Public Health - 2023

Kazemian A, Hoseinzadeh M, **Banihashem Rad SA***, Jouya A,
Tahani B.

* Co-authorship

Own contribution:
All authors listed have made a substantial, direct, and intellectual contribution to the work.

frontiers | Frontiers in Public Health

TYPE Original Research
PUBLISHED 08 December 2023
DOI 10.3389/fpubh.2023.1243246

OPEN ACCESS

EDITED BY
Sourabha Kumar Patro,
Post Graduate Institute of Medical Education and Research (PGIMER), India

REVIEWED BY
Nishant Nishant,
Post Graduate Institute of Medical Education and Research (PGIMER), India
Navjot Kaur,
Dr. B. R. Ambedkar State Institute of Medical Sciences, India

*CORRESPONDENCE
Bahareh Tahani
✉ tahani@dnt.mui.ac.ir

RECEIVED 20 June 2023
ACCEPTED 24 November 2023
PUBLISHED 08 December 2023

CITATION
Kazemian A, Hoseinzadeh M, Banihashem Rad SA, Jouya A and Tahani B (2023) Nudging oral habits; application of behavioral economics in oral health promotion: a critical review.
Front. Public Health 11:1243246.
doi: 10.3389/fpubh.2023.1243246

Nudging oral habits; application of behavioral economics in oral health promotion: a critical review

Ali Kazemian[1], Melika Hoseinzadeh[2], Seyed Ahmad Banihashem Rad[3,4], Anahid Jouya[1] and Bahareh Tahani[5]*

[1]Department of Community Oral Health, School of Dentistry, Mashhad University of Medical Sciences, Mashhad, Iran, [2]Dental Research Center, Mashhad Dental School, Mashhad University of Medical Sciences, Mashhad, Iran, [3]Department of Restorative, Preventive and Pediatric Dentistry, University of Bern, Bern, Switzerland, [4]Graduate School for Health Sciences, University of Bern, Bern, Switzerland, [5]Department of Oral Public Health, Dental Research Center, School of Dentistry, Dental Research Institute, Isfahan University of Medical Sciences, Isfahan, Iran

Background: Oral health disorders significantly contribute to the global incidence of chronic diseases. Nudge interventions have demonstrated effectiveness in enhancing people's decision-making and self-management capacities in a cost-efficient manner. As a result, these interventions could be valuable tools for fostering improved oral care habits. This critical review explores potential behavioral nudges applicable to promoting oral health.

Methods: A thorough electronic literature search was conducted on Scopus, Embase, and PubMed databases for papers published post-2008. The search focused on empirical evidence concerning the direct and indirect application of Nudge theory in oral health enhancement. In addition, the investigation included the nudge intervention's role in managing common non-communicable disease risk factors (tobacco, alcohol, and sugar) and their use in other health sectors.

Results and conclusion: There is a dearth of studies on behavioral economics, particularly those involving reward and reminder techniques. However, various successful nudge interventions have been identified in other sectors that aim to improve health decisions. These include strategies encouraging healthier nutritional choices, tobacco and alcohol cessation, medication compliance, routine physical activity, and regular health check-ups. Such interventions can also have direct or indirect positive impacts on oral health. Implementing these interventions within an oral care framework could promote oral health due to similar underlying cognitive mechanisms. However, different types of nudge interventions have varying degrees of effectiveness. Furthermore, factors such as the method of delivery and the characteristics of the targeted population significantly influence the outcome of the intervention. Hence, it is imperative to conduct extensive studies in diverse socioeconomic settings to fully understand the potentials, limitations, and impacts of nudge interventions in promoting oral health.

KEYWORDS

oral health, dental care, choice architecture, nudge, behavioral economics

1 Introduction

Behavioral economics is a new field of social study that uses the findings of psychology in economics. Two Nobel Prizes in Economics for Daniel Kahneman in 2002 and Richard Thaler in 2017 brought behavioral economics to particular academic attention in different disciplines. Thaler's theory, known as Nudge Theory, deals with cheap and easy interventions that effectively change people's behavior. Nudge theory focuses on Easy, Attractive, Social, and Timely interventions (EAST) to encourage desirable and healthy behaviors.

Although it seems logical that people would make the best health decisions, many continue to prioritize short-term pleasures despite being aware of the long-term negative effects on their health (1). Nudge theory acknowledges behavioral complexity and rejects the idea that humans would make optimum decisions when given the right information (2). Instead, nudges are used as interventions that are neither mandatory nor choice-restricting but design choices effectively and desirably.

There is promising evidence that nudges can be used to improve a wide range of health policy domains, including preventive healthcare. According to the World Health Organization (WHO), focusing on the most cost-effective and feasible interventions to prevent and control noncommunicable diseases in low-and middle-income countries could save close to 7 billion lives by 2030 (3). Noncommunicable diseases, such as type 2 diabetes, have been investigated as potential nudge intervention targets (4). Nudges have also been shown to have a positive impact on patient's lifestyle choices, such as diet, medication adherence, and physical activity, as well as the use of tobacco and alcohol (5–7). Previous systematic reviews found that the majority of current nudge studies were conducted in nutritional sciences, which is critical for other health topics such as oral health (8–10).

Oral health diseases, i.e., dental caries, periodontal diseases, and oral cancer, are among significant contributors to the worldwide burden of chronic diseases (11). Poor oral health has a detrimental effect on one's quality of life and may raise one's chance of developing chronic diseases (12). For instance, prolonged discomfort from an infected tooth might impair food intake and nutrition. Moreover, evidence supports that bacteria associated with chronic periodontitis might be linked to diabetes and cardiovascular disease (13). Besides the importance of considering social and commercial determinants of oral health, there is abundant evidence for the significance of proper oral self-care, e.g., adequate and frequent tooth brushing and controlling sugar intake to prevent oral diseases. Healthy oral habits include eating healthily (8), brushing and flossing adequately and properly (14), and regular dental checkups (15), all of which depend on people's self-management. Nudging, which targets better and healthier choices and adopting strategies to promote self-management, could be useful in improving oral care habits and decreasing the burden of oral disease. However, there is little existing literature about the nudge implications in oral health; therefore, this critical review aimed to synthesize behavioral nudges that can be used to directly or indirectly promote oral health. A Better understanding of behavioral Nudges might assist policymakers, clinicians, and researchers in developing and implementing useful nudge interventions to improve oral health.

2 Method and materials

The critical review protocol was registered at OSF Registries with registration code (https://doi.org/10.17605/OSF.IO/7FXCV) and is based on Daly and Carnwell's framework (16) for the critical review, which includes determining the scope of the critical study, identifying and selecting relevant data sources, reviewing studies, and summarizing and categorizing the obtained evidence.

2.1 Scope of the review

This review endeavored to answer the following research question: "What are Nudge theory applications in developing healthy oral habits?"

Regarding the limited available evidence on the effective direct application of the Nudge theory in oral health promotion, papers in the other health sectors and oral disease risk factors (tobacco, alcohol, and sugar consumption) that were found potentially relevant were also included. The focused question was developed following the SPIDER tool (17):

S (Sample): Health, Oral Health.

P (Phenomenon) of ***I*** (Interest): All the articles that related to Nudge theory interventions.

D (Design): not restricted.

E (Evaluation): behavior change.

R (Research type): not restricted.

2.2 Search strategy and terms

An electronic search was undertaken using Scopus, Embase, and PubMed databases for literature published after 2008. Authors extracted text words from relevant papers' titles, abstracts, and index keywords to identify the articles. A search string was created using the keywords and synonyms in conjunction with the Boolean operators "AND" and "OR." Only papers published in English were considered. All age groups were included. Search terms included combinations, plurals, and various conjugations of the words relating to identified nudge strategies. we set our search limit at 2008, since the conceptualization of the nudge theory, first introduced to a wide audience by Thaler and Sunstein in their 2008 book, Nudge: Improving decisions about health, wealth, and happiness (18).

(nudge[Title/Abstract] OR nudges[Title/Abstract] OR nudging[Title/Abstract] OR "choice architecture"[Title/Abstract] OR ("behavioral economics"[Title/Abstract] OR "behavioural economics"[Title/Abstract] OR "behavioral model"[Title/Abstract] OR "behavioural model"[Title/Abstract] OR "behavioral control"[Title/Abstract] OR "behavioural control"[Title/Abstract] OR "behavior control"[Title/Abstract]) AND "health promotion"[MeSH Terms] OR health promotion[Text Word] OR "oral health"[MeSH Terms] OR oral health[Text Word] OR "health"[MeSH Terms] OR Health[Text Word]).

2.3 Reviewing the studies

After eliminating duplicates, the authors conducted a comprehensive review and provided a summary of the selected literature. The primary focus was on oral health promotion and

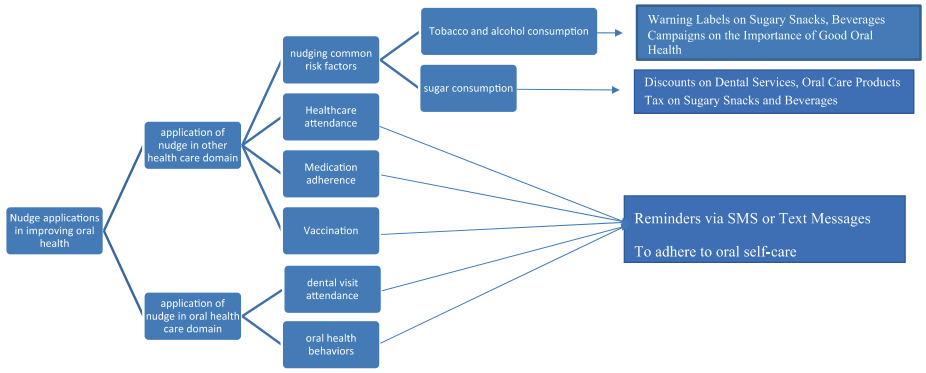


FIGURE 1
Concept map showing the resources selection procedure and key applications of Nudge theory in improving oral health.

behavior changes across various populations. The decision to include specific resources that demonstrated the effectiveness of the Nudge theory in sectors beyond oral health promotion was reached through consensus among the authors during focus group discussions.

To select these resources, two main approaches were taken into consideration. Firstly, the common risk factor approach was employed, where articles highlighting the successful application of the Nudge theory in modifying common behavioral risk factors associated with non-communicable diseases such as tobacco, sugar, and alcohol were collected. These risk factors have been established to impact oral health concurrently. Additionally, other resources that indicated the efficacy of the Nudge theory in modifying or promoting self-care behaviors with shared cognitive mechanisms, such as regular physical activity, attending physician visits, and medication adherence, were also included (Figure 1).

3 Results and discussion

3.1 Studies on nudging oral habits

Despite the growing popularity of nudge theory in various fields, including economics, public policy, and healthcare, there is a noticeable lack of research on its applications in oral health and dentistry. While nudges have been shown to be effective in promoting healthy behaviors and improving patient outcomes in other healthcare settings, such as smoking cessation and medication adherence, their potential impact on oral health behaviors remains largely unexplored. In this part of the review, we aim to report the limited papers on nudge theory in oral health and dentistry.

One of the most relevant papers on nudging in dental settings is a perspective article by Scarbecz (19). The author discussed how dental team members could use behavioral economics principles to improve patients' oral health and lead patients to make healthy choices. Patients' choices will be influenced by the way health information is provided to them, dental team members should use the best ways to present information to patients to improve their welfare and preserve their autonomy. It has been argued that the decision-making process for dental patients is usually complex and difficult due to a number of economic, medical, and psychological factors. As dental patients often do not receive immediate feedback on their treatment outcomes, nudges might be helpful. Scarbecz discussed common decision-making biases in dental settings, such as anchoring, availability heuristics, frequency-based judgments, optimism, status quo bias, and conformity. Using the "choice architecture" concept, he proposed practical strategies. For example, dental teams could offer incentives such as discounts for positive oral health behaviors during recall appointments, using decision diagrams that outline treatment options and their implications, and implement feedback mechanisms to counter the lack of immediate rewards for behaviors such as flossing. Patients might make better decisions about their oral health by using these approaches. However, it was a perspective study and not all of the interventions proposed by the author were tested or applied clinically.

In a recent study, Shariati et al. (20) investigated the self-reported oral health of a random cluster of residents in Mashhad in relation to their estimation of the oral health of the majority of people in Mashhad. They found a positive correlation between the self-and others' oral health levels and decayed and missing teeth (DMT). Their findings indicated that people might be "nudgeable" for behavioral change by social norm interventions.

In a commentary and discussion paper, Wang and Wang (21) attempted to elucidate how behavioral economics can help clinicians analyze patients' fear of COVID-19 and assist them in making an informed treatment choice. Based on behavioral economics principles, it is asserted that clinicians are able to determine how fear of COVID-19 infection can influence patients' decisions and, consequently, oral health outcomes. The risk compensation bias suggests that some patients may overestimate the risks of COVID-19 and underestimate the advantages of receiving care. While the dangers of the pandemic are unquestionably grave, they may be exaggerated due to availability bias or the tendency of humans to place a greater cognitive weight on information that is more readily accessible. Therefore, clinicians have to reduce the risk of COVID-19 exposure

and, through effective communication, clarify the disadvantages of delaying treatment. They can frame their explanation as a gain or a loss. Additionally, it may be beneficial to clarify what other patients in comparable situations have chosen to do and leverage social norms.

In a field study conducted by the Social Policy Institute at Washington University in St. Louis (22, 23), the effect of two nudges intended to encourage parents of infants to participate in Teeth Brushing Meetings (TBM) was evaluated among 2,050 children in 41 daycare centers. Parents were reminded to take care for their children's oral health in the weeks preceding the TBM. To serve as a daily reminder in the 2 weeks preceding the oral health workshop, a collaborative poster board was placed at the entrance of the nursery classrooms, asking parents to place stickers in two columns labeled "We brushed our child's teeth" and "We did not brush our child's teeth." The second nudge was intended to remind parents of the possible benefits (vs. losses) of good (vs. poor) oral hygiene routines using differing wording in their invitation letters; the control group was given a neutral invitation letter to learn about caring for their child's oral health. The second group (nudge) received a "Negative accountability letter," which reminded them that their child's poor oral health is their responsibility. The letter included a graphic depicting the consequences of poor oral hygiene. The invitation letter of the third group, or "Positive accountability letter" group, illustrated a beaming child with a healthy mouth and emphasized that children's oral hygiene results due to parents meeting their responsibility. According to the findings of the study, the interventions successfully increased parental participation in the TBM. However, there was not a substantial distinction between the three groups.

In another experiment (24) in Early Head Start (EHS) sites in the Los Angeles, California area, the BEECON (Behavioural Economics for Oral Health Innovation) pilot trial was carried out during 8 study weeks based on the concepts of nudging behavior with appropriate incentives. This project was to motivate low-income parents of children aged 1–3 to brush their children's teeth frequently and attend scheduled dental visits by evaluating and contrasting the concept of a fixed monetary incentive package, a combined lottery incentive package (to capitalize on the propensity for individuals to be more inspired by immediate rather than delayed gratification), and a waiting list (delayed incentive) control. During the study period, participants were provided with Bluetooth-enabled powered toothbrushes that synchronized data to a mobile app in order to monitor toothbrushing compliance. In the fixed incentive group, participants received $5 per week if they met an inferior performance threshold (7 episodes, daily, 1 min) and $10 per week if they met a higher performance threshold (14 episodes, twice daily, 1 min). The lottery monetary incentive group obtained a weekly SMS regarding their entry into a lottery drawing. The likelihood of success relied on the participant's level of accomplishment. After 8 weeks of study, participants in the control group earned the same amount of money as those in the fixed incentive group. All participants received messages regarding their brushing performance and reminders to integrate their toothbrushing data with the app. In the lottery incentive group, the mean number of weekly grooming episodes over 8 weeks was 6, compared to 4.1 in the fixed incentive group and 3.9 in the control group. The lottery group reported brushing their teeth 53% more frequently than the control group and 47% more frequently than the fixed group. It was determined that an integrated (two-tiered) lottery incentive program is a viable method for encouraging good dental hygiene in young children.

In another commentary article, Wang et al. (22) sought to demonstrate how behavioral economics might be used to reduce missed dental appointments. They first outlined the basic issues that may be caused by these missed appointments, such as the exacerbation of dental cavities and the complication of dental treatments, as well as the strains on the patient-provider relationship caused by the erosion of trust. Again, Wang et al. (22) addressed salience bias, present bias, planning fallacy, and risk compensation bias as the related cognitive-behavioral obstacles and then suggested a strategy to illustrate how these insights could be combined to reduce missed appointments. Then, they offered suggestions based on the principles of behavioral economics, such as substituting the term "dental cleanings" with "oral health examination" when communicating with patients in person or via reminder messages, and mentioning the advantages of an oral health examination. The reminder text may briefly summarize the effects of oral diseases such as periodontitis and oral cancer. Additionally, they recommended integrating pre-commitment devices into the automated text reminders. For instance, a reminder can be sent to the patient 1 week prior to the appointment, necessitating active affirmation.

One useful strategy in addressing patient reluctance or a "wait and see" attitude is to emphasize the potential financial implications of delaying necessary treatment. Healthcare providers can effectively raise patient awareness of the importance of timely treatment by highlighting the long-term consequences and expenses associated with treatment delay. This approach enables patients to comprehend that the immediate financial investment in treatment is typically outweighed by the physical distress and financial strain that can arise from the progression of disease. Consequently, patients are more inclined to undertake appropriate measures promptly rather than postponing action (19).

In total, what we have in accordance with the implication of behavioral economics in dental care are mostly hypothetical suggestions based on the cognitive bias of humankind and the proposed solutions that might arise from the principles of behavioral economics. There are also some limited empirical studies piloting the use of these principles, especially rewarding and reminding, to steer the oral hygiene behaviors (such as toothbrushing or dental visit attendance) in parents of children. However, behavioral economics is not limited to being relevant only to oral hygiene behaviors, and the other relevant fields need to be tested through clinical or field trials.

3.2 Studies on nudging common risk factors

3.2.1 Nutritional choices and sugar consumption

Nudge theory has implications for improving oral health outcomes by influencing sugar, tobacco, and alcohol consumption. Most nudge interventions have been studied in nutritional sciences; therefore, we used the previous reviews in this field. Studies have reported a moderate effect of nudge interventions on food choices and nutritional decisions (25). Recent research by Mertens et al. (26) on the influence of nudging across behavioral domains indicated that choice architecture interventions encourage behavior change with a small to moderate effect size. The effect magnitude of food choice nudges, according to the authors, was 2.5 times greater than that of other behavioral domains (26). According to a meta-analysis by Arno

et al. (9), nudge interventions, on average, increases healthier dietary or nutritional decisions by 15.3%, measured by changes in healthy choices frequency or overall caloric intake.

The main nudge interventions for diet were categorized in a systematic review and meta-synthesis as (1) repositioning and replacing food items, (2) food items presentations in the form of amounts and servings, (3) using posters, calorific labels, stickers, and signs to promote healthy food choice, (4) using reminders in forms of text messages, emails, and online lessons, and applications to notify individuals about nutrition and healthy eating, (5) financial incentives, (6) affecting senses (sight, smell, and taste) to influence lunch choice or healthy food selection, and (7) cognitive loading, where cognitive resources for making decisions are restricted (27). A meta-analysis by Vargas-Alvarez et al. (28) revealed that specific portion control tools have small size effects and may be effective instruments for inclusion as part of weight loss interventions.

Managing diet and nutrition is one of the most important aspects of maintaining health in patients with noncommunicable diseases. In a systematic review, Kwan et al. (29) investigated the influence of nudge interventions on the diet of diabetic adults. They found that nudge interventions' delivery mode is influential in changing patients' behavior. Using social modeling delivered through group meeting sessions effectively modified the patient's diet, physical activity level, self-efficacy, and HbA1c control. Whereas digital devices alert to reminded patients to eat less were ineffective.

The population's socioeconomic status appears to influence the effectiveness of nutritional nudge strategies. Schüz et al. (30), systematically reviewed the equity effects of nutritional nudging strategies in individuals from different socioeconomic backgrounds. According to most of the equity comparisons in the literature, cognitive nudges (i.e., nudges that encourage information presentation about the food) worked similarly in more and less disadvantaged populations; however, in some studies, these kinds of nudges favored less economically disadvantaged people. In addition, they discovered that certain behavioral nudges (altering the accessibility or convenience of food options) favored disadvantaged individuals. In consistent with previous studies, Harbers et al. (25) declared that there is evidence that nudges were more effective in low socioeconomic status groups, but studies on these populations are scarce.

Regarding sugar consumption, Venema et al. (31) found that decreasing tea spoon size reduced sugar intake on average by 27% among participants. However, the nudge effect was less pronounced when people had a strong habit of adding sugar to tea. Villinger et al. (32) reported that modifying the sugar shakers' design to release a smaller amount of sugar in each pour reduced added sugar by 20% over 4 weeks. In a randomized clinical trial, authors have found that sugar-sweetened-beverage consumption and healthier drink choice can be nudged by Instagram image priming (33).

In summary, nudge interventions have demonstrated the potential in swaying nutritional choices, thereby directly influencing oral health through the reduction of high-calorie and sugary products. The efficacy of these interventions, however, is not uniform and hinges on several factors such as the method of delivery and the socioeconomic status of the target audience. Various strategies, including food repositioning, reminders, and alterations in food presentation, have shown their effectiveness in this context.

3.2.2 Tobacco and alcohol consumption

The nudge theory can promote healthier behaviors related to tobacco and alcohol cessation. Nudge interventions can be designed to provide support for individuals who want to quit tobacco or alcohol by offering reminders, incentives, or access to resources such as quit lines or counseling services. These interventions could help individuals overcome barriers to quitting and increase their motivation to adopt healthier behaviors, leading to improved oral health outcomes and overall well-being.

Research has shown that graphic warning labels on cigarette packs can nudge people toward quitting smoking. Nurchis et al. (34) discovered that enhancing the salience of information or incentives emerged as the most widely utilized nudge intervention, demonstrating a higher success rate when compared to other nudge strategies. The proposed underlying mechanism suggests that these interventions elicit negative emotional stimuli, including fear, worry, and disgust. Similarly, warning labels on alcohol bottles could remind people of the risks of excessive alcohol consumption, and raise their awareness. The scientific literature highlighted the larger effectiveness of image-based warning cues in avoiding dangerous activities (35). Fakir and Bharati (36) examined the efficacy of two behavioral strategies to reduce tobacco use in an ultra-poor rural area of Bangladesh, where traditional approaches such as taxes are impractical. The first strategy required participants to record their daily use of tobacco costs. The second strategy consisted of placing two graphic banners with warnings about the adverse impacts of tobacco use on tobacco users and their offspring. While both strategies decreased household tobacco consumption expenses, male participants who recorded their expenditures opted for inexpensive smokeless tobacco. Males who are married to non-smokers have a greater decrease in their tobacco consumption. An exploratory analysis showed that risk-averse males who invested a greater proportion of their income on tobacco replied better to the logbook strategy. Male patients with children younger than five and a higher level of education reacted more effectively to the poster strategy (36).

Clarke et al. (37) highlighted the effectiveness of Health warning labels (HWLs) on products containing tobacco and alcoholic beverages to decrease smoking and drinking. Three hundred and ninety-nine adults over the age of 18 who purchased beer or wine weekly for consumption at home make up the sample. Participants were randomly assigned to one of three groups based on the HWL displayed on the packaging of alcoholic beverages: (a) image-and-text HWL; (b) text-only HWL; and (c) no HWL. They found no obvious evidence of a difference between the HWL groups and the control group in terms of the quantity of alcoholic drinks selected. Substantial greater negative emotional arousal and lower acceptance were observed in the image-and-text HWL group relative to the text-only HWL group.

People are often influenced by what others around them are doing. Nudging people toward healthier behaviors can be achieved by highlighting the social norm of healthy behavior. For example, campaigns could potentially showcase how many people have quit smoking or reduced their alcohol intake. Highlighting social norms of healthier behaviors, such as emphasizing that most people do not smoke or only drink in moderation, can nudge individuals toward aligning their behavior with the norm (38).

One way to nudge people toward healthier choices is to change the default option. For example, making non-smoking the default option

in public spaces or making low-alcohol beverages the default option in bars and restaurants can encourage people to make healthier choices without restricting their freedom. Nudge theory can be used to change the default option, such as making non-smoking or non-drinking the default option in certain situations. Hempel-Bruder et al. (39) evaluated the effectiveness of educating General Practitioners (GPs) to provide treatment as the default option with current tobacco users seen in primary care using an encounter decision aid. The use of default options and an electronic decision aid are low-cost, readily disseminable interventions. They hypothesized that general practitioners who provide smoking cessation treatment as the default option using an encounter decision aid will boost the percentage of patients who cease smoking (39).

Increasing taxes on tobacco and alcohol products can nudge people toward reducing their consumption. Studies have shown that higher prices could deter people from purchasing these products. Providing incentives for healthy behaviors could also nudge people toward healthier choices. For example, discounts on healthy food and beverage options or rewards for not smoking or drinking can encourage people to make healthier choices. Nudge theory can be used to provide incentives for behavior change. For example, a workplace could incentivize employees who quit smoking or reduce their alcohol consumption. Cho et al. (40) discovered that the cost of cigarettes had become the most frequently cited reason for quitting or cutting back on smoking, particularly for those living in low socioeconomic areas, consuming more cigarettes daily, drinking alcohol, and experiencing high/very high emotional distress. Since 2013, a change in the primary federal tobacco control strategy implemented in Australia, from mass-media campaigns to tobacco tax rises, has likely resulted in cost, rather than health, being cited as the main driver for altering smoking behavior (40).

Nudge theory can be used to provide information about the harms of tobacco and alcohol consumption in a way that is easily accessible and understandable. For example, putting up posters or signs in public places such as bars or restaurants that highlight the risks of smoking or drinking excessively. Jenssen et al. (41) conducted a trial in nine clinical sites within the Cancer Control Implementation Lab of the Implementation Science Centre to assess the effect of behavioral economic implementation strategies provided via embedded messages (or "nudges") encouraging patient involvement with the Tobacco Use Treatment Service. Nudges were electronic medical record (EMR)-based messages sent to patients, clinicians, or both, intending to counter specific patient and clinician biases that reduce treatment engagement (41). Drake et al. (42) proposed a Clinical Decision Support (CDS) intervention to encourage clinicians to use the CDS instrument in order to increase tobacco cessation among tobacco users. Using user-centered design principles and the CDS Five Rights, they created a CDS tool that dynamically inserts useful data about current tobacco users into the Assessment and Plan section of clinicians' notes. They evaluated the efficacy of the CDS tool on time to tobacco cessation among patients at four primary care practices in the Denver metropolitan area (42).

Providing individuals with timely feedback on their tobacco or alcohol consumption, such as through apps, can nudge them toward making healthier choices and monitoring their behavior. Bhatt et al. (43) emphasized the necessity of understanding and valuing the dynamics of social and cultural variables in order to develop an effective de-addiction strategy. The patient was provided with disease-specific pamphlets and SMS (short text messages) in their native language were provided with basic tips for handling his tobacco cravings (such as not purchasing tobacco pouches on his own and not requesting anyone else to do so). The patients received a counseling session to heighten their awareness of tobacco use. Participants were asked to watch videos about how their tobacco use contributed to diseases and enhanced risk of complications.

Drawing from the success of nudge interventions in tobacco and alcohol cessation efforts, similar strategies could be applied to promote oral health. Just as graphic warning labels on cigarette packs effectively nudge people toward quitting smoking, labels emphasizing the risk of oral cancers may heighten public awareness. One way to do this is by implementing graphic warning labels on oral health-related products, like sugary snacks or beverages, bringing the risks of poor oral health to the fore.

It's also beneficial to emphasize social norms surrounding oral hygiene. Launching campaigns that underline the importance of maintaining good oral health can significantly improve public consciousness in this regard. Providing incentives can further motivate individuals to adhere to proper oral health behaviors. This could take the form of offering discounts on dental services or oral care products to those who comply.

Moreover, another effective strategy could be implementing a tax on sugary snacks and beverages. This financial deterrent might discourage excessive consumption, ultimately contributing to better oral health outcomes.

3.3 Modeling nudge interventions from other health-related conditions

The evidence of implementing nudges in promoting oral health is scarce. However, the components of oral health behavior are similar to other health-related behaviors among healthy populations and patients with chronic diseases. Based on the proposed health behavior taxonomies (44, 45), similar psychological factors or goal structures may underlie similar behaviors. Consequently, successful behavioral and nudging interventions for some types of behaviors might apply to optimizing others. In addition, targeting multiple behaviors in intervention programs is an effective method for maximizing efficiency and cost-effectiveness. Therefore, we investigated studies on other health promotion actions and hypothetically correlated them with oral health behaviors, including daily oral hygiene adherence, receiving oral disease preventive care, attending dental checkup appointments, and obtaining dental care insurance.

3.3.1 Medication adherence/daily oral hygiene adherence

According to the WHO, adherence is the degree to which a person's behavior corresponds with the agreed-upon recommendations of a healthcare provider (46). In this regard, daily oral hygiene adherence might be analogous to medication adherence because both should be repeated regularly to improve health. Approximately one-fourth of patients do not adhere to their prescribed medication regimens or medical advice, which increases

morbidity, mortality, and healthcare costs (47). Numerous studies have been conducted to determine the effect of nudge interventions on medication adherence. Reminders via SMS or text messages are the most prevalent nudge strategies (48). Möllenkamp et al. (47) conducted a systematic review to determine nudges' efficacy in enhancing self-management of drug consumption among patients with chronic diseases. Interventions such as medication reminders, social support, and feedback nudges significantly enhanced medication adherence in patients with heart disease. Using reminders also substantially improved asthma and stroke medication adherence. In another systematic review, Kwan et al. (29) investigated the nudge interventions' influence on diabetes management in adults. Text messages/email reminders and a pedometer/device were found to have a significant impact on medication adherence. In contrast, Luong et al. (49) reported in a randomized clinical trial that reminder text messages increased medication refills in patients with cardiovascular diseases and a 7-day refill interval, but the effect was insignificant. In another randomized controlled trial, Horne et al. (50) found that personalized nudges using machine learning of subjects' characteristics derived from psychographic assessment, demographics, social determinants, and the Intermountain Mortality Risk Score (IMRS) significantly improved patients' statin adherence after 12 months follow-up.

Rumi et al. (51) examined the influence of using an inhaler with a Turbo+ device on asthma patients' inhaler usage management. This device transmits medication usage information to a smartphone application, sends reminders and motivational prompt messages, and visualizes medication usage. The device substantially improved patients' inhaler usage within 90 days; however, because the study lacked a control group, it cannot be ruled out that improvements in health behavior may have been attributed to standard care. Ding et al. (48) evaluated the influence of applying the theory of planned behavior and the nudge strategies (salience nudge, social nudge, and feedback) on taking anticoagulant therapy in a 6-month follow-up. The authors observed that patients' medication adherence decreased in both groups; however, providing messages in WeChat groups, encouraging patients to share their medication usage experiences, and praising participants who gained high scores significantly improved medication adherence at the 3-and 6-month follow-ups. However, the described studies suggest that nudge interventions, mainly reminders, have led to short-term improvements in medication adherence. The nudge intervention delivery mode and the patient characteristics may impact the efficacy of interventions (29).

The barriers to regular oral care vary according to age and socioeconomic status. The most common barriers, however, are a lack of knowledge, time, a negative attitude, insufficient toothbrushing resources, and forgetfulness (52, 53). In addition to educational interventions, nudge interventions such as smartphone reminders, gamification, social nudges within the family or among peers, and prompts may also improve compliance with oral hygiene behaviors or regular dental visits. Moreover, encouraging individuals who adhere to oral care behaviors in social network groups, for example, for students, might also improve oral care behavior adherence. However, provided studies regarding medication adherence often reported the short-term efficacy of the interventions. Since oral health care is a lifetime activity, nudges that influence daily activities might be more relevant to the field of oral healthcare.

3.3.2 Physical activity/daily oral hygiene adherence

Inactivity and excessive sedentary behavior increase the risk of developing noncommunicable diseases and can diminish a person's lifespan (54). However, many adults and adolescents do not meet the recommended amounts of physical exercise (55). Physical activity is also commonly addressed for nudge intervention in chronic disease management. Möllenkamp et al. (47) discovered that nudge interventions such as reminders, planning prompts, feedback, behavioral contracts, and salience nudges successfully enhanced objective and self-reported physical activity in patients suffering from various chronic conditions. Similarly, Kwan et al. (29) also found that gamification and reminders had a substantial favorable result in diabetes management. Similarly, a recent meta-analysis found that gamified smartphone apps may boost physical activity in healthy individuals (55).

Systematic reviews of nudge interventions in healthy people found that prompt interventions primarily promoted stair use (54, 56, 57); however, stair use decreased after the interventions were removed, and many programs failed to show long-term positive impacts. Longer-duration interventions successfully maintained the habit when the intervention was removed. Individuals may acclimate to nudge intervention over time and no longer perceive it. According to Li et al. (58), wearable activity trackers improve exercise behavior but are inefficient at changing habitual behavior, such as light physical or sedentary behavior. Furthermore, participant characteristics and intervention elements were linked to efficiency.

Teeth brushing and exercise are among daily routines for health maintenance (44). Although the approach and effects of nudge interventions for increasing individuals' physical activity vary, applying behavioral nudges, such as reminders, gamification, and prompts, may also enhance dental hygiene practice. However, nudge interventions aimed at encouraging exercise habits in healthy individuals appear to be effective only for a short term, as people tend to adapt to them quickly. Therefore, when designing nudge interventions to promote oral health behaviors, it may be necessary to not only extend the duration of these initiatives but also to offer a variety of nudges to prevent individuals from growing accustomed to them.

3.3.3 Vaccination/receiving oral disease preventive care

Several meta-analyses have found that patient reminders, such as phone calls, SMS, postcards, mail, or a mix of these methods, improve children, adolescents, and adult immunization against numerous diseases (59–63). Eze et al. (60) discovered that these reminders are significantly more effective than in upper-middle-income countries in increasing childhood immunization coverage and that sending more than two SMS reminders improves the timely receipt of childhood vaccines than sending one or two SMS reminders. In contrast to the beneficial effect of reminder nudges, Levine et al. (64) discovered that customized voice call reminders led to 10.5% higher coverage of on-time childhood vaccination while advising vaccination opportunities by a community health volunteer and providing a small incentive led to 49.5% increase in vaccination in rural Northern Ghana. In circumstances where network availability and phone access are limited, the impact of nudge vaccination via voice calls may be limited. In contrast, according to the Oyo-Ita et al. (65)

meta-analysis, financial incentives did not affect childhood immunization coverage in low-and middle-income countries. However, they discovered that health education at village meetings, home, and facility-based health education, and revised vaccination reminder cards might boost total vaccine coverage.

Jacobson et al. (66) discovered that, whereas public health messaging and financial incentives boosted COVID-19 vaccination intentions, they did not raise immunization rates among vaccine-hesitant people. The outcomes of the Sasaki et al. study (67) emphasized the importance of tailoring social norm nudges to the purpose and target audience.

A significant portion of the direct costs of providing dental health care is used to treat highly preventable diseases in children and adolescents, which is burdensome for patients, governments, and insurance providers. In moderate-and high-risk individuals, applying fluoride varnish or resin-based fissure sealants of permanent teeth can prevent occlusal caries (68). Due to the common preventative nature of vaccines and dental professional preventive treatments and the limited number of interventions required, the nudge interventions that have effectively increased vaccination rates and timeliness may also encourage parents to receive dental preventive treatments. Personalized reminders and incentives, in addition to parental education and organizational infrastructures, may improve parental attendance at the dental office.

3.3.4 Healthcare attendance/attending dental checkup appointments

Regular dental visits allow for the early detection of oral diseases and prompt, cost-effective treatment of dental problems (69). Appointment non-attendance in the primary healthcare system is costly, reduces access to limited resources, and is notably prevalent among vulnerable individuals. Patients' perceptions that regular dental treatment is unnecessary or unusual, accessibility, participant characteristics (socioeconomic situation and history of drug, tobacco, and alcohol use), waiting time in the virtual queue, inability to get time off from work/school, and forgetfulness are all factors that influence non-attendance and no-show ups in dental offices (70–73). As a result, identifying the obstacles to attending dental appointments and carefully analyzing the "nudgeable" barriers identified in similar studies on healthcare attendance may improve populations' oral health.

Möllenkamp et al. (47) investigated the effects of nudge interventions on patients with chronic disease attendance to physicians. They discovered weak to moderate evidence that small financial incentives, reminders, and planning prompts have a favorable effect. Huf et al. (74) evaluated the influence of text messages with varying content on cervical screening attendance. They discovered that SMS messages from primary care physicians dramatically increased people's attendance. Furthermore, based on these findings, the National Health Service Cervical Screening Programme launched a London-wide screening campaign using text messages, resulting in a 4.8% increase in attendance in 6 months. In South Africa, Friedman et al. (75) showed that providing small incentives and massage reframe boosted attendance at counseling sessions for Voluntary Medical Male Circumcision as a free preventive treatment to reduce HIV infection.

Regarding no-show-ups, Boksmati et al.'s meta-analysis (76) showed that SMS appointment reminder within 48 h is an effective and operative method in decreasing appointment no-show-ups in a healthcare setting. In contrast to these findings, Ruggeri et al. (6) discovered that reminders did not affect disadvantaged people's attendance. They looked at 53,149 visits and discovered whether patients were assigned to established physicians and appointment lead time was among the strongest predictors of no-show rates. According to the authors, underserved groups face numerous healthcare challenges. As a result, evaluating obstacles and planning treatments that target people in need is critical for the effectiveness of healthcare programs, including dental appointments and screening.

3.3.5 Health insurance and retirement savings/ dental care insurance

Private health insurance is usually a critical resource in covering dental care costs. Behavioral interventions might encourage people to choose their insurance plans more efficiently, along with the need for policymakers and insurance companies to provide more convenient dental insurance packages. Furthermore, insurance influences health-seeking behavior and oral health, particularly among vulnerable groups (77, 78). Many people often do not acquire health insurance, struggle to find appropriate coverage, or transfer plans despite changing needs. Based on the available evidence, Krishnan et al. (79) highlighted the behavioral traits and interventions that might steer consumer decision-making in health insurance market purchasing. The behavioral interventions were categorized as decision information-based, decision structure-based, or decision assistance-based. Successful nudges included framing, simplicity, social norms, defaults, sorting, callouts, labeling, reminders, and personalized information. They can motivate consumers to get dental insurance and improve the quality of their options. However, as the authors pointed out, there was a shortage of data from low-income and developing nations, and thus, the findings may not directly apply to these countries. In another study, Marzilli Ericson (80) found that nudging through letters or emails increased health insurance purchases in Colorado, but personalized nudges did not result in plan switching.

The prevalence of chronic non-communicable diseases, including oral disease, and demand for their treatment rise as people live longer. As a result, numerous nudge treatments to encourage early retirement savings have been examined. Even experts believe that financial literacy and awareness of the significance of saving are insufficient to motivate people to act. García and Vila (81) discovered that the default choice greatly enhances long-term voluntary savings of financially literate pension contribution system participants. Beshears et al. (82) discovered that framing the future time point around a fresh start date (e.g., the recipient's birthday) enhanced the participants' likelihood of contributing to a saving plan in a large-scale randomized field experiment on university employees. Dur et al. (83) studied the influence of social norm nudges on household buffer savings in a large-scale randomized field experiment at a retail bank. They discovered that while the norm nudge boosted individuals' saving intentions, it did not enhance their savings. This study emphasized the methodological aspect of conducting nudge interventions, suggesting that using data other than final decisions may lead to

TABLE 1 Summary of the results and included studies in the review.

Health/oral health care	Domains	Sub-domains	Key research papers	Nudging related interventions	Implications for oral health
Implication of Nudge theory in other health domains with potentials for oral health related outcomes	Nudging common risk factors	Nutritional choices	Arno et al. (9), Harbers et al. (25), Mertens et al. (26), Ledderer et al. (27), Vargas-Alvarez et al. (28), Kwan et al. (29), Schüz et al. (30), Venema et al. (31), Villinger et al. (32), Kay (33)	Repositioning and replacing food items, food items presentations in the form of amounts and servings, using signs to promote healthy food choices, using reminders to notify individuals about nutrition and healthy eating, financial incentives, affecting senses to influence healthy food selection, cognitive loading, social modeling, decreasing tea spoon size	Limiting the consumption of daily sugar as the main risk factor of dental caries
		Tobacco and alcohol consumption	Nurchis et al. (34), Towner (35), Fakir and Bharati (36), Clarke et al. (37), Blaga et al. (38), Hempel-Bruder et al. (39), Cho et al. (40), Jenssen et al. (41), Drake et al. (42), Bhatt et al. (43)	Supportive interventions like as reminders, incentives, or access to resources such as quit lines or counseling services, graphic warning labels on cigarette packs, warning labels on alcohol bottles, highlighting the social norm of healthy behavior, making non-smoking the default option in public spaces, Increasing taxes on tobacco and alcohol products, Clinical Decision Support (CDS) intervention, timely feedback on tobacco or alcohol consumption	Limiting the consumption of alcohol and tobacco as main risk factors of oral diseases
	Medication adherence		Möllenkamp et al. (47), Kwan et al. (29), Luong et al. (49), Horne et al. (50), Rumi et al. (51), Ding et al. (48)	Reminders via SMS or text messages and motivational prompt messages, personalized nudge using machine learning	Increasing daily oral hygiene adherence
	Physical activity		Möllenkamp et al. (47), Kwan et al. (29), Landais et al. (54), Yang et al. (55), Forberger et al. (56, 57), Li et al. (58)	Reminders, planning prompts, feedback, behavioral contracts, salience nudges, gamification, wearable activity trackers	Increasing daily oral hygiene adherence
	Vaccination		Eze et al. (60), Levine et al. (64), Oyo-Ita et al. (65), Jacobson et al. (66), Sasaki et al. (67)	Patient reminders, education at village meetings, home, and facility-based health education, tailoring social norm	Receiving more oral disease preventive care such as fissure sealant and varnish fluoride
	Healthcare attendance		Möllenkamp et al. (47), Huf et al. (74), Friedman et al. (75), Boksmati et al. (76)	Financial incentives, reminders, planning prompts	Attending more dental checkup appointments
	Health insurance and retirement savings		Krishnan et al. (79), Marzilli Ericson (80), Beshears et al. (82), Dur et al. (83)	Framing, simplicity, social norms, defaults, sorting, callouts, labeling, reminders, personalized information. Framing the future time point around a fresh start date, social norm	Encouraging people to buy dental care insurance
Application of Nudge theory in oral health domains	Dental visit attendance		Wang et al. (21), Wang et al. (22)	Clarify the disadvantages of delaying treatment (gain and loss), social norm	Decreasing the missed dental appointments
	Oral health behavior change		Shariati et al. (20), Marciano et al. (23), White et al. (24)	Social norm, launch campaigns on the importance of good oral health, reminders, remind possible benefits of good oral hygiene routines, monetary incentive	Improving oral health behaviors such as tooth brushing

researchers wrongly claiming that the intervention had an effect. Therefore, given that individuals might be receptive to nudges concerning oral health behaviors (20), it is vital to explore the real impact of norm nudges on concrete clinical measures such as plaque index and the long-term status of decayed, missing, and filled teeth (DMFT).

Some criticisms of nudge strategies assert that the philosophy of nudging contrasts with holistic, people-centered health-promoting interventions that incorporate the social and moral aspects of the setting approach (84). Others argue that with nudging, behavior and education are detached; education and contexts are prioritized over behavior (27). Moreover, studies show great heterogenicity that arises from study design, the method of measuring the efficacy of the interventions, sample group characteristics, and publication bias. Furthermore, most studies are conducted in high-income Global North nations, particularly in the United States. Therefore, Szaszi et al. (85) have argued that scholars must investigate when and where some nudges have huge positive effects. Since then, there has been "No reason to expect large and consistent effects of nudge interventions."

Some authors support nudge interventions despite the critiques and the need for further investigations and high-quality studies in different cultures and settings. For instance, Benartzi et al. (86) discovered, for instance, that the ratios of effect to cost for nudge interventions frequently compare favorably with conventional policy tools, such as tax incentives and other financial inducements. Moreover, previous research has shown that using choice architecture to complement more traditional intervention approaches can enhance the impact of economic interventions such as taxes or financial incentives (87, 88). Mertens et al. (26) also stated that nudge interventions facilitate behavior change across various behavioral domains, population segments, and geographical locations. Therefore, we argue that nudge interventions can be useful for oral health promotion. Oral health is a multi-component phenomenon. We have described multiple nudge interventions that are directly conducted on oral health promotion or indirectly can affect oral health by influencing diet and tobacco consumption. We also explained interventions in other fields analogous to oral health components. Therefore, using different kinds of nudge interventions simultaneously by studying cultural elements and as a complement to other health promotion techniques might lead to significant outcomes (Table 1).

A unique characteristic of nudge interventions is their ability to influence behavior without being mandatory or restrictive. Instead of imposing choices on individuals, they use subtle design strategies to encourage them to make better decisions. In order to facilitate positive behaviors, these interventions utilize insights from behavioral science to shape the decision-making environment. The purpose of nudges is to gently guide individuals toward beneficial outcomes by making design choices that are effective and appealing.

This study has several limitations. Dated from the first major publishing of nudge theory in 2008 and limited to studies labeled as "nudges," our search was limited to those that explicitly employ nudge theory in clinical practice enhancement. These criteria eliminate the probable number of clinical interventions before and after 2008 that employed the behavioral science theories on which "nudges" are based without using the term "nudge." The criteria for English-language studies may have precluded relevant studies published in languages other than English.

4 Conclusion

The interventions made based on the nudge theory has been proven to be relatively efficient in conducting healthy decisions among patients. Despite the limited number of studies, their application in the field of oral health promotion has also yielded encouraging results. Besides, according to the common psychological mechanisms underlying many of the health behavioral patterns, reviewing the effective application of nudge theory in health domains rather than oral health might also be helpful in shaping new interventions in the field of oral health behavior changes. Therefore, we in this critical review, investigated the effectiveness of nudge strategies across domains including nutrition, tobacco and alcohol consumption, vaccination, medication adherence, visits to healthcare facilities, and health insurance purchase decisions. We argued that nudge theory could appropriately be applied to change the common risk factors of non-communicable diseases such as dental problems including sugar, tobacco and alcohol consumption. In addition, we presented that this theory might effectively enhance the recommended regular self-care behaviors such as oral hygiene practice among people. And finally, this theory might be a promising lead for encouraging people to buy appropriate insurance coverages including dental insurance. However, further exploration and clinical adaptation of these nudge interventions are highly recommended to enhance oral health promotion strategies holistically.

A comparative analysis of nudge interventions and non-nudge approaches is recommended for future research. The purpose of this exploration is to reveal the distinct impact of nudges on oral health behaviors, and thus provide valuable insights for advancing oral health interventions. A comparative analysis of nudge interventions and non-nudge approaches is recommended for future research. The purpose of this exploration is to reveal the distinct impact of nudges on oral health behaviors, and thus provide valuable insights for advancing oral health interventions.

Data availability statement

The original contributions presented in the study are included in the article/supplementary material, further inquiries can be directed to the corresponding author.

Author contributions

All authors listed have made a substantial, direct, and intellectual contribution to the work and approved it for publication.

Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Publisher's note

References

1. Hofmann W, Friese M, Wiers RW. Impulsive versus reflective influences on health behavior: a theoretical framework and empirical review. *Health Psychol Rev*. (2008) 2:111–37. doi: 10.1080/17437190802617668

2. Hansen PG, Jespersen AM. Nudge and the manipulation of choice: a framework for the responsible use of the nudge approach to behaviour change in public policy. *Eur J Risk Regulat*. (2013) 4:3–28. doi: 10.1017/S1867299X00002762

3. World Health Organization. Saving lives, spending less: The case for investing in noncommunicable diseases. (2021) Available at: https://www.who.int/publications/i/item/9789240041059

4. Kullgren JT, Hafez D, Fedewa A, Heisler M. A scoping review of behavioral economic interventions for prevention and treatment of type 2 diabetes mellitus. *Curr Diab Rep*. (2017) 17:1–15. doi: 10.1007/s11892-017-0894-z

5. Angellotti E, Wong JB, Pierce A, Hescott B, Pittas AG. Combining wireless technology and behavioral economics to engage patients (WiBEEP) with cardiometabolic disease: a pilot study. *Pilot Feas Stud*. (2019) 5:1–6. doi: 10.1186/s40814-019-0395-8

6. Ruggeri K, Folke T, Benzerga A, Verra S, Büttner C, Steinbeck V, et al. Nudging New York: adaptive models and the limits of behavioral interventions to reduce no-shows and health inequalities. *BMC Health Serv Res*. (2020) 20:363. doi: 10.1186/s12913-020-05097-6

7. Reddy A, Huseman TL, Canamucio A, Marcus SC, Asch DA, Volpp K, et al. Patient and partner feedback reports to improve statin medication adherence: a randomized control trial. *J Gen Intern Med*. (2017) 32:256–61. doi: 10.1007/s11606-016-3858-0

8. Gondivkar SM, Gadbail AR, Gondivkar RS, Sarode SC, Sarode GS, Patil S, et al. Nutrition and oral health. *Dis Mon*. (2019) 65:147–54. doi: 10.1016/j.disamonth.2018.09.009

9. Arno A, Thomas S. The efficacy of nudge theory strategies in influencing adult dietary behaviour: a systematic review and meta-analysis. *BMC Public Health*. (2016) 16:1–11. doi: 10.1186/s12889-016-3272-x

10. Hollands GJ, Shemilt I, Marteau TM, Jebb SA, Kelly MP, Nakamura R, et al. Altering micro-environments to change population health behaviour: towards an evidence base for choice architecture interventions. *BMC Public Health*. (2013) 13:1–6. doi: 10.1186/1471-2458-13-1218

11. Collaborators GOD, Bernabe E, Marcenes W, Hernandez C, Bailey J, Abreu L, et al. Global, regional, and national levels and trends in burden of oral conditions from 1990 to 2017: a systematic analysis for the global burden of disease 2017 study. *J Dent Res*. (2020) 99:362–73. doi: 10.1177/0022034520908533

12. Linden GJ, Lyons A, Scannapieco FA. Periodontal systemic associations: review of the evidence. *J Periodontol*. (2013) 84:S8–S19. doi: 10.1902/jop.2013.1340010

13. Carramolino-Cuéllar E, Tomás I, Jiménez-Soriano Y. Relationship between the oral cavity and cardiovascular diseases and metabolic syndrome. *Med Oral Patol Oral Cirugia Bucal*. (2014) 19:e289:–e294. doi: 10.4317/medoral.19563

14. Boustedt K, Dahlgren J, Twetman S, Roswall J. Tooth brushing habits and prevalence of early childhood caries: a prospective cohort study. *Eur Arch Paediatr Dent*. (2020) 21:155–9. doi: 10.1007/s40368-019-00463-3

15. Nowak AJ, Warren JJ. Infant oral health and oral habits. *Pediatr Clin N Am*. (2000) 47:1043–66. doi: 10.1016/S0031-3955(05)70257-1

16. Carnwell R, Daly W. Strategies for the construction of a critical review of the literature. *Nurse Educ Pract*. (2001) 1:57–63. doi: 10.1054/nepr.2001.0008

17. Cooke A, Smith D, Booth A. Beyond PICO: the SPIDER tool for qualitative evidence synthesis. *Qual Health Res*. (2012) 22:1435–43. doi: 10.1177/1049732312452938

18. Thaler RH, Sunstein CR. *Nudge: Improving decisions about health, wealth, and happiness*. New Haven, Connecticut, USA: Yale University Press (2008).

19. Scarbecz M. Nudging'your patients toward improved oral health. *J Am Dent Assoc*. (2012) 143:907–15. doi: 10.14219/jada.archive.2012.0297

20. Shariati M, Noori N, Hoseinzadeh M, Feizi M, Kazemian A. Adults' estimated prevalence of healthy behavior in society and self-reported oral health status and behaviors. *Community Dent Health*. (2023) 40:182–6. doi: 10.1922/CDH_00089Shariati05

21. Wang TT, Wang S. Applying behavioral economics to address COVID-19 fear among oral and maxillofacial surgery patients. *J Oral Maxillofac Surg*. (2021) 79:741–2. doi: 10.1016/j.joms.2020.12.020

22. Wang TT, Mehta H, Myers D, Uberoi V. Applying behavioral economics to reduce broken dental appointments. *J Am Dent Assoc*. (2021) 152:3–7. doi: 10.1016/j.adaj.2020.07.024

23. Marciano D, Tikotsky A, Orenstein MK, Goldberg H, Vered Y. Nudging parents to improve Children's Oral health: A field study (2021). St. Louis: Social Policy Institute: Washington University.

24. White JS, Ramos-Gomez F, Liu JX, Jue B, Finlayson TL, Garza JR, et al. Monetary incentives for improving smartphone-measured oral hygiene behaviors in young children: a randomized pilot trial. *PLoS ONE*. (2020) 15:e0236692. doi: 10.1371/journal.pone.0236692

25. Harbers MC, Beulens JWJ, Rutters F, de Boer F, Gillebaart M, Sluijs I, et al. The effects of nudges on purchases, food choice, and energy intake or content of purchases in real-life food purchasing environments: a systematic review and evidence synthesis. *Nutr J*. (2020) 19:103. doi: 10.1186/s12937-020-00623-y

26. Mertens S, Herberz M, Hahnel UJJ, Brosch T. The effectiveness of nudging: a meta-analysis of choice architecture interventions across behavioral domains. *Proc Natl Acad Sci U S A*. (2022) 119:119. doi: 10.1073/pnas.2107346118

27. Ledderer L, Kjær M, Madsen EK, Busch J, Fage-Butler A. Nudging in public health lifestyle interventions: a systematic literature review and Metasynthesis. *Health Educ Behav*. (2020) 47:749–64. doi: 10.1177/1090198120931788

28. Vargas-Alvarez MA, Navas-Carretero S, Palla L, Martínez JA, Almiron-Roig E. Impact of portion control tools on portion size awareness, choice and intake: systematic review and Meta-analysis. *Nutrients*. (2021) 13:1978. doi: 10.3390/nu13061978

29. Kwan YH, Cheng TY, Yoon S, Ho LYC, Huang CW, Chew EH, et al. A systematic review of nudge theories and strategies used to influence adult health behaviour and outcome in diabetes management. *Diabetes Metab*. (2020) 46:450–60. doi: 10.1016/j.diabet.2020.04.002

30. Schüz B, Meyerhof H, Hilz LK, Mata J. Equity effects of dietary nudging field experiments: systematic review. *Front Public Health*. (2021) 9:668998. doi: 10.3389/fpubh.2021.668998

31. Venema TAG, Kroese FM, Verplanken B, de Ridder DTD. The (bitter) sweet taste of nudge effectiveness: the role of habits in a portion size nudge, a proof of concept study. *Appetite*. (2020) 151:104699. doi: 10.1016/j.appet.2020.104699

32. Villinger K, Wahl DR, Engel K, Renner B. Nudging sugar portions: a real-world experiment. *BMC Nutr*. (2021) 7:65. doi: 10.1186/s40795-021-00473-9

33. Kay E, Kemps E, Prichard I, Tiggemann M. Instagram-based priming to nudge drink choices: subtlety is not the answer. *Appetite*. (2023) 180:106337. doi: 10.1016/j.appet.2022.106337

34. Nurchis MC, Di Pumpo M, Perilli A, Greco G, Damiani G. Nudging interventions on alcohol and tobacco consumption in adults: a scoping review of the literature. *Int J Environ Res Public Health*. (2023) 20:1675. doi: 10.3390/ijerph20031675

35. Towner EB. Danger in public spaces: strengths and limitations of image-and text-based warning signs. *Bus Prof Commun Q*. (2019) 82:53–73. doi: 10.1177/2329490618815697

36. Fakir AM, Bharati T. Healthy, nudged, and wise: experimental evidence on the role of information salience in reducing tobacco intake. *Health Econ*. (2022) 31:1129–66. doi: 10.1002/hec.4509

37. Clarke N, Blackwell AK, De-loyde K, Pechey E, Hobson A, Pilling M, et al. Health warning labels and alcohol selection: a randomised controlled experiment in a naturalistic shopping laboratory. *Addiction*. (2021) 116:3333–45. doi: 10.1111/add.15519

38. Blaga OM, Frăţilă TD, Meghea CI. Using behavioral nudges to engage pregnant women in a smoking cessation trial: an online field quasi-experiment. *Healthcare*. (2020) 8:531. doi: 10.3390/healthcare8040531

39. Hempel-Bruder C, Habfast-Robertson I, Durand M-A, Berlin I, Marti J, Khazaal Y, et al. Combining default choices and an encounter decision aid to improve tobacco cessation in primary care patients: protocol for a cluster-randomized trial. *BMC Primary Care*. (2022) 23:246. doi: 10.1186/s12875-022-01859-9

40. Cho A, Chan G, Gartner C. Motivations to change smoking behaviors between 2007 and 2019 in Australia: a repeated cross-sectional study. *Nicotine Tob Res*. (2022) 25:674–81. doi: 10.1093/ntr/ntac176

41. Jenssen BP, Schnoll R, Beidas R, Bekelman J, Bauer A-M, Scott C, et al. Rationale and protocol for a cluster randomized pragmatic clinical trial testing behavioral economic implementation strategies to improve tobacco treatment rates for cancer patients who smoke. *Implement Sci*. (2021) 16:1–12. doi: 10.1186/s13012-021-01139-7

42. Drake LA, Suresh K, Chrastil H, Lewis CL, Altman RL. Improving tobacco cessation rates using inline clinical decision support. *Appl Clin Inform*. (2022) 13:1116–22. doi: 10.1055/a-1961-9800

43. Bhatt G, Goel S, Shergill G. One size doesn't fit all: contouring and addressing social vitals in reversing tobacco epidemic in Punjab, India. *BMJ Case Rep*. (2020) 13:e231890. doi: 10.1136/bcr-2019-231890

44. Nudelman G, Shiloh S. Mapping health behaviors: constructing and validating a common-sense taxonomy of health behaviors. *Soc Sci Med*. (2015) 146:1–10. doi: 10.1016/j.socscimed.2015.10.004

45. McEachan RR, Lawton RJ, Conner M. Classifying health-related behaviours: exploring similarities and differences amongst behaviours. *Br J Health Psychol*. (2010) 15:347–66. doi: 10.1348/135910709X466487

46. World Health Organization. *Adherence to long-term therapies: Evidence for action*. Geneva. Switzerland: World Health Organization (2003).

47. Möllenkamp M, Zeppernick M, Schreyögg J. The effectiveness of nudges in improving the self-management of patients with chronic diseases: a systematic literature review. *Health Policy*. (2019) 123:1199–209. doi: 10.1016/j.healthpol.2019.09.008

48. Ding Y, Jiang H, Liu J, Chen D, Yang F. Effects of the theory of planned behavior and nudge strategy-based intervention on the adherence to anticoagulation treatment in patients with non-valvular atrial fibrillation. *Geriatr Nurs*. (2023) 51:17–24. doi: 10.1016/j.gerinurse.2023.01.023

49. Luong P, Glorioso TJ, Grunwald GK, Peterson P, Allen LA, Khanna A, et al. Text message medication adherence reminders automated and delivered at scale across two institutions: testing the nudge system: pilot study. *Circ Cardiovasc Qual Outcomes*. (2021) 14:e007015. doi: 10.1161/CIRCOUTCOMES.120.007015

50. Horne BD, Muhlestein JB, Lappé DL, May HT, Le VT, Bair TL, et al. Behavioral nudges as patient decision support for medication adherence: the ENCOURAGE randomized controlled trial. *Am Heart J*. (2022) 244:125–34. doi: 10.1016/j.ahj.2021.11.001

51. Rumi G, Canonica GW, Foster JM, Chavannes NH, Valenti G, Contiguglia R, et al. Digital coaching using smart inhaler technology to improve asthma Management in Patients with Asthma in Italy: community-based study. *JMIR Mhealth Uhealth*. (2022) 10:e25879. doi: 10.2196/25879

52. Hoben M, Clarke A, Huynh KT, Kobagi N, Kent A, Hu H, et al. Barriers and facilitators in providing oral care to nursing home residents, from the perspective of care aides: a systematic review and meta-analysis. *Int J Nurs Stud*. (2017) 73:34–51. doi: 10.1016/j.ijnurstu.2017.05.003

53. Aliakbari E, Gray-Burrows KA, Vinall-Collier KA, Edwebi S, Salaudeen A, Marshman Z, et al. Facilitators and barriers to home-based toothbrushing practices by parents of young children to reduce tooth decay: a systematic review. *Clin Oral Investig*. (2021) 25:3383–93. doi: 10.1007/s00784-021-03890-z

54. Landais LL, Damman OC, Schoonmade LJ, Timmermans DRM, Verhagen E, Jelsma JGM. Choice architecture interventions to change physical activity and sedentary behavior: a systematic review of effects on intention, behavior and health outcomes during and after intervention. *Int J Behav Nutr Phys Act*. (2020) 17:47. doi: 10.1186/s12966-020-00942-7

55. Yang Y, Hu H, Koenigstorfer J. Effects of gamified smartphone applications on physical activity: a systematic review and Meta-analysis. *Am J Prev Med*. (2022) 62:602–13. doi: 10.1016/j.amepre.2021.10.005

56. Forberger S, Reisch L, Kampfmann T, Zeeb H. Nudging to move: a scoping review of the use of choice architecture interventions to promote physical activity in the general population. *Int J Behav Nutr Phys Act*. (2019) 16:1–14. doi: 10.1186/s12966-019-0844-z

57. Forberger S, Wichmann F, Comito CN. Nudges used to promote physical activity and to reduce sedentary behaviour in the workplace: results of a scoping review. *Prev Med*. (2022) 155:106922. doi: 10.1016/j.ypmed.2021.106922

58. Li C, Chen X, Bi X. Wearable activity trackers for promoting physical activity: a systematic meta-analytic review. *Int J Med Inform*. (2021) 152:104487. doi: 10.1016/j.ijmedinf.2021.104487

59. Dathini H, Sharoni SKA, Robert KT. Parental reminder strategies and the cost implication for improved immunisation outcomes: a systematic review and Meta-analysis. *Healthcare*. (2022) 10:1996. doi: 10.3390/healthcare10101996

60. Eze P, Lawani LO, Acharya Y. Short message service (SMS) reminders for childhood immunisation in low-income and middle-income countries: a systematic review and meta-analysis. *BMJ Glob Health*. (2021) 6:e005035. doi: 10.1136/bmjgh-2021-005035

61. Yunusa U, Garba SN, Umar AB, Idris SH, Bello UL, Abdulrashid I, et al. Mobile phone reminders for enhancing uptake, completeness and timeliness of routine childhood immunization in low and middle income countries: a systematic review and meta-analysis. *Vaccine*. (2021) 39:209–21. doi: 10.1016/j.vaccine.2020.11.043

62. Mohamed R, Kelly KM, Nili M, Kelley GA. A systematic review with meta-analysis of parental interventions for human papillomavirus vaccine uptake. *J Am Pharm Assoc*. (2003) 62:1142–53. doi: 10.1016/j.japh.2022.04.004

63. Jacobson Vann JC, Jacobson RM, Coyne-Beasley T, Asafu-Adjei JK, Szilagyi PG. Patient reminder and recall interventions to improve immunization rates. *Cochrane Database Syst Rev*. (2018) 2018:Cd003941. doi: 10.1002/14651858.CD003941.pub3

64. Levine G, Salifu A, Mohammed I, Fink G. Mobile nudges and financial incentives to improve coverage of timely neonatal vaccination in rural areas (GEVaP trial): a 3-armed cluster randomized controlled trial in northern Ghana. *PLoS One*. (2021) 16:e0247485. doi: 10.1371/journal.pone.0247485

65. Oyo-Ita A, Wiysonge CS, Oringanje C, Nwachukwu CE, Oduwole O, Meremikwu MM. Interventions for improving coverage of childhood immunisation in low-and middle-income countries. *Cochrane Database Syst Rev*. (2016) 2016:Cd008145. doi: 10.1002/14651858.CD008145.pub3

66. Jacobson M, Chang TY, Shah M, Pramanik R, Shah SB. Can financial incentives and other nudges increase COVID-19 vaccinations among the vaccine hesitant? A randomized trial. *Vaccine*. (2022) 40:6235–42. doi: 10.1016/j.vaccine.2022.08.060

67. Sasaki S, Saito T, Ohtake F. Nudges for COVID-19 voluntary vaccination: how to explain peer information? *Soc Sci Med*. (2022) 292:114561. doi: 10.1016/j.socscimed.2021.114561

68. Kashbour W, Gupta P, Worthington HV, Boyers D. Pit and fissure sealants versus fluoride varnishes for preventing dental decay in the permanent teeth of children and adolescents. *Cochrane Database Syst Rev*. (2020) 11:CD003067. doi: 10.1002/14651858.CD003067.pub5

69. Nazir MA. Predictors of routine dental check-up among male adolescents in Saudi Arabia. *Acta Stomatol Croat*. (2019) 53:255–63. doi: 10.15644/asc53/3/7

70. Listl S, Moeller J, Manski R. A multi-country comparison of reasons for dental non-attendance. *Eur J Oral Sci*. (2014) 122:62–9. doi: 10.1111/eos.12096

71. Gomes MAG, Abreu MHNG, Ferreira FM, Fraiz FC, Menezes JVNB. No-shows at public secondary dental care for pediatric patients: a cross-sectional study in a large Brazilian city. *Cien Saude Colet*. (2019) 24:1915–23. doi: 10.1590/1413-81232018245.19312017

72. Wilson LF, Xu Z, Doust J, Mishra GD, Dobson AJ. Associations of socioeconomic and health factors with dental non-attendance: a comparison of three cohorts of women. *Community Dent Oral Epidemiol*. (2022) 51:452–61. doi: 10.1111/cdoe.12776

73. Shabbir A, Alzahrani M, Khalid AA. Why do patients miss dental appointments in eastern province military hospitals, Kingdom of Saudi Arabia? *Cureus*. (2018) 10:e2355. doi: 10.7759/cureus.2355

74. Huf S, Kerrison RS, King D, Chadborn T, Richmond A, Cunningham D, et al. Behavioral economics informed message content in text message reminders to improve cervical screening participation: two pragmatic randomized controlled trials. *Prev Med*. (2020) 139:106170. doi: 10.1016/j.ypmed.2020.106170

75. Friedman W, Wilson N. Can nudging overcome procrastinating on preventive health investments? *Econ Hum Biol*. (2022) 45:101040. doi: 10.1016/j.ehb.2021.101040

76. Boksmati N, Butler-Henderson K, Anderson K, Sahama T. The effectiveness of SMS reminders on appointment attendance: a meta-analysis. *J Med Syst*. (2016) 40:1–10. doi: 10.1007/s10916-016-0452-2

77. Al-Hanawi MK, Mwale ML, Kamninga TM. The effects of health insurance on health-seeking behaviour: evidence from the kingdom of Saudi Arabia. *Risk Manag Healthcare Policy*. (2020) 13:595–607. doi: 10.2147/RMHP.S257381

78. Mussa EC, Palermo T, Angeles G, Kibur M, Otchere F, Gavrilovic M, et al. Impact of community-based health insurance on health services utilisation among vulnerable households in Amhara region, Ethiopia. *BMC Health Serv Res*. (2023) 23:55. doi: 10.1186/s12913-023-09024-3

79. Krishnan SS, Iyer SS, Balaji SMRS. Insights from behavioral economics for policymakers of choice-based health insurance markets: a scoping review. *Risk Manag Insurance Rev*. (2022) 25:115–43. doi: 10.1111/rmir.12205

80. Marzilli Ericson KM, Kingsdale J, Layton T, Sacarny A. Nudging leads consumers in Colorado to shop but not switch ACA marketplace plans. *Health Aff*. (2017) 36:311–9. doi: 10.1377/hlthaff.2016.0993

81. García JM, Vila J. Financial literacy is not enough: the role of nudging toward adequate long-term saving behavior. *J Bus Res*. (2020) 112:472–7. doi: 10.1016/j.jbusres.2020.01.061

82. Beshears J, Dai H, Milkman KL, Benartzi S. Using fresh starts to nudge increased retirement savings. *Organ Behav Hum Decis Process*. (2021) 167:72–87. doi: 10.1016/j.obhdp.2021.06.005

83. Dur R, Fleming D, van Garderen M, van Lent M. A social norm nudge to save more: a field experiment at a retail bank. *J Public Econ*. (2021) 200:104443. doi: 10.1016/j.jpubeco.2021.104443

84. Ewert B. Promoting health in schools: theoretical reflections on the settings approach versus nudge tactics. *Soc Theory Health*. (2017) 15:430–47. doi: 10.1057/s41285-017-0036-3

85. Szaszi B, Higney A, Charlton A, Gelman A, Ziano I, Aczel B, et al. No reason to expect large and consistent effects of nudge interventions. *Proc Natl Acad Sci U S A*. (2022) 119:e2200732119. doi: 10.1073/pnas.2200732119

86. Benartzi S, Beshears J, Milkman KL, Sunstein CR, Thaler RH, Shankar M, et al. Should governments invest more in nudging? *Psychol Sci*. (2017) 28:1041–55. doi: 10.1177/0956797617702501

87. Hardisty DJ, Johnson EJ, Weber EU. A dirty word or a dirty world? Attribute framing, political affiliation, and query theory. *Psychol Sci*. (2010) 21:86–92. doi: 10.1177/0956797609355572

88. Homonoff TA. Can small incentives have large effects? The impact of taxes versus bonuses on disposable bag use. *Am Econ J Econ Pol*. (2018) 10:177–210. doi: 10.1257/pol.20150261

4.4 Results: Journal Article #4

Evaluating the Effectiveness of the Nudge Theory in improving the Oral Self-care of Schoolchildren with Refugee and Immigrant Backgrounds in Mashhad, Iran: A Field Trial

Published in:
Dentistry Journal - 2024

Banihashem Rad SA[*], Esteves-Oliveira M, Kazemian A, Azami N, Khorshid M, Sohrabi A, Attaran Khorasani A, Campus G.

[*] First authorship

Own contribution:
Conceptualization, methodology, literature search and data extraction, formal analysis and data curation, validation, writing—original draft preparation, writing—review and editing.

dentistry journal

MDPI

Article

Evaluating the Effectiveness of the Nudge Theory in Improving the Oral Self-Care of Schoolchildren with Refugee and Immigrant Backgrounds in Mashhad, Iran

Seyed Ahmad Banihashem Rad [1,2], Marcella Esteves-Oliveira [1,3,4], Ali Kazemian [5], Negar Azami [6], Mehrzad Khorshid [6], Aylin Sohrabi [6], Amir Attaran Khorasani [6] and Guglielmo Campus [1,7,8,*]

1 Department of Restorative, Preventive and Pediatric Dentistry, University of Bern, Freiburgstrasse 7, 3010 Bern, Switzerland; seyedahmad.banihashemrad@unibe.ch (S.A.B.R.); marcella.esteves@med.uni-tuebingen.de (M.E.-O.)
2 Graduate School for Health Sciences, University of Bern, Mittelstrasse 43, 3012 Bern, Switzerland
3 Department of Restorative Dentistry and Endodontology, Justus-Liebig-University Giessen, 35390 Giessen, Germany
4 Department of Conservative Dentistry, Periodontology and Endodontology, University Centre of Dentistry, Oral Medicine and Maxillofacial Surgery (UZMK), University of Tübingen, 72076 Tübingen, Germany
5 Department of Community Oral Health, School of Dentistry, Mashhad University of Medical Sciences, Mashhad 9177948959, Iran; kazemiana@mums.ac.ir
6 Department of Dentistry, Mashhad University of Medical Sciences, Mashhad 9177948959, Iran; negar.azami.info@gmail.com (N.A.); mehrzad.khorshid@gmail.com (M.K.); ailin.sohraby@gmail.com (A.S.); attaranka971@mums.ac.ir (A.A.K.)
7 Department of Cariology, Saveetha Dental College and Hospitals, SIMATS DEEMED University, Chennai 600077, India
8 Department of Oral and Maxillofacial Sciences, Sapienza University of Rome, Piazzale Aldo Moro 5, 00185 Rome, Italy
* Correspondence: guglielmo.campus@unibe.ch; Tel.: +41-312-664-0987

Abstract: Nudge theory proposes using subtle interventions to encourage individuals to make better decisions. The aim of this study was to evaluate the effectiveness of the Nudge theory in plaque control and assess caries experience among third-grade primary schoolchildren with refugee and immigrant backgrounds in Mashhad, Iran. Moreover, Afghan and Iranian schoolchildren were compared to assess differences in oral health outcomes. A quasi-experimental field trial was conducted in three public primary schools, comprising 309 participants approximately 9 years old. Interventions were randomly assigned to three schools: School I Messages based on Social Norms (MSN), School II Messages based on Fear of Negative Outcome (MFNO), and School III control group (C). MSN and MFNO received customized motivational video clips at baseline, while C only received Oral hygiene instruction (OHI). All participants received OHI, a brush, and toothpaste. Baseline plaque index (PI) and caries experience in primary and permanent dentition (dmft/DMFT) were recorded. PI was reassessed at two weeks, two months, and six months post-intervention. All data were subjected to statistical analysis. The mean PI decreased significantly in all three groups at the two-week follow-up ($p < 0.01$). The PI improvements declined over a six-month follow-up period in all groups, and the mean PI difference after six months compared to the pre-intervention was significant only in MSN and MFNO ($p < 0.01$), while C reverted almost to the pre-study level. Schoolchildren with at least one filled tooth or Iranian nationality showed a greater PI reduction ($p < 0.01$, $p = 0.05$). The overall mean ± SD dmft and DMFT were 4.24 ± 2.11 and 1.70 ± 1.24, respectively. Among all the examined participants, 32 (10.40%) individuals were caries-free. The mean dmft was statistically significantly higher in Afghan children than in Iranians ($p = 0.01$). MSN was more effective on PI reduction in the short term, while MFNO was more long-lasting. Using the Nudge theory via visual aids was more effective in motivating children to perform better oral self-care than solely traditional OHI.

check for updates

Citation: Banihashem Rad, S.A.; Esteves-Oliveira, M.; Kazemian, A.; Azami, N.; Khorshid, M.; Sohrabi, A.; Attaran Khorasani, A.; Campus, G. Evaluating the Effectiveness of the Nudge Theory in Improving the Oral Self-Care of Schoolchildren with Refugee and Immigrant Backgrounds in Mashhad, Iran. *Dent. J.* **2024**, *12*, 228. https://doi.org/10.3390/dj12070228

Academic Editor: Gabriel Krastl

Received: 22 May 2024
Revised: 21 June 2024
Accepted: 3 July 2024
Published: 19 July 2024

Keywords: oral health education; Nudge theory; plaque index; intervention; DMFT; dental caries; dental public health; pediatric dentistry; Iran

1. Introduction

According to the United Nations High Commissioner for Refugees (UNHCR), the worldwide refugee population reached 100 million in 2022 [1,2]. Simultaneously, the global population of immigrants reached 281 million in 2020, as stated in the World Migration Report [3]. Despite the increasing number of refugees and immigrants globally, there is limited research on oral health-promotion interventions within this population [4].

The global prevalence of oral health diseases (i.e., dental caries and periodontal problems) is a constant reminder of the global need for appropriate oral health education and prevention programmes [5,6]. Oral health education is an essential component of the acquisition of healthy behaviors [7]. A meta-analysis [8] supported all oral health education interventions, such as improving individuals' knowledge, self-care and health behaviors, including brushing and flossing.

Previous studies have highlighted the high prevalence of oral health problems among refugees and the importance of providing oral health care to this population [9]. Moreover, dental diseases in Western cultures might profoundly impact self-image, self-esteem, social behaviors, employability, housing and social perceptions by others [10]. Therefore, interventions aimed at enhancing health literacy should focus on disadvantaged and migrant populations [11,12]. Ultimately, the assimilation of immigrants and refugees might be facilitated by improvement in their oral health.

Proper oral health is essential to a person's overall health and quality of life [13]. An individual's oral health includes being able to properly speak, smile, taste, chew, swallow and express a variety of emotions without experiencing pain or discomfort [14]. Some aspects of health can be improved by simple behavioral changes, such as oral hygiene.

The findings of behavioral economics, a new branch of economics that incorporates findings from psychology into economics, could be useful in promoting healthy behaviors. Two Nobel Prizes in Economics were awarded in 2002 and 2017 to Daniel Kahneman and Richard Thaler, respectively, who brought behavioral economics to the attention of various academic disciplines.

Thaler's theory, known as the Nudge theory, deals with cheap and easy interventions that are effective in changing people's behavior. According to Nudge theory, desirable and healthy behaviors can be encouraged through Easy, Attractive, Social and Timely interventions (EAST) [15]. The Nudge theory was originally described for behavioral economics, but it applies to several fields of science, as it mainly describes ways to influence decision-making without coercion. A nudge makes it more likely that an individual will make a particular choice, or behave in a particular way, by altering the environment so that automatic cognitive processes are triggered to favor the desired outcome [16].

In the context of oral health, Nudge theory has been applied in different ways to affect people's behavior. Dental practices could employ choice architecture by offering discounts for positive oral health behaviors during check-ups to incentivize patients for better oral health maintenance. Additionally, sending personalized text message reminders to patients to schedule dental check-ups proved to improve consistent oral hygiene [17,18]. Interventions based on social norms, such as campaigns highlighting the prevalence of good oral health habits among peers, encourage similar behaviors [19]. Visual cues such as posters and pamphlets could potentially reinforce healthy oral hygiene practices. Behavioral economics principles are also utilized by framing dental treatments in terms of long-term health benefits to address patient fears to encourage patients to seek out dental treatment in a timely and proactive manner. These applications demonstrate how targeted nudges can effectively promote positive oral health behaviors and decisions [17,20]

Iran is home to one of the largest and most protracted urban refugee populations in the world, according to UNHCR. Iran has a high number of Afghan migrants and refugees [21] who have been fleeing their homeland for decades because of war, insecurity, violence, drought and unemployment. More than 4.5 million Afghans live under a variety of legal, economic and social conditions in Iran [22]. Mashhad is an Iranian city in the north-eastern part of the Iranian plateau. It is the second largest city, with the highest number of foreign immigrants after Tehran and with some suburbs comprised primarily of Afghan immigrants [23]. Despite the widespread presence of Afghans in Iran, their oral health status has rarely been studied.

Social norms play an important role in influencing behavior by showcasing what others do in similar situations, while the fear of negative outcomes emphasizes the negative consequences of adopting a behavior [24–26]. These concepts were applied by showing video clips to schoolchildren suggesting that proper oral self-care is a social norm nowadays in one intervention group and indicating the possible negative consequences of not adopting proper oral self-care in another intervention group.

Given the advantages of prevention over treatment and the cultural weakness of the general public regarding oral health, as well as the high cost of treatment needed by society and the attention of international organizations to prevention, the importance of prevention methods and research in this regard is clear.

There is little existing literature about the Nudge implications in oral health [27,28]; thus, a field trial was conducted to evaluate the effectiveness of the Nudge theory in the promotion of better oral self-care and behavioral change of third-grade primary schoolchildren with refugee and immigrant background in Mashhad, Iran. Moreover, the study aimed to assess differences in oral health outcomes, caries prevalence and changes in plaque index (PI) among Afghan and Iranian schoolchildren following the interventions. Additionally, the relationship between age and nationality with caries experience was evaluated. A better understanding of behavioral Nudges might assist policymakers, clinicians and researchers in developing and implementing useful nudge interventions to improve oral health.

2. Materials and Methods

2.1. Trial Design and Study Participants

The study was based on the pattern of quasi-experimental studies as a population-intervention with non-random allocation. The field trial was conducted in three public primary schools with immigrants and refugee backgrounds (similar in socioeconomic status and standard of teaching) in the fifth district of Mashhad.

2.2. Ethical Considerations and Trial Registration

The field trial protocol was registered and approved by the Ethical Committee at Mashhad Dental School under the reference number IR.MUMS.DENTISTRY.REC.1398.002. A one-time verbal consent was obtained from each subject in the presence of the class teacher.

2.3. Sample Size

Sample size calculation was based on the plaque index (PI) (effect size (ES) = 0.28, α err prob = 0.05, Power ($1-\beta$ err prob) = 0.99), and the total sample size was estimated to be 256. F test ANOVA via G*Power 3.1 was used to calculate the sample size [29,30]. Considering the possibility of attrition, the sample size was increased.

2.4. Eligibility Criteria

The inclusion criteria required that children were in good general health and enrolled in the third grade (approximately 9 years of age), and had supplied the written consent form signed by parents/guardians. This study excluded children who were taking medication known to reduce the salivary flow rate, as well as those who had systemic conditions or

chronic diseases. Exclusions were also made for children who were absent on examination days or refused to participate.

2.5. Randomization

Three public primary schools were randomly selected by a random sequence generator out of the boys' public school list of the fifth district of Mashhad using the RAND function to generate random numbers for sorting, with the top three schools being chosen for the study [31]. All third-grade students in all three schools were enrolled in the study by the census method. The question of which school receives which intervention was decided by a random sequence generator in Microsoft Excel (Version 16.55).

2.6. Blinding

The examiners were blinded to the study groups and types of interventions. A coding scheme of School I Messages based on Social Norms (MSN), School II Messages based on Fear of Negative Outcome (MFNO) and School III control group (C) was used for the different groups. This coding scheme was not revealed during data entry and analysis.

2.7. Questionnaire and Content Validity

A pilot study was performed on 32 children aged 9 and 10 years to check the comprehension of the video clips. These subjects were not enrolled in the study.

Two types of questionnaires were designed for MSN and MFNO groups. Each questionnaire consisted of 10 questions, of which three items were relevant questions (Likert-scale questions) and seven items were binary questions (yes/no questions). The content of the structured questionnaires was validated by 10 subject experts. The Likert-scale for the relevant questions was as follows: (1) not relevant, (2) somewhat relevant, (3) quite relevant and (4) highly relevant. The number of experts in agreement (scored 3 or 4) for each item was calculated. The questionnaires used for the content validity of video clips were already validated [32,33].

2.8. Calibration of Examiners

Three examiners were calibrated before the clinical examinations, for measuring the dmft/DMFT and PI on 10 children with similar age under supervision of an Associate professor of Mashhad Dental School acting as a benchmark. The inter-rater agreements among examiners for each item, decayed, missing and filled teeth (for dmft/DMFT index) and plaque score (at tooth surface level for PI), were measured by Fleiss' Kappa.

2.9. Clinical Examination

Each participant underwent a comprehensive examination in the classroom or school hall, where they were seated in reclining chairs. In accordance with the World Health Organization's recommended protocols, portable lights, dental mirrors, gloves, tongue blades and periodontal probe were used in a standardized environment during the examination process [34]. During the baseline examination, the PI was initially recorded, followed by the assessment of dmft/DMFT, which was facilitated by the use of cotton rolls to ensure a dry oral environment. Further moisture mitigation was achieved by applying cotton rolls and gauze.

The plaque index (PI) of the Silness–Loe Plaque Index was recorded. These six teeth were selected to shorten the examination time. The Silness–Loe [35] PI includes the following teeth:

1. Maxillary Right First Molar (Tooth #16);
2. Maxillary Right Lateral Incisor (Tooth #12);
3. Maxillary Left First Bicuspid (Tooth #24);
4. Mandibular Left First Molar (Tooth #36);
5. Mandibular Left Lateral Incisor (Tooth #32);
6. Mandibular Right First Bicuspid (Tooth #44).

To record the PI, the plaque present in the cervical edge of the distobuccal, buccal, mesiobuccal and lingual (four) surfaces of each tooth was evaluated using a probe in appropriate light. Each level was given a score between 0 and 3 based on the amount of plaque present, and at the end, the PI of an individual was determined by summing the values obtained for each tooth and calculating the averages.

In cases where any of the selected teeth were missing, no replacement was provided, and the index was calculated based on all the existing teeth. The scoring scheme for the PI is included below:

0: Absence of plaque;

1: When the plaque is not visible to the naked eye and can be detected only by a probe;

2: Average accumulation of plaque that is visible to the eye;

3: The large volume of debris and plaque.

2.10. Intervention

The study was conducted between April and October 2023. The examinations were conducted between 9 and 11 in the morning at schools.

The field trial focused on providing oral health messages to children. The principal investigator (SABR) was always present in the students' classes to provide the health messages/intervention.

In the present study, interventions were designed to improve oral self-care in children with refugee and immigrant backgrounds using two messages from Nudge theory: the effect of social norms, and the fear of negative outcome.

The population enrolled was randomly divided into three groups on school-based:

Case group (MSN): Participants watched a video featuring interviews of children who had good oral health and expressions of satisfaction with their hygiene habits. The speech that accompanied it emphasized the prevalence of good oral hygiene among peers of comparable age. This intervention's main goal was to give participants the impression that maintaining good oral hygiene, which includes brushing twice a day and limiting the intake frequency of sugary snacks, is a social norm that is widely recognized by their peers. For this purpose, interviews with peers who supported these activities as the normative standard were shown to the participants. In addition, this group received the control group's intervention.

Case group (MFNO): Participants watched a video featuring interviews of children who had poor oral health and complained about oral health issues due to poor oral hygiene, talking about their experiences of pain and discomfort. The speech that accompanied it emphasized the potential negative consequences of poor oral hygiene practices and high sugar-intake frequency. This intervention's main goal was to instil fear-based messages about the negative consequences of poor oral self-care, emphasizing the importance of regular oral hygiene practices to prevent similar negative outcomes. In addition, this group received the control group's intervention.

Control group (C): The control group received adequate tools and skills in tooth brushing, flossing and tongue cleaning (frequency, duration and technique). The proper technique for brushing [36] and flossing was demonstrated to students via video and on a dentiform.

All students received an oral health package containing a brush and toothpaste in the first examination. In a two-week follow-up, students received a leaflet designed based on the relative intervention group as a reminder (Second intervention). On the back of the leaflet, a calendar was drawn to encourage students to keep the leaflet. Despite the fact that the interventions and leaflets were primarily in Farsi, a translated version is attached in the Supplementary Materials (Figures S1, S2 and S3 on pages 2, 3 and 4).

The content of video clips in case groups included responses to the following interview questions:

1. Do you brush your teeth? How many times a day and when?
2. How much do you like/eat chocolate and sweets?
3. Have you ever had a toothache? When did you feel the pain? What did you do about it?
4. Have you ever been to a dentist? What did they do for you?

2.11. Evaluation of Intervention

The Plaque Index (PI) [35], which has a score between 0 and 3, was assessed a total of four times (before the intervention, and two weeks, two months and six months [37] after the first examination) to measure the effectiveness of behavior-change methods. The PI was recorded by three calibrated dentists.

2.12. Data Analysis

The content validity of the two questionnaires was evaluated by means of the Content Validity Index (CVI), which was calculated for each item (question) and both questionnaires using Microsoft Excel. The Item-Content Validity Index (I-CVI) for each question, as well as the Scale-Content Validity Index (S-CVI), which is the overall scale (the average of I-CVI scores) for each questionnaire, were measured. Kappa–Cohen (K*) was used to determine the inter-rater agreement among the experts. After the trial was completed, the data obtained were entered into Microsoft Excel 2016 (Microsoft Corporation, Washington, DC, USA) and analyzed using the IBM SPSS Statistics (Version 27). Tests such as the chi-square test for categorical data and parametric tests such as Repeated Measures ANOVA (Analysis of Variance), Independent *t*-test and One-Way ANOVA for quantitative data were used, and *p*-value less than 0.05 was considered statistically significant. The Chi-square test was applied to evaluate the significance of study characteristics on a categorical scale and measure the percentage of caries-free individuals.

Repeated Measures ANOVA test was used to determine whether there were differences in PI changes among participants across the three groups. When the ANOVA test showed significant differences, post hoc Tukey's test identified which means differed. The relationship between dmft/DMFT and age was measured using One-Way Analysis of Variance (ANOVA), while the relationship with nationality was measured using the Independent Samples *t*-test.

The assumptions of parametric tests were checked using the Shapiro–Wilk test ($p < 0.05$). Parametric tests, such as ANOVA, were used because they are robust to violations of normality with large sample sizes (N: 309) [38–40]. Bonferroni correction was used for pairwise and multiple comparisons.

3. Results

3.1. Study Sample

Three public primary schools were randomly selected from boys' public schools (totaling 16 schools) in the fifth district of Mashhad. Using a census approach, a total of 315 students were enrolled. Upon fulfilling the inclusion criteria, 309 students were included in the study. There were 102, 107 and 100 students from the MSN group (Kashani School), MFNO group (Imam Sadegh School) and control group (Pasdaran School), respectively. The schoolchildren underwent a baseline examination to determine PI and dmft/DMFT indices. In total, 38 individuals were lost to follow-up due to absence on the day of the examination. Consequently, the PI of 271 students was compared at four different time points. The study procedure is visually depicted in Figure 1.

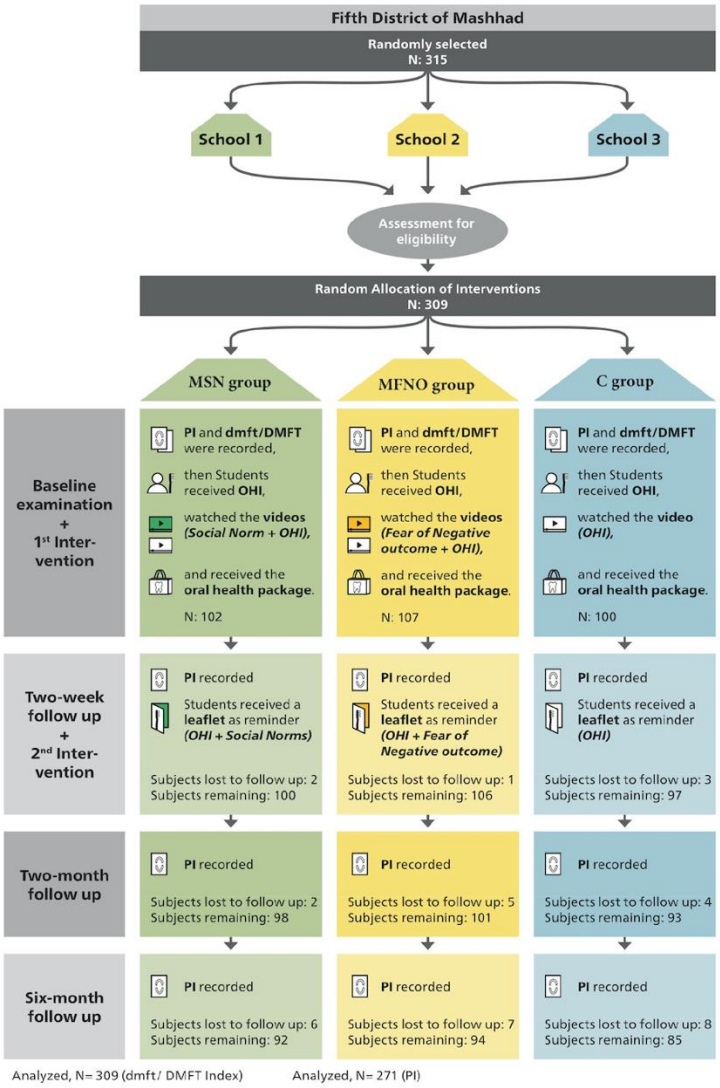


Figure 1. Schematic representation of study procedure. N: Number; MSN: Messages based on "Social Norms"; MFNO: Messages based on "Fear of Negative Outcome"; C: Control; OHI: Oral Hygiene Instruction; PI: Plaque Index; DMFT: Caries experience in the permanent dentition; dmft: Caries experience in the primary dentition.

3.2. Content Validity

The interpretations of I-CVI for each item (question) and S-CVI/Ave in both questionnaires were acceptable (I-CVI > 0.78, S-CVI > 0.9). Kappa coefficient interpretation was excellent for each question (k* = [0.75–1]). The content validity table for both questionnaires is presented in the Supplementary Materials (Table S1, on page 5).

3.3. Calibration

The calibration of examiners was measured at the tooth level. Inter-rater agreement among examiners, as shown by Fleiss' Kappa, was estimated to be 0.81 for PI, and it was 0.64, 0.89 and 0.91 for Decayed (D/d), Missing (M/m) and Filled (F/f) teeth, respectively. There was a significant level of agreement among examiners ($p < 0.05$). The agreement obtained for PI, M/m and F/f was almost perfect, and a substantial agreement was obtained for D/d between the examiners.

3.4. Tests and Analysis

3.4.1. Categorical and Demographic Data

Among all the examined participants, only 32 (10.40%) were caries-free. As the number of 11 year olds was too few (n = 9), they were accounted to the 10-year-old age group category (Table 1).

Table 1. Demographic data on categorical scale and caries-free individuals.

Category	Subcategory	Number (%)
Nationality	IR [1]	81 (26.20%)
	AF [2]	228 (73.80%)
	Total	309 (100%)
Age	8	72 (23.30%)
	9	203 (65.70%)
	10	34 (11%)
	Total	309 (100%)
Caries free	MSN [3]	11 (3.60%)
	MFNO [4]	12 (3.90%)
	C [5]	9 (2.90%)
	Total	32 (10.40%)

[1] IR: Iranians; [2] AF: Afghans; [3] MSN: Messages based on "Social Norms"; [4] MFNO: Messages based on "Fear of Negative Outcome"; [5] C: Control.

3.4.2. Plaque Index Measurement of All Three Schools in Time Intervals

The mean PI (SD) pre-intervention for the MSN group was 1.90 (0.65), the MFNO group was 2.02 (0.76) and the C group was 1.96 (0.70). The mean PI in the three groups did not differ significantly from each other at baseline.

After the oral health education and intervention, in a two-week follow-up, the mean PI were 1.39 in MSN, 1.67 in MFNO and 1.70 in the control group. In all three groups, there was a significant decrease after two weeks of follow-up compared to baseline examination ($p < 0.01$).

In the second follow-up (from two weeks to two months post-intervention), there was an insignificant decrease in MSN and MFNO and an insignificant increase in the C.

In the final follow-up (six-months post-intervention), the mean PI in MSN, MFNO and C were 1.70, 1.69 and 1.92, respectively. From two to six months follow-up, there was a significant increase in mean PI in MSN and C and an insignificant increase in MFNO (Tables 2 and 3). Additional tables of PI means in school groups and time are attached in the Supplementary Materials (Tables S2 and S3, on page 6).

At six-month follow-up, the PI mean differences in intervention groups (MSN and MFNO) were significant compared to the baseline, as opposed to the C, which was not significant (Figure 2).

Table 2. Intragroup comparison of plaque index in different time intervals.

Groups	N	Time Points	PI	Time Intervals	*p*-Value
MSN [1]	92	baseline (T1)	1.90 (0.65)	T1 to T2	<0.01 *
		two weeks (T2)	1.39 (0.78)	T2 to T3	0.73
		two months (T3)	1.33 (0.77)	T3 to T4	<0.01 *
		six months (T4)	1.70 (0.72)	T4 to T1	<0.01 *
MFNO [2]	94	baseline (T1)	2.02 (0.76)	T1 to T2	<0.01 *
		two weeks (T2)	1.67 (0.80)	T2 to T3	1.00
		two months (T3)	1.61 (0.77)	T3 to T4	0.90
		six months (T4)	1.69 (0.81)	T4 to T1	<0.01 *
C [3]	85	baseline (T1)	1.96 (0.70)	T1 to T2	<0.01 *
		two weeks (T2)	1.70 (0.70)	T2 to T3	1.00
		two months (T3)	1.72 (0.78)	T3 to T4	<0.01 *
		six months (T4)	1.92 (0.72)	T4 to T1	1.00
Total	271				

[1] MSN: Messages based on "Social Norms"; [2] MFNO: Messages based on "Fear of Negative Outcome"; [3] C: Control; N: Number; PI: Plaque Index (*p*-value *: Statistically significant); Data presented as mean (SD) unless otherwise specified.

Table 3. Intergroup comparison of plaque index at different time points.

Time Points	Total PI	Groups	*p*-Value
baseline (T1)	1.96 (0.70)	MSN [1] and MFNO	0.82
		MFNO [2] and C	1.00
		C [3] and MSN	1.00
two weeks (T2)	1.58 (0.77)	MSN and MFNO	0.04 *
		MFNO and C	1.00
		C and MSN	0.02 *
two months (T3)	1.55 (0.79)	MSN and MFNO	0.03 *
		MFNO and C	1.00
		C and MSN	<0.01 *
six months (T4)	1.76 (0.76)	MSN and MFNO	1.00
		MFNO and C	0.11
		C and MSN	0.14

[1] MSN: Messages based on "Social Norms"; [2] MFNO: Messages based on "Fear of Negative Outcome"; [3] C: Control; PI: Plaque Index (*p*-value *: Statistically significant); Data presented as mean (SD) unless otherwise specified.

3.4.3. Nationality and Dental Filling Effects on PI Changes

Iranian schoolchildren showed a greater reduction in PI mean in the six-month follow-up compared to Afghan schoolchildren, but this difference was not statistically significant ($p = 0.05$). The table and graph of PI changes in nationality groups are presented in the Supplementary Materials (Table S4 and Figure S4, on page 7).

In the six-month follow-up, the PI mean difference between children with no dental fillings and children who already had at least a dental filling (f/F) was statistically significant ($p < 0.01$), and plaque reduction was greater in those who had already had at least a dental filling in their mouth compared to those who had not. The related graph and table are presented in the Supplementary Materials (Table S5 and Figure S5, on page 8).

3.4.4. Nationality and dmft/DMFT Relationship

The mean dmft (SD) for Afghan children was 4.41 (2.01), and for Iranian children it was 3.74 (2.29). The difference was statistically significant ($p = 0.01$). The mean DMFT (SD) for Afghan children was 1.78 (1.25), and for Iranian children it was 1.47 (1.17). No significant difference was found between the DMFT index of Iranian and Afghan children ($p = 0.05$) (Table 4).

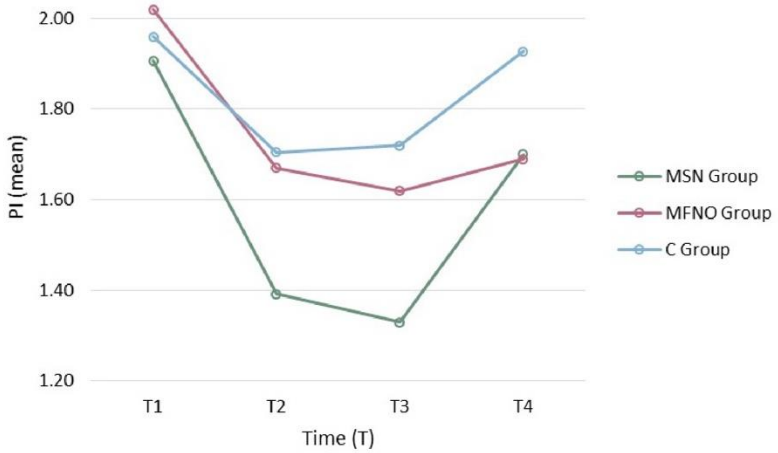


Figure 2. The plaque index mean changes in the study school groups at different time points. MSN: Messages based on Social Norms; MFNO: Messages based on Fear of Negative Outcome; C: Control. Horizontal axis shows "Time (follow-ups)": T1: Baseline; T2: Two weeks; T3: Two months; T4: Six months. The vertical axis shows "Plaque Index means".

Table 4. Comparison of dmft and DMFT indices based on "Nationality" and "Age".

Nationality	dt [3]	mt [4]	ft [5]	dmft [1]	*p*-Value
IR[9] AF [10]	3.23 (2.19) 4.05 (1.88)	0.22 (0.52) 0.24 (0.64)	0.28 (0.71) 0.12 (0.40)	3.74 (2.29) 4.41 (2.01)	0.01*
	DT [6]	MT [7]	FT [8]	DMFT [2]	*p*-value
IR AF	1.20 (1.05) 1.63 (1.14)	0.09 (0.28) 0.12 (0.35)	0.19 (0.39) 0.04 (0.18)	1.47 (1.17) 1.78 (1.25)	0.05
Age	dt	mt	ft	dmft	*p*-value
8 9 10	4.11 (2.21) 4.05 (1.86) 1.97 (1.24)	0.35 (0.73) 0.23 (0.60) 0.03 (0.17)	0.15 (0.49) 0.19 (0.54) 0.03 (0.17)	4.61 (2.35) 4.47 (1.91) 2.03 (1.24)	<0.01 *
	DT	MT	FT	DMFT	*p*-value
8 9 10	1.24 (0.99) 1.44 (1.07) 2.56 (1.28)	0.11 (0.36) 0.10 (0.32) 0.15 (0.36)	0.01 (0.12) 0.09 (0.29) 0.09 (0.29)	1.36 (1.09) 1.64 (1.17) 2.79 (1.36)	<0.01 *

[1] dmft: caries experience in the primary dentition; [2] DMFT: caries experience in the permanent dentition; [3] dt—decayed teeth in the primary dentition; [4] mt—missing teeth in the primary dentition; [5] ft—filled teeth in the primary dentition; [6] DT—decayed teeth in the permanent dentition; [7] MT—missing teeth in the permanent dentition; [8] FT—filled teeth in the permanent dentition; [9] IR: Iranians; [10] AF: Afghans. (*p*-value *: Statistically significant); Data presented as mean (SD) unless otherwise specified.

3.4.5. Age and dmft/DMFT Relationship

The mean dmfts (SD) for 8-, 9- and 10-year-old children were 4.61 (2.35), 4.47 (1.91) and 2.03 (1.24), respectively. The mean dmft for 10-year-old children was statistically significantly lower than 8- and 9-year-old children ($p < 0.01$). The mean DMFTs for 8-, 9- and 10-year-old children were 1.36 (1.09), 1.64 (1.17) and 2.79 (1.36), respectively. The mean DMFT for 10-year-old children was statistically significantly higher than 8- and 9-year-old children; however, the mean differences of both dmft and DMFT indices between 8- and 9-year-old children were not statistically significant ($p = 0.86, 0.20$) (Table 4).

Overall, the mean (SD) dmft and DMFT indices were 4.24 (2.11) and 1.70 (1.24), respectively, and the median dmft and DMFT indices were 5 and 2, respectively, for all the participants (n = 309). The table of dmft/DMFT indices in school groups is presented in the Supplementary Materials (Table S6, on page 9).

4. Discussion

Due to the ease of accessibility, the present study targeted school-going children. The population of public schools is often characterized by many individuals of almost similar age and socioeconomic status.

Motivating children to improve oral self-care is more cost-effective than constantly running programs to look after them. Having a good understanding of proper oral hygiene practices is crucial for maintaining optimal oral health. Implementing school-based oral health education can greatly benefit a large number of children by improving their knowledge and behavior, all at a minimal cost [41]. The present study showed that nudging primary school children to better oral self-care resulted in better plaque control than traditional, widely used oral health instruction methods.

Children in the third grade were selected for the current study. Establishing healthy oral hygiene habits in childhood would lay the foundation for good dental health in adolescence. When children practice good oral hygiene from an early age, it might remain as a value and potentially make it an enduring habit for them [42]. In addition, at the age of nine, children are in the middle of their mixed dentition, resulting in an appropriate time for evaluating caries experiences in both primary and permanent dentition [43].

Despite Nudge theory's widespread usage in economics, public policy and healthcare, its application in oral health and dentistry is notably understudied. Although Nudge theory has been shown to be beneficial in promoting healthy behaviors and improving patient outcomes in areas such as smoking cessation and medication adherence, its potential in oral health remains largely unexplored [27]. This lack of research extends to immigrant and refugee populations, with no prior studies focusing on nudge messages for promoting their oral health. Although direct comparisons to other studies were difficult, the authors attempted to analyze the findings alongside similar studies to offer insights and contextualize our results within the existing literature.

In the present study, interventions were designed using two messages from Nudge theory: the effect of social norms and the fear of negative outcome.

First, based on the findings of behavioral economics, one of the strategies for behavior change is to use messages based on social norms. People in society are strongly influenced by the question of what other people will do in a similar situation. Based on this approach, social norms seem to have a great impact on changing people's habits and behavior. The findings of behavioral economics indicate that statistically people are likely to behave as what they believe to be the prevalent comportment. Moreover, Attitudes that become social norms spread more rapidly in society [44]. A number of recent experiments have examined the impacts of social norms to encourage desired behavior [24,25].

Second, according to the findings of behavioral economics, another way to influence people's comportment is to show the positive and negative consequences of adopting a behavior. In particular, showing the negative results of behavior to people causes a sense of danger that can lead to a change in a person's behavior. On average, loss aversion is a greater motivator than the pleasure of gain [26,45,46]. However, a recent review demonstrates that there are some situations where loss aversion might not emerge, and individuals give equal weight to gains and losses [47].

Prior research has indicated the small to moderate impact of nudge interventions on individuals' food choices and nutritional decision-making [48,49]. Arno et al. [50] conducted a meta-analysis which found that nudge interventions, on average, result in a 15.3% increase in healthier dietary or nutritional decisions. This increase was measured by changes in the frequency of healthy choices or overall calorie intake.

The effectiveness of nutritional nudge methods seems to be influenced by the socioeconomic status of the target population and the delivery mode of nudge. The application of social modeling during group meeting sessions successfully altered patients' dietary habits and physical activity levels; however, the use of digital devices' notifications to encourage patients to eat less proved to be unsuccessful. Harbers et al. [48] observed compelling evidence indicating that nudges had a greater impact on individuals from low socioeconomic status groups. On the other hand, Ruggeri et al. [51] found that nudge treatments had a more substantial impact on those with higher socioeconomic levels. This finding is further emphasized by Eze et al. [52], who highlighted the pronounced effects of these interventions on this demographic group.

In the present study, after receiving the oral health package and education, PI was significantly decreased in all three groups in the two-week and two-month follow-ups. These findings were found to be in accordance with the studies conducted by Ingale et al. [43], Shahapur et al. [53] and Zarabadipour et al. [54], where a significant reduction in mean PI was reported after educational intervention. In contrast, Palenstein et al. [55] found no significant reduction in PI after oral health intervention.

In the six-month follow-up, the PI in the C group nearly reverted to pre-study levels, confirming Sharma et al.'s [56] finding that intervention groups showed PI improvements while controls deteriorated. Similarly, Ivanovic et al. [57] found that short-term health education only transiently improved gingival health in schoolchildren, suggesting sustained benefits required prolonged, professional instruction. In the present study, the C group showed a short-term effect, which was in agreement with the findings of Ivanovic et al. [57].

The present study, alongside Evans et al. [58], explored how different communication strategies affect oral hygiene behavior. While Evans et al. highlighted the benefits of positive messaging, we found that fear-based messages were more effective in the long run (six-month follow-up). Both studies reported declining improvements over time, emphasizing the need for ongoing message reinforcement. Our findings support Evans et al.'s observation of the short-term effect of positive messages, particularly those rooted in social norms. There is, however, only limited research comparing fear and positive appeals on oral health, which indicates a notable gap in understanding in this regard [58].

Our results showed that age had a direct relationship with caries experience in permanent dentition and an inverse relationship with caries experience in primary dentition. This finding was in agreement with Soltani et al.'s meta-analysis of caries prevalence among Iranian children [59]. In our study, the reported caries experience was higher than Soltani et al.'s report of average caries experience among Iranian children (overall mean of 3.80 and 2.13 for dmft and DMFT, respectively) [59]. Considering previous research on caries experience in Mashhad school children, our findings revealed that children with an immigrant background had a higher caries experience than those with an Iranian background [60].

Participants with filled teeth in the mouth (f, F) or Iranian nationality showed a greater reduction in PI following the oral health intervention. The existence of restored teeth and Iranian citizenship might suggest enhanced accessibility to dental care facilities and may mirror a more affluent socioeconomic position among parents [61]. This finding aligns with the hypothesis that conversion factors such as parental socioeconomic status, mental health and parental education level might play a crucial role in the translation of health literacy to health outcomes, meaning individuals with favorable social and personal factors (those already privileged) might derive greater health benefits from interventions aimed at enhancing health literacy [62]. Nevertheless, it is crucial to acknowledge the presence of numerous confounding variables at play and methodological limitations, which limit the confidence of any conclusions drawn in this context.

By combining verbal instruction with visual aids, such as leaflets and educational videos, the learning process is enhanced, and a lasting impact might be ensured. The educational content of our study was effectively delivered through a variety of visual aids, including videos and leaflets. Consistent with our finding, Aljafari et al. [63] reported a significant increase in children's awareness via audio–visual educational interventions

for children aged 4 to 10 with a high caries risk. There was only one exposure to the video in this study, unlike those in Lees and Rock's study [64], where the children took the video home. Repeated exposures could have further led to improvements in oral hygiene. Also, Ghaffari et al.'s findings [8] demonstrated that diverse health education interventions effectively enhance individuals' knowledge and promote essential self-care behaviors such as brushing and flossing. Our study consistently revealed that all interventions resulted in a reduction of PI in school children.

4.1. Strengths of the Study

To the best of the authors' knowledge, the present study was the first to use the Nudge theory to promote oral self-care among children with immigrant and refugee backgrounds. Moreover, it provided the first report on both the prevalence of caries and the effectiveness of oral health promotion interventions for this population in Iran. These distinctive contributions highlighted how important our research was for informing the next public health programs in Mashhad, Iran.

4.2. Limitation

Limitations of this study include the limited representativeness of the selected public schools, which mainly catered to immigrant and refugee children in Mashhad, potentially limiting the generalizability of our findings. Uncontrolled variables such as participants' personal characteristics, socioeconomic status and prior oral health education from other sources could have caused heterogeneity, potentially confounding the results. A notable limitation of this study was the focus solely on male schoolchildren, which introduces a gender bias and limits the exploration of sex differences in oral hygiene behaviors and outcomes, thus affecting the generalizability of the results. Furthermore, a larger sample size and longer follow-up periods could have strengthened the study's findings and provided a more comprehensive understanding of the effectiveness and sustainability of the interventions.

4.3. Recommendations for Further Studies

Future research may evaluate the comparative effectiveness of various nudge and non-nudge approaches across various social contexts to improve oral health. In addition to providing valuable insights into the most effective strategies for promoting oral health behaviors among different demographic groups, such research may also facilitate the development of customized interventions. The development of innovative approaches and studies aimed at motivating children to take better oral care within various social settings is a pressing need.

5. Conclusions

Our findings showed that applying the Nudge theory along with oral health education was more effective than the traditional method of oral health education, and oral health education via visual aids (leaflets and videos) was effective in plaque control.

It was noteworthy that the short-term and long-term effectiveness of the intervention strategies differed. Messages based on social norms demonstrated immediate reductions in PI after two weeks and two months, while messages based on fear of negative outcome showed more sustained effects after six months.

Supplementary Materials: The following supporting information can be downloaded at: https://www.mdpi.com/article/10.3390/dj12070228/s1, Figure S1: Effect of social norm (MSN) group reminder, Figure S2: Fear of negative outcome (MFNO) group reminder, Figure S3: Leaflet for the control (C) group that includes only oral health instruction, Figure S4: Nationality and PI changes, Figure S5: Dental filling and PI changes; Table S1: Content Validity of the questionnaires, Table S2: Estimated Marginal Means of "Plaque Index" in school groups, Table S3: Estimated Marginal Means of "Plaque Index" in Time, Table S4: Nationality and PI, Table S5: Dental filling and PI, Table S6: dmft/DMFT comparison in school groups.

Author Contributions: Conceptualization, S.A.B.R., G.C., M.E.-O. and A.K.; methodology, S.A.B.R., G.C., A.K. and M.E.-O.; literature search and data extraction, A.S., A.K., N.A., M.K. and S.A.B.R.; formal analysis and data curation, N.A., S.A.B.R. and G.C.; supervision, M.E.-O., A.K. and G.C.; validation, S.A.B.R., N.A., M.K., A.A.K. and G.C.; writing—original draft preparation, M.E.-O., S.A.B.R., N.A. and G.C.; writing—review and editing, A.K., S.A.B.R., M.E.-O., N.A., A.A.K. and G.C. All authors have read and agreed to the published version of the manuscript.

Funding: The research presented in the manuscript received funding from Swiss Government Excellence Scholarship Grants: #2021.0876/Iran/OP. This work was also supported by the Department of Community Oral Health, School of Dentistry, Mashhad University of Medical Sciences, Mashhad, Iran. The funding sponsors did not contribute to the study's design, data collection, analysis, interpretation, article writing, or decision to publish.

Institutional Review Board Statement: The study was conducted according to the guidelines of the Declaration of Helsinki, and approved by the Ethical Committee at Mashhad Dental School under the reference number IR.MUMS.DENTISTRY.REC.1398.002. A one-time verbal consent was obtained from each subject in the presence of the class teacher.

Informed Consent Statement: Informed consent was obtained from all subjects involved in this study.

Data Availability Statement: Raw data that support the findings of this study is available from the corresponding author, upon reasonable request.

Acknowledgments: The authors express gratitude for the cooperation of the school administration and all participants who granted approval to participate in the field trial. The authors would like to thank Ines Badertscher and Bernadette Rawyler from the Multimedia Department, School of Dental Medicine, University of Bern, Switzerland, for their help in creating the figures.

Conflicts of Interest: The authors declare no conflicts of interest.

References

1. Blair, C.W.; Grossman, G.; Weinstein, J.M. Forced displacement and asylum policy in the developing world. *Int. Organ.* **2022**, *76*, 337–378. [CrossRef]
2. Sampson, R.; Mitchell, G. Global trends in immigration detention and alternatives to detention: Practical, political and symbolic rationales. *J. Migr. Hum. Secur.* **2013**, *1*, 97–121. [CrossRef]
3. McAuliffe, M.; Khadria, B. International Organization for Migration (2021). World Migration Report. In *The Europa Directory of International Organizations 2021*; Routledge: London, UK, 2022.
4. Keboa, M.T.; Hiles, N.; Macdonald, M.E. The oral health of refugees and asylum seekers: A scoping review. *Glob. Health* **2016**, *12*, 59. [CrossRef] [PubMed]
5. GBD 2017 Oral Disorders Collaborators; Bernabe, E.; Marcenes, W.; Hernandez, C.R.; Bailey, J.; Abreu, L.G.; Alipour, V.; Amini, S.; Arabloo, J.; Arefi, Z.; et al. Global, regional, and national levels and trends in burden of oral conditions from 1990 to 2017: A systematic analysis for the global burden of disease 2017 study. *J. Dent. Res.* **2020**, *99*, 362–373. [PubMed]
6. WHO. *Dental Health Education: Report of a WHO Expert Committee [Meeting Held in Geneva from 2 to 8 December 1969]*; World Health Organization: Geneva, Switzerland, 1970.
7. Modha, B. Utilising dentist-dental health educator skill-mix to implement oral health promotion that better supports diverse communities. *J. Integr. Care* **2022**, *30*, 237–250. [CrossRef]
8. Ghaffari, M.; Rakhshanderou, S.; Ramezankhani, A.; Noroozi, M.; Armoon, B. Oral health education and promotion programmes: Meta-analysis of 17-year intervention. *Int. J. Dent. Hyg.* **2018**, *16*, 59–67. [CrossRef] [PubMed]
9. Banihashem Rad, S.A.; Esteves Oliveira, M.; Maklennan, A.; Castiglia, P.; Campus, G. Higher prevalence of dental caries and periodontal problems among refugees: A scoping review. *J. Glob. Health* **2023**, *13*, 04111. [CrossRef] [PubMed]
10. Ilma de Souza Cortes, M.; Marcenes, W.; Sheiham, A. Impact of traumatic injuries to the permanent teeth on the oral health-related quality of life in 12–14-year-old children. *Community Dent. Oral Epidemiol.* **2002**, *30*, 193–198. [CrossRef]
11. Ellermann, C. Promoting health literacy to reduce health inequalities in societies: Christin Ellermann. *Eur. J. Public Health* **2017**, *27* (Suppl. S3), ckx187-517. [CrossRef]
12. Van Der Heide, I.; Wang, J.; Droomers, M.; Spreeuwenberg, P.; Rademakers, J.; Uiters, E. The relationship between health, education, and health literacy: Results from the Dutch Adult Literacy and Life Skills Survey. *J. Health Commun.* **2013**, *18* (Suppl. S1), 172–184. [CrossRef]
13. Sheiham, A. *Oral Health, General Health and Quality of Life*; SciELO Public Health: São Paulo, Brazil, 2005; p. 644.
14. Glick, M.; Williams, D.M.; Kleinman, D.V.; Vujicic, M.; Watt, R.G.; Weyant, R.J. A new definition for oral health developed by the FDI World Dental Federation opens the door to a universal definition of oral health. *Br. Dent. J.* **2016**, *221*, 792–793. [CrossRef]
15. Thaler, R.; Sunstein, C. (Eds.) Nudge: Improving decisions about health, wealth and happiness. In *Amsterdam Law Forum*; HeinOnline: Getzville, NY, USA, 2008.

16. Parkinson, J.; Eccles, K.; Goodman, A. Positive impact by design: The wales centre for behaviour change. *J. Posit. Psychol.* **2014**, *9*, 517–522. [CrossRef]
17. Scarbecz, M. 'Nudging'your patients toward improved oral health. *J. Am. Dent. Assoc.* **2012**, *143*, 907–915. [CrossRef] [PubMed]
18. Brent Bowen, T.; Rinchuse, D.J.; Zullo, T.; DeMaria, M.E. The influence of text messaging on oral hygiene effectiveness. *Angle Orthod.* **2015**, *85*, 543–548. [CrossRef] [PubMed]
19. Shariati, M.; Noori, N.; Hoseinzadeh, M.; Feizi, M.; Kazemian, A. Adults' estimated prevalence of healthy behavior in society and self-reported oral health status and behaviors. *Community Dent Health.* **2023**, *40*, 182–186.
20. Wang, T.T.; Mehta, H.; Myers, D.; Uberoi, V. Applying behavioral economics to reduce broken dental appointments. *J. Am. Dent. Assoc.* **2021**, *152*, 3–7. [CrossRef]
21. Koepke, B. Iran's Relations with Afghanistan's National Unity Government. In *The Arab World and Iran: A Turbulent Region in Transition*; Palgrave Macmillan: New York, NY, USA, 2016; pp. 145–163.
22. Modrzejewska-Leśniewska, J. *Afghan Migrants in Iran in Modern Times*; Studia z Polityki Publicznej: Warszawa, Poland, 2020; Volume 28, pp. 9–30.
23. Hosseini, A.; Finn, B.M.; Sajjadi, S.A.; Mosavei, T. Urban Disparities and Quality of Life Among Afghan Refugees Living in Informal Settlements in Mashhad, Iran. *Appl. Res. Qual. Life* **2023**, *18*, 1073–1097. [CrossRef]
24. Czajkowski, M.; Zagórska, K.; Hanley, N. Social norm nudging and preferences for household recycling. *Resour. Energy Econ.* **2019**, *58*, 101110. [CrossRef]
25. John, P.; Blume, T. How best to nudge taxpayers? The impact of message simplification and descriptive social norms on payment rates in a central London local authority. *J. Behav. Public Adm.* **2018**, *1*. [CrossRef]
26. Massar, S.A.A.; Pu, Z.; Chen, C.; Chee, M.W.L. Losses Motivate Cognitive Effort More Than Gains in Effort-Based Decision Making and Performance. *Front. Hum. Neurosci.* **2020**, *14*, 287. [CrossRef]
27. Kazemian, A.; Hoseinzadeh, M.; Banihashem Rad, S.A.; Jouya, A.; Tahani, B. Nudging oral habits; application of behavioral economics in oral health promotion: A critical review. *Front. Public Health* **2023**, *11*, 1243246. [CrossRef] [PubMed]
28. Last, B.S.; Buttenheim, A.M.; Timon, C.E.; Mitra, N.; Beidas, R.S. Systematic review of clinician-directed nudges in healthcare contexts. *BMJ Open* **2021**, *11*, e048801. [CrossRef] [PubMed]
29. Wei, C.T.; Lo, K.Y.; Lin, Y.C.; Hu, C.Y.; Chen, F.L.; Huang, H.L. Effects of health-promoting school strategy on dental plaque control and preventive behaviors in schoolchildren in high-caries, rural areas of Taiwan: A quasi-experimental design. *BMC Oral Health* **2021**, *21*, 573. [CrossRef] [PubMed]
30. D'Cruz, A.M.; Aradhya, S. Impact of oral health education on oral hygiene knowledge, practices, plaque control and gingival health of 13-to 15-year-old school children in Bangalore city. *Int. J. Dent. Hyg.* **2013**, *11*, 126–133. [CrossRef] [PubMed]
31. Quirk, T.J.; Quirk, M.H.; Horton, H.F. Random Number Generator. In *Excel 2019 for Biological and Life Sciences Statistics*; Springer: Cham, Switzerland, 2020; pp. 21–36.
32. Nascimento, L.A.d.; Rodrigues, A.P.; Joventino, E.S.; Vieira, N.F.C.; Pinheiro, P.N.d.C.; Ximenes, L.B. *Validation of Educational Video to Promote Self-Efficacy in Preventing Childhood Diarrhea*; Health (Irvine): Orange, CA, USA, 2015.
33. Silveira de Castro, M.; Pilger, D.; Danni Fuchs, F.; Cardoso Ferreira, M.B. Development and validity of a method for the evaluation of printed education material. *Pharm. Pract.* **2007**, *5*, 89–94. [CrossRef] [PubMed]
34. World Health Organization. *Oral Health Surveys: Basic Methods*; World Health Organization: Geneva, Switzerland, 2013.
35. Silness, J.; Loe, H. Periodontal disease in pregnancy II. Correlation between oral hygiene and periodontal condition. *Acta Odontol. Scand.* **1964**, *22*, 121–135. [CrossRef] [PubMed]
36. Janakiram, C.; Varghese, N.; Ramanarayanan Venkitachalam, J.J.; Vineetha, K. Comparison of modified Bass, Fones and normal tooth brushing technique for the efficacy of plaque control in young adults-A randomized clinical trial. *J. Clin. Exp. Dent.* **2020**, *12*, 123. [CrossRef] [PubMed]
37. Sniehotta, F.F.; Araujo Soares, V.; Dombrowski, S. Randomized controlled trial of a one-minute intervention changing oral self-care behavior. *J. Dent. Res.* **2007**, *86*, 641–645. [CrossRef] [PubMed]
38. Ghasemi, A.; Zahediasl, S. Normality tests for statistical analysis: A guide for non-statisticians. *Int. J. Endocrinol. Metab.* **2012**, *10*, 486. [CrossRef]
39. Pallant, J. *SPSS Survival Manual: A Step by Step Guide to Data Analysis Using IBM SPSS*; McGraw-hill Education: UK, London, 2020.
40. Fagerland, M.W. t-tests, non-parametric tests, and large studies—A paradox of statistical practice? *BMC Med. Res. Methodol.* **2012**, *12*, 78. [CrossRef]
41. Kumar, S.R.; Narayanan, M.A.; Jayanthi, D. Comparison of oral hygiene status before and after health education among 12–18-year-old patients. *J. Indian Assoc. Public Health Dent.* **2016**, *14*, 121–125. [CrossRef]
42. Alm, A. On Dental carries and carries related factor in children. *Swed. Dent. J. Supple.* **2008**, *195*, 7–63.
43. Ingle, N.A.; Reddy, V.C.; Chaly, P.E.; Priyadarshni, V.I. Effect of short oral health education intervention on oral hygiene of 8-10 years old school children, Maduravoyal, Chennai. *J. Indian Assoc. Public Health Dent.* **2011**, *9* (Suppl. S3), S321–S327.
44. Hallsworth, M.; Snijders, V.; Burd, H.; Prestt, J.; Judah, G.; Huf, S.; Halpern, D. *Applying Behavioral Insights: Simple Ways to Improve Health Outcomes*; World Innovation Summit for Health: Doha, Qatar, 2016; pp. 29–30.
45. Ariely, D.; Jones, S. *Predictably Irrational*; HarperCollins: New York, NY, USA, 2008.
46. Tunstall, S.L.; Beymer, P.N. Learning to Think Slower: Review of Thinking, Fast and Slow by Daniel Kahneman (2011). *Numeracy* **2017**, *10*, 16. [CrossRef]

47. Yechiam, E.; Hochman, G. Loss attention in a dual-task setting. *Psychol. Sci.* **2014**, *25*, 494–502. [CrossRef] [PubMed]
48. Harbers, M.C.; Beulens, J.W.; Rutters, F.; De Boer, F.; Gillebaart, M.; Sluijs, I.; Van Der Schouw, Y.T. The effects of nudges on purchases, food choice, and energy intake or content of purchases in real-life food purchasing environments: A systematic review and evidence synthesis. *Nutr. J.* **2020**, *19*, 103. [CrossRef] [PubMed]
49. Mertens, S.; Herberz, M.; Hahnel, U.J.; Brosch, T. The effectiveness of nudging: A meta-analysis of choice architecture interventions across behavioral domains. *Proc. Natl. Acad. Sci. USA* **2022**, *119*, e2107346118. [CrossRef]
50. Arno, A.; Thomas, S. The efficacy of nudge theory strategies in influencing adult dietary behaviour: A systematic review and meta-analysis. *BMC Public Health* **2016**, *16*, 676. [CrossRef]
51. Ruggeri, K.; Folke, T.; Benzerga, A.; Verra, S.; Büttner, C.; Steinbeck, V.; Yee, S.; Chaiyachati, K. Nudging New York: Adaptive models and the limits of behavioral interventions to reduce no-shows and health inequalities. *BMC Health Serv. Res.* **2020**, *20*, 363. [CrossRef]
52. Eze, P.; Lawani, L.O.; Acharya, Y. Short message service (SMS) reminders for childhood immunisation in low-income and middle-income countries: A systematic review and meta-analysis. *BMJ Glob. Health* **2021**, *6*, e005035. [CrossRef]
53. Shahapur, R.; Shahapur, P. *Evaluation of Oral Health Education Intervention on Oral Hygiene Status among High School Students*; BLDE (Deemed to be University): Bijapur, India, 2013.
54. Zarabadipour, M.; Makhlooghi Sari, M.; Moghadam, A.; Kazemi, B.; Mirzadeh, M. Effects of Educational Intervention on Dental Plaque Index in 9-Year-Old Children. *Int. J. Dent.* **2022**, *2022*, 7339243. [CrossRef] [PubMed]
55. Van Palenstein Helderman, W.; Munck, L.; Mushendwa, S.; Van't Hof, M.; Mrema, F. Effect evaluation of an oral health education programme in primary schools in Tanzania. *Community Dent. Oral Epidemiol.* **1997**, *25*, 296–300. [CrossRef] [PubMed]
56. Sharma, G.; Vashishth, S. Effectiveness of dental health education program in improving the oral health status of 6–13 year old government residential school children of Mysore District. *Glob. J. Res. Anal.* **2018**, *6*, 6–8.
57. Ivanovic, M.; Lekic, P. Transient effect of a short-term educational programme without prophylaxis on control of plaque and gingival inflammation in school children. *J. Clin. Periodontol.* **1996**, *23*, 750–757. [CrossRef] [PubMed]
58. Evans, R.I.; Rozelle, R.M.; Lasater, T.M.; Dembroski, T.M.; Allen, B.P. Fear arousal, persuasion, and actual versus implied behavioral change: New perspective utilizing a real-life dental hygiene program. *J. Personal. Soc. Psychol.* **1970**, *16*, 220. [CrossRef] [PubMed]
59. Soltani, M.R.; Sayadizadeh, M.; Estabragh, S.R.; Ghannadan, K.; Malek-Mohammadi, M. Dental caries status and its related factors in Iran: A meta-analysis. *J. Dent.* **2020**, *21*, 158.
60. Banihashem-Rad, S.A.; Movahed, T.; Partovi, S.; Sharifi, M.; Banihashem-Rad, S.A.A. Prevalence of dental caries experience among 8 to 11-year-old students in primary schools of Mashhad. *J. Mashhad Med. Counc.* **2015**, *19*, 11–14.
61. Drugan, C.S.; Downer, M.C. Dental filling as an indicator of socio-economic status. *J. Public Health* **2005**, *27*, 397–398. [CrossRef]
62. Rüegg, R.; Abel, T. Challenging the association between health literacy and health: The role of conversion factors. *Health Promot. Int.* **2022**, *37*, daab054. [CrossRef]
63. Aljafari, A.; Gallagher, J.E.; Hosey, M.T. Can oral health education be delivered to high-caries-risk children and their parents using a computer game?—A randomised controlled trial. *Int. J. Paediatr. Dent.* **2017**, *27*, 476–485. [CrossRef]
64. Lees, A.; Rock, W. A comparison between written, verbal, and videotape oral hygiene instruction for patients with fixed appliances. *J. Orthod.* **2000**, *27*, 323–328. [CrossRef] [PubMed]

Supplementary Materials for

"Evaluating the Effectiveness of the Nudge Theory in improving the Oral Self-care of Schoolchildren with Refugee and Immigrant Backgrounds in Mashhad, Iran"

Figure S1. Effect of social norm (MSN) group reminder

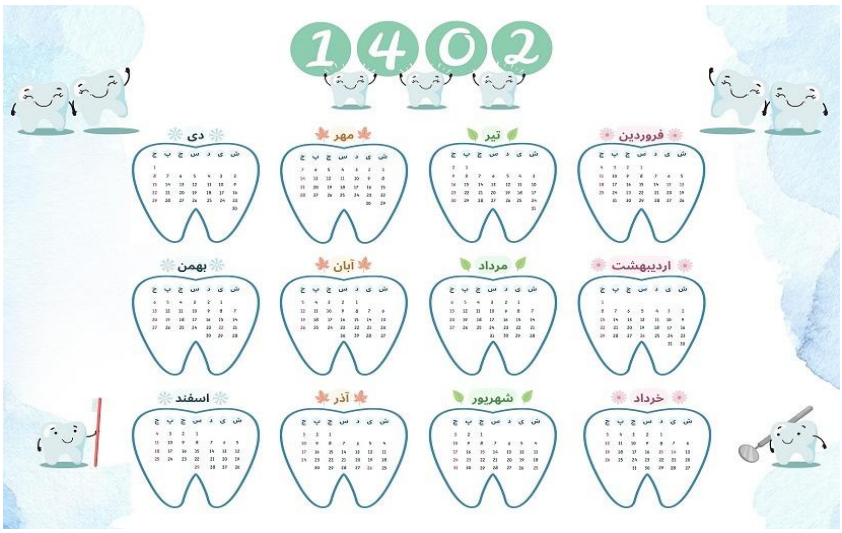


Figure S2. Fear of negative outcome (MFNO) group reminder

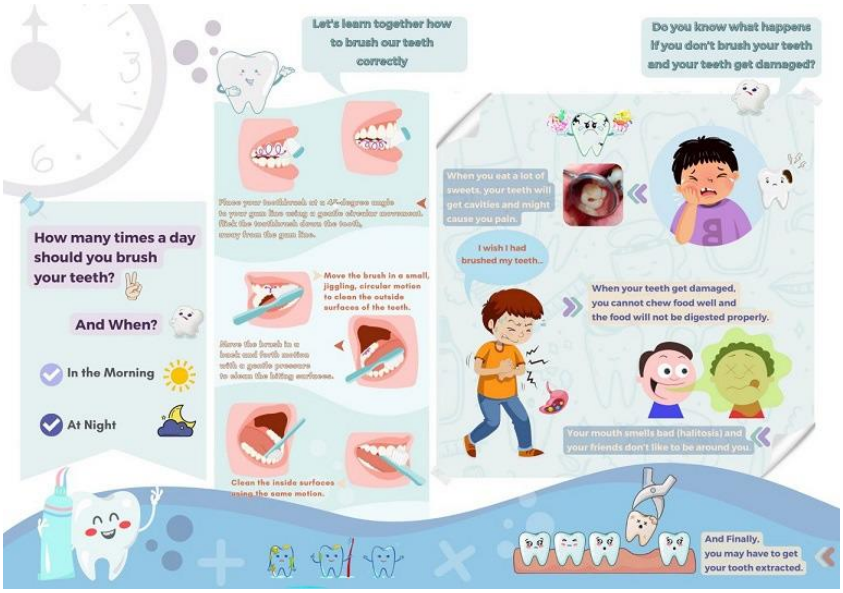


Figure S3. Leaflet for the control (C) group that includes only oral health instruction

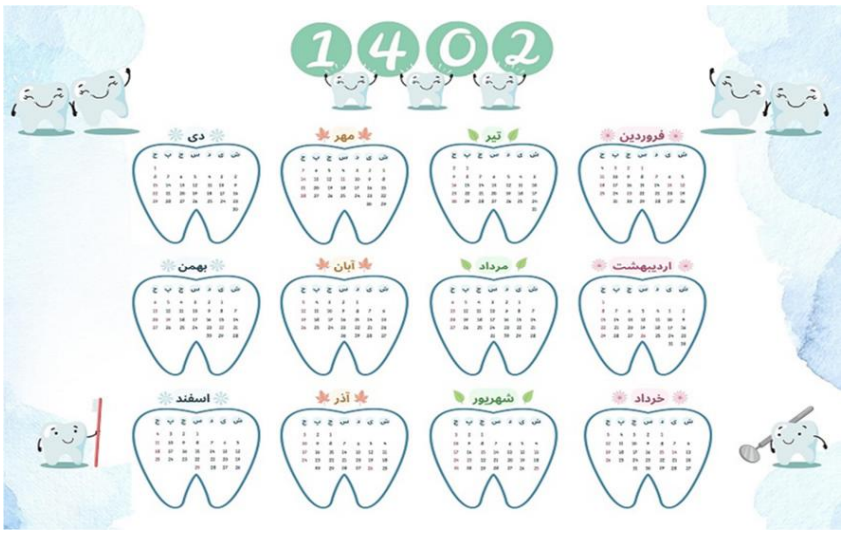


Table S1. Content Validity of the questionnaires

Questionnaire 1: *MSN*					
Likert-scale questions/ Items	Number of Experts in Agreement	I-CVI(R)	PC	K*	Interpretation
1	3	0.9	0.0195	0.8980	Excellent
2	4	1	0.0009	1	Excellent
3	2	0.8	0.1757	0.7573	Excellent
S-CVI(R)/Ave	0.9				
Questionnaire 2: *MFNO*					
1	2	0.9	0.0195	0.8980	Excellent
2	4	1	0.0009	1	Excellent
3	4	1	0.0009	1	Excellent
S-CVI(R)/Ave	0.9666				

MSN: ***Messages based on "Social Norms"*****, MFNO:** ***Messages based on "Fear of Negative Outcome"***
I-CVI (R): Content validity index for individual items (relevance item level)
S-CVI (R)/Ave: Scale-Content Validity Index/Average of I-CVIs (relevance level)
PC: probability of chance agreement
****K: Kappa coefficient***

Table S2. Estimated Marginal Means of "Plaque Index" in school groups

			95% Confidence Interval	
Group	Mean	Std. Error	Lower Bound	Upper Bound
MSN	1.58	.071	1.44	1.72
MFNO	1.75	.070	1.61	1.88
C	1.82	.074	1.68	1.97

MSN: *Messages based on "Social Norms"*, MFNO: *Messages based on "Fear of Negative Outcome"*, C: *Control*

Table S3. Estimated Marginal Means of "Plaque Index" in Time

			95% Confidence Interval	
Time	Mean	Std. Error	Lower Bound	Upper Bound
T1	1.96	.043	1.87	2.04
T2	1.58	.047	1.49	1.68
T3	1.55	.047	1.46	1.65
T4	1.77	.046	1.68	1.86

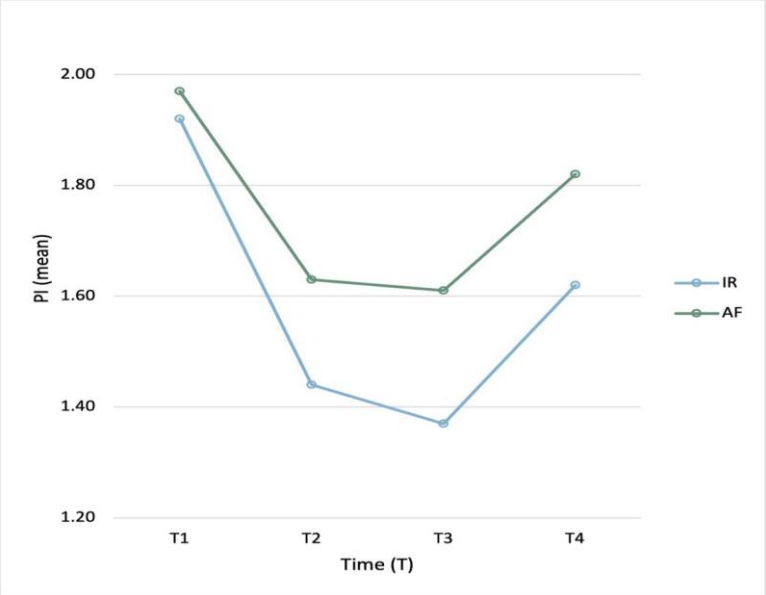
T1: Baseline, T2: Two weeks, T3: Two months, T4: Six months

Table S4. Nationality and PI

Time	Nationality	PI	N
T1	**IR**	1.92 (0.66)	72
	AF	1.97 (0.72)	199
T2	**IR**	1.44 (0.87)	72
	AF	1.63 (0.73)	199
T3	**IR**	1.37 (0.84)	72
	AF	1.61 (0.76)	199
T4	**IR**	1.62 (0.74)	72
	AF	1.82 (0.76)	199

IR: *Iranians*, AF: *Afghans*, PI*: Plaque Index,* N: *Number*, *T1: Baseline, T2: Two weeks, T3: Two months, T4: Six months*

Figure S4. Nationality and PI changes



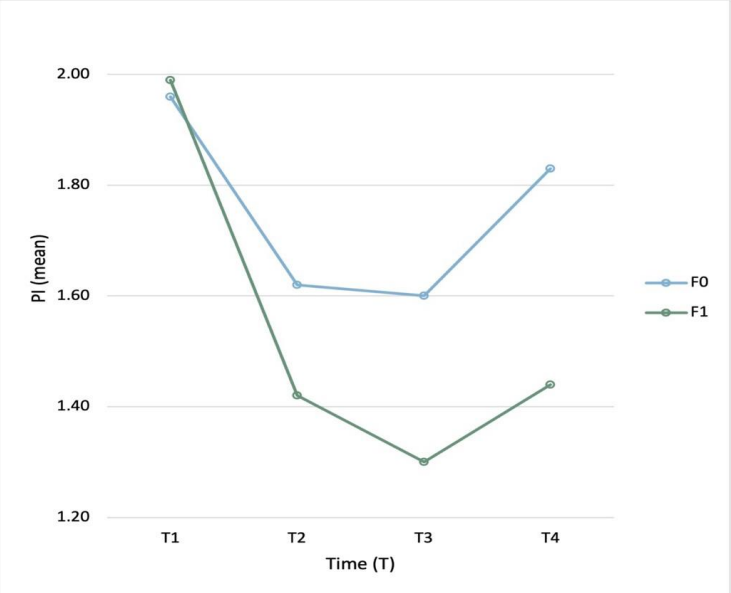
Plaque index means at different time points based on "Nationality"
Horizontal axis shows "*Time (follow-ups)": T**1**: Baseline, T**2**: Two weeks, T**3**: Two months and T**4**: Six months*
Longitudinal axis shows *"PI means"*
IR: Iranians, AF: Afghans

Table S5. Dental filling and PI

Time	F	PI	N
T1	**0**	1.96 (0.69)	227
	1	1.99 (0.76)	44
T2	**0**	1.61 (0.76)	227
	1	1.41 (0.83)	44
T3	**0**	1.60 (0.78)	227
	1	1.30 (0.81)	44
T4	**0**	1.83 (0.76)	227
	1	1.44 (0.67)	44

F: *Dental Filling*, PI: *Plaque Index,* N: *Number*, *T1: Baseline, T2: Two weeks, T3: Two months, T4: Six months*

Figure S5. Dental filling and PI changes



Plaque index means at different time points based on "Dental Filling"
Horizontal axis shows "*Time (follow-ups)": T**1**: Baseline, T**2**: Two weeks and T**3**: Two months*
Longitudinal axis shows *"PI means"*
F: dental filling, F0: without fillings, F1: with fillings

Table S6. dmft/DMFT comparison in school groups

Group	N	dt	Mt	Ft	dmft	Median	IQR	P-value
MSN	102	3.92 (1.97)	0.19 (0.46)	0.16 (0.44)	4.26 (2.03)	5	1	
MFNO	107	3.64 (2.01)	0.20 (0.52)	1.15 (0.55)	3.98 (2.09)	4	2	0.22
C	100	3.96 (2.01)	0.33 (0.53)	0.19 (0.53)	4.48 (2.18)	5	3	
Total	309	3.83 (2.00)	0.24 (0.61)	0.17 (0.51)	4.24 (2.10)			

Group	N	Dt	Mt	Ft	DMFT	Median	IQR	P-value
MSN	102	1.14 (0.95)	0.10 (0.33)	1.07 (0.25)	1.30 (1.07)	1	2	
MFNO	107	1.78 (1.15)	0.12 (0.36)	0.09 (0.29)	1.99 (1.24)	2	2	<0.01 *
C	100	1.62 (1.20)	0.11 (0.31)	0.06 (0.24)	1.79 (1.31)	2	2	
Total	309	1.51 (1.14)	0.11 (0.33)	0.07 (0.26)	1.70 (1.24)			

MSN: *Messages based on "Social Norms"*, MFNO: *Messages based on "Fear of Negative Outcome"*, C: *Control*, DMFT: *caries experience in the permanent dentition,* dmft: *caries experience in the primary dentition,* SD*: Standard deviation,* DT – *decayed teeth in the permanent dentition,* MT – *missing teeth in the permanent dentition,* FT – *filled teeth in the permanent dentition*, dt – *decayed teeth in the primary dentition*, mt – *missing teeth in the primary dentition,* ft – *filled teeth in the primary dentition,* IQR*: Interquartile range*

(P-value: Statistically significant), #Data presented as mean (SD) unless otherwise specified.*

5. Discussion

5.1 Summary of main findings

Publication 1: This study was planned to review the existing evidence on the global prevalence of oral health problems among refugees, including 26 studies. The prevalence and severity of oral health were relatively higher among refugee populations than in native-born populations of host countries. The incidence of dental caries among refugee populations is a major public health concern, as highlighted in various studies. The findings showed a wide range of caries prevalence, from 4.6% to 98.7% and gingivitis prevalence from 5.7% to 100%, indicating heterogeneity in their oral health. Moreover, 17% to 72% of refugees had never been to a dentist, showing a very low level of accessibility to dental care facilities. Many refugees resorted to tooth extraction due to the high costs of dental care and lack of oral screening in host countries, leading to undetected oral health problems that require more invasive treatments. They often faced challenges such as language, economic, cultural, and social barriers, that hindered their access to dental services. These barriers have contributed to a general neglect of oral health, as refugees prioritize resettlement issues over dental care. Dietary changes, especially increased sugar consumption, upon arrival in host countries, further deteriorated their oral health. Additionally, geographical variations and the country of origin influenced caries prevalence, with refugees from the Middle East exhibiting higher rates of decayed teeth compared to those from Africa. The impact of oral health on the overall well-being of refugees was also emphasized, with dental disorders affecting their social, physical, and mental health. The lack of information regarding pre-arrival oral health conditions

complicated the assessment of their current oral health status and progression.

Publication 2: This research was designed to evaluate the evidence concerning the worldwide prevalence of oral health issues and inequalities among immigrants, including 32 studies. The results indicated that immigrants are generally more susceptible to oral health issues compared to the general populations in host countries, perceived as urgent problems for them. Dentin caries prevalence among immigrants ranged from 22% to 88.7% in the primary dentition, 5.6% to 90.9% in the permanent dentition and gingivitis from 5.1% to 100%. The overall mean (SD) for d3mft (primary dentition) and D3MFT (permanent teeth) were 3.63 (2.47) and 1.7 (1.2), respectively. Between 52% and 88% of immigrant children had never been to a dentist, indicating a significant lack of access to dental health services. Untreated dental caries (D3T and d3t) represented the largest portion of caries experience (D3MFT and d3mft) among immigrant children, whereas the local population had the highest percentage of caries experience due to filled teeth (FT and ft). Various factors contributed to the increased prevalence of dental caries and periodontal diseases, including family socioeconomic status (e.g., parental education and income levels), household acculturation, lack of insurance, and limited access to oral health care. Notably, younger children showed higher rates of dental caries, which could be improved with age due to improved socioeconomic conditions and increased familiarity with local health practices. Interestingly, second-generation immigrant children often had lower caries prevalence than first-generation immigrants, suggesting that acculturation may positively influence oral health outcomes over time. It was also noted that disparities in oral health were not limited only to immigrant groups but they

were widespread in many countries, reflecting broader global trends.

Publication 3: The study highlighted the potential of behavioral economics to effectively influence health-related decisions. Various successful nudge interventions with varying degrees of effectiveness have been identified in other sectors, such as nutritional choices (e.g., replacing food items, using posters/stickers/signs, financial incentives, affecting senses; sight, smell, and taste), tobacco and alcohol cessation (e.g., graphic warning labels on packages, increasing taxes), medication compliance (e.g., reminders via SMS or text messages), routine physical activity, and regular health checkups. These interventions often leveraged cognitive mechanisms that are shared across different health behaviors, suggesting that strategies effective in one area may also be applicable to oral health. For instance, smartphone reminders via text messages or emails, gamification, social nudges among family members or friends or any educational intervention may help to increase engagement and compliance with oral hygiene practices or regular dental visits. The findings also showed that the effectiveness of nudge interventions can vary depending on several factors, including the method of delivery and the characteristics of the target population.

Publication 4: This study targeted school-going children involving 309 individuals (approximately 9 years old with refugee and immigrant backgrounds) to examine the effectiveness of behavioral nudges in improving oral self-care. The mean PI (SD) pre-intervention in MSN, MFNO, and C were 1.90 (0.65), 2.0.2 (0.76), and 1.96 (0.70), respectively. The mean PI decreased significantly in all three groups at the two-week follow-up ($p < 0.01$). From two to six months follow-up, there was a significant increase in mean PI in MSN and C and an insignificant increase in MFNO. In the final follow-up (six-months

post-intervention), the mean PI in MSN, MFNO, and C were 1.70 (0.72), 1.69 (0.81), and 1.92 (0.72), respectively. These improvements diminished over six months, with significant long-term benefits observed only in the MSN and MFNO ($p < 0.01$), while C nearly returned to the pre-study level ($p = 1.00$). The overall mean (SD) dmft and DMFT were 4.24 (2.11) and 1.70 (1.24), respectively, and the caries-free prevalence was 10.40%. The mean dmft was statistically significantly higher in Afghan children than in Iranians ($p = 0.01$). According to the findings, nudge theory via visual aids (leaflets and videos) was more effective in oral self-care promotion than conventional oral health instructions (OHI). MSN demonstrated immediate reduction and greater effectiveness in the short term, whereas MFNO proved to be more enduring over time. This research suggested that combining verbal instruction with visual aids could enhance learning and foster lasting behavior changes, which is consistent with previous studies that have demonstrated the effectiveness of diverse health education interventions. In addition, Age and nationality significantly impacted caries experience, with Afghan children exhibiting higher caries rates than their Iranian counterparts. Age had a direct relationship with caries experience in permanent dentition and an inverse relationship with caries experience in primary dentition. Moreover, schoolchildren with at least one filled tooth or Iranian nationality showed a greater plaque reduction. The presence of restored teeth and Iranian citizenship could imply improved access to dental healthcare services and may reflect a relatively elevated socioeconomic status among parents.

5.2 Strengths and limitations

The strengths and limitations of each Study have been widely discussed within the Results section and the final paragraph of each publication. In the following section, a summary of the strengths and limitations to the whole PhD project will be elaborated.

In this thesis project, the first three Publications were types of literature reviews and Publication 4 was a field trial. publications 1 and 2 faced some limitations, including significant heterogeneity among the included studies regarding sampling procedures, power calculations, geographical locations, and population characterization. This variability made it difficult to compare results across studies; thus, meta-analyses were not conducted in the reviews. The findings were less generalizable to all refugee and immigrant populations, given that only studies published after 2011 were considered, as well as the limited number of publications on this topic. Additionally, human error could have resulted in information loss or biased outcomes. In publication 3, the review was restricted to studies explicitly labeled as "nudges" published after 2008. This criterion may have excluded relevant interventions that utilized behavioral nudges without using the term "nudge," potentially overlooking insights from earlier research. Moreover, a dearth of research targeting nudging in oral health identified a gap in the literature. In Publication 4, all participants were male schoolchildren, which created a gender bias and restricted the exploration of sex differences in oral hygiene behaviors. Another limitation was the restricted representativeness of the selected public schools, which mainly catered to immigrant and refugee children in Mashhad, thereby potentially constraining the applicability of our conclusions to a broader population. Furthermore, uncontrolled variables (e.g., individuals'

characteristic and socioeconomic status) could have caused heterogeneity. Overall, in this thesis, all the limitations mentioned in the four Studies could affect the generalizability of the results and insights it offers.

Despite the limitations, a key strength of this PhD thesis was its comprehensive approach in the three reviews (Publications 1, 2 and 3), using a systematic literature search across multiple databases. This thorough methodology which contained a wide range of studies, ensured robust findings and provided a solid foundation for conclusions. Three studies were pioneering in the systematic global evaluations of dental caries and periodontal disease in marginalized populations (Publications 1 and 2), and the utilization of the nudge theory to promote oral self-care among children with immigrant and refugee backgrounds (Publication 4), which should therefore be listed as a strength point of this thesis work. Inequalities in immigrants and refugees' oral health care are often masked by population-level data since they constitute a small proportion of the populations in host countries; thus, as part of this thesis, the oral health of these populations in their respective countries as well as their special needs in the field of oral health were successfully addressed (Publications 1 and 2). The other strengths of this work lie in its innovative application of Nudge theory, its robust methodological framework, and its pioneering insights into the oral health of immigrant and refugee children in Iran (Publication 4). Moreover, by synthesizing existing research and identifying successful nudge interventions, this thesis has shed light on future investigations and practical applications in oral health promotion (Publication 3). Overall, these strengths highlight this thesis's potential to draw attentions to the vulnerable populations' problems pertaining oral health and inform strategies for improving oral hygiene practices among them.

5.3 Conclusions

- This PhD thesis represents the first systematic evaluation of global dental caries and periodontal disease prevalence among immigrant and refugee populations. Furthermore, this is the first research which has applied the Nudge theory to promote oral self-care among schoolchildren from these backgrounds. These findings provide new insights into the oral health disparities experienced by marginalized groups and introduce innovative strategies for addressing these inequalities.
- The prevalence and severity of oral health problems (e.g., dental caries and periodontal disease) among refugee and Immigrant communities are relatively high compared to the general population of the host countries, regardless of age, sex, or nationality.
- Interventions and policies must be designed to mitigate oral health inequalities among marginalized populations. In addition, host countries must adopt strategies to enhance their access to oral health care.
- Nudge theory via visual aids along with oral health education is more effective than the conventional oral health education method in oral hygiene improvement.
- Nudge theory presents a potentially effective approach to enhancing oral health behaviors; however, its long-term efficacy requires further investigation among different populations.

6. References

Adekunle T, Mbonu CB, Ogunjimi A, Alade A, Awotoye W, Kikuni M, et al (2023). "Baseline assessment of oral health needs among underserved populations in the United States". *Journal of Global Oral Health, 6:38-42*. DOI: 10.25259/JGOH_3_2023.

Almeida C, Azevedo J, Fogel A, Lopes E, Vale C, Padrao P (2024). "Effectiveness of nudge interventions to promote fruit and vegetables' selection, purchase, or consumption: A systematic review". *Food Quality and Preference*, 105122. DOI: 10.1016/j.foodqual.2024.105122.

Angellotti E, Wong JB, Pierce A, Hescott B, Pittas AG (2019). "Combining wireless technology and behavioral economics to engage patients (WiBEEP) with cardiometabolic disease: a pilot study". *Pilot and Feasibility Studies*, 5:1–6. DOI: 10.1186/s40814-019-0395-8.

Arno A, Thomas S (2016). "The efficacy of nudge theory strategies in influencing adult dietary behaviour: a systematic review and meta-analysis". *BMC Public Health*,16:1–11. DOI: 10.1186/s12889-016-3272-x.

Asfari E, Rodriguez A, Dakessian A, Yuan S (2024). "Exploring refugees' experience of accessing dental health services in host countries: a scoping review". *Frontiers in Oral Health*,12;5:1328862. DOI: 10.3389/froh.2024.1328862. PMID: 38532903; PMCID: PMC10963490.

Bala R, Sargaiyan V, Rathi SA, Mankar SS, Jaiswal AK, Mankar SA (2023). "Mobile dental clinic for oral health services to underserved rural Indian communities". *Bioinformation*, 19(13):1383-1387. DOI: 10.6026/973206300191383. PMID: 38415028; PMCID: PMC10895535.

Blackmore R, Boyle JA, Fazel M, Ranasinha S, Gray KM, Fitzgerald G (2020). "The prevalence of mental illness in refugees and asylum seekers: a systematic review and and meta-analysis". *PLoS Medicine*, 17(9):e1003337. DOI: 10.1371/journal.pmed.1003337.

Cherian JM, Kurian N, Varghese KG, Thomas HA (2023). "World Health Organization's global oral health status report: Paediatric dentistry in the spotlight". *Journal of Paediatrics and Child Health*, 59(7):925-926. DOI: 10.1111/jpc.16427. PMID: 37199250.

Chew KS, Ooi SK, Abdul Rahim NF, Wong SS, Kandasamy V, Teo SS (2023). "Perception of nudge interventions to mitigate medication errors risk in healthcare service delivery". *BMC Health Services Research*, 23(1):1310. DOI: 10.1186/s12913-023-10247-7. PMID: 38012617; PMCID: PMC10683206.

Davidson N, Skull S, Calache H, Chesters D, Chalmers J (2007). "Equitable access to dental care for an at-risk group: a review of services for Australian refugees". *Australian and New*

Zealand Journal of Public Health, 31(1):73-80. DOI: 10.1111/j.1753-6405.2007.00014.x. PMID: 17333613.

Esimekara J, Lee H (2022). "Oral Health Literacy in Young Migrant/Refugee Mothers from Developing Countries". *European Journal of Public Health*,1;32(Supplement_3):ckac129-259. DOI: 10.1093/eurpub/ckac129.259.

Fisher-Owens SA, Barker JC, Adams S, Chung LH, Gansky SA, Hyde S, Weintraub JA (2008). "Giving Policy Some Teeth: Routes to Reducing Disparities in Oral Health". *Health Affairs (Millwood)*, 27(2):404-12. DOI: 10.1377/hlthaff.27.2.404. PMID: 18332496.

Forberger S, Reisch L, Kampfmann T, Zeeb H (2019). "Nudging to move: a scoping review of the use of choice architecture interventions to promote physical activity in the general population". *International Journal of Behavioral Nutrition and Physical Activity*, 16(1):77. DOI: 10.1186/s12966-019-0844-z. PMID: 31481090; PMCID: PMC6724306.

Fukuma S, Sasaki S, Taguri M, Goto R, Misumi T, Saigusa Y, Tsugawa Y (2021). "Effect of Nudge-Based Intervention on Adherence to Physician Visit Recommendations and Early Health Outcomes among Individuals Identified with Chronic Kidney Disease in Screens". *American Society of Nephrology*, 33(1):175-185. DOI: 10.1681/ASN.2021050664. PMID: 34903568; PMCID: PMC8763194.

Geltman PL, Hunter Adams J, Penrose KL, Cochran J, Rybin D, Doros G, Henshaw M, Paasche-Orlow M (2014). "Health literacy, acculturation, and the use of preventive oral health care by Somali refugees living in Massachusetts". *Journal of Immigrant and Minority Health*;16(4):622-30. DOI: 10.1007/s10903-013-9846-0. PMID: 23748902; PMCID: PMC3815479.

Gibbs L, Waters E, Christian B, Gold L, Young D, de Silva A, Calache H, Gussy M, Watt R, Riggs E, Tadic M, Hall M, Gondal I, Pradel V, Moore L (2015). "Teeth Tales: a community-based child oral health promotion trial with migrant families in Australia". *BMJ Open*, 5(6):e007321. DOI: 10.1136/bmjopen-2014-007321. PMID: 26068509; PMCID: PMC4466605.

Glasgow RE, Knoepke CE, Magid D, Grunwald GK, Glorioso TJ, Waughtal J, Marrs JC, Bull S, Ho PM (2021). "The NUDGE trial pragmatic trial to enhance cardiovascular medication adherence: study protocol for a randomized controlled trial". *Trials*, 22(1):528. DOI: 10.1186/s13063-021-05453-9. PMID: 34380527; PMCID: PMC8356469.

Glick M, Williams DM, Kleinman DV, Vujicic M, Watt RG, Weyant RJ (2016). "A new definition for oral health developed by the FDI World Dental Federation opens the door to a universal definition of oral health". *British dental journal*,16;221(12):792-3. DOI: 10.1111/idj.12294. PMID: 27885673; PMCID: PMC9376665.

Gondivkar SM, Gadbail AR, Gondivkar RS, Sarode SC, Sarode GS, Patil S, et al (2019). "Nutrition and oral health". *Disease a Month*, 65:147–54. DOI: 10.1016/j.disamonth.2018.09.009.

Grant S, Solicitors HG (2005). “International Migration and Human Rights”. *paper prepared for the Policy Analysis and Research Programme of the Global Commission on International Migration (GCIM).*

Hansen PG, Jespersen AM (2013). “Nudge and the manipulation of choice: a framework for the responsible use of the nudge approach to behaviour change in public policy”. *European Journal of Risk Regulation*, 4:3–28. DOI: 10.1017/S1867299X00002762.

Hofmann W, Friese M, Wiers RW (2008). “Impulsive versus reflective influences on health behavior: a theoretical framework and empirical review”. *Health Psychology Review*, 2:111–37. DOI: 10.1080/17437190802617668.

Hollands GJ, Shemilt I, Marteau TM, Jebb SA, Kelly MP, Nakamura R, et al (2013). “Altering micro environments to change population health behaviour: towards an evidence base for choice architecture interventions”. *BMC Public Health*,13:1–6. DOI: 10.1186/1471-2458-13-1218.

Hosseinpoor AR, Itani L, Petersen PE (2012). “Socio-economic inequality in oral healthcare coverage: results from the World Health Survey”. *Journal of Dental Research*, 91(3):275-81. DOI: 10.1177/0022034511432341. PMID: 22205634.

Karnaki P, Katsas K, Diamantis DV, Riza E, Rosen MS, Antoniadou M, Gil-Salmerón A, Grabovac I, Linou A (2022). “Dental health, caries perception and sense of discrimination among migrants and Refugees in Europe: results from the Mig-healthcare project”. *Applied Sciences*, 12(18):9294. DOI: 10.3390/app12189294.

Kateeb E, Zaheer K, Fisher J, Ghani A.A.E, Williams D, Dartevelle S (2020). “Promoting Oral Health for Refugees: An Advocacy Guide”. *FDI World Dental Federation; Geneva, Switzerland, 2020*.

Keboa MT, Hiles N, Macdonald ME (2016). “The oral health of refugees and asylum seekers: a scoping review”. *Global Health*, 12(1):59. DOI: 10.1186/s12992-016-0200-x. PMID: 27717391; PMCID: PMC5055656.

Keboa MT, Hovey R, Nicolau B, Esfandiari S, Carnevale F, Macdonald ME (2019). “Oral healthcare experiences of humanitarian migrants in Montreal, Canada”. *Canadian Journal of Public Health*, 110(4):453-461. DOI: 10.17269/s41997-019-00193-5. PMID: 30850954; PMCID: PMC6964583.

Kullgren JT, Hafez D, Fedewa A, Heisler M (2017). “A scoping review of behavioral economic interventions for prevention and treatment of type 2 diabetes mellitus”. *Current Diabetes Reports*, 17:1–15. DOI: 10.1007/s11892-017-0894-z.

Lauritano D, Moreo G, Carinci F, Campanella V, Della Vella F, & Petruzzi M (2021). “Oral Health Status among Migrants from Middle- and Low-Income Countries to Europe: A Systematic Review”. *International journal of environmental research and public health.* DOI: 10.3390/ijerph182212203. PMID: 34831957; PMCID: PMC8624247.

McAuliffe M, Khadria B (2021). International Organization for Migration (IOM). *World Migration Report, 2022.*

Muller R, Bilich L, Jones M (2024). "Impact of an Oral Health Education Program on the Oral Health Literacy of Refugees". *Journal of Immigrant and Minority Health,* 26(4):699-710. DOI: 10.1007/s10903-024-01594-6. PMID: 38589753; PMCID: PMC11289270.

Nazaret A, Sapiro G (2023). "A large-scale observational study of the causal effects of a behavioral health nudge". *Science Advances*, 9(38):eadi1752. DOI: 10.1126/sciadv.adi1752. PMID: 37738345; PMCID: PMC10516489.

Nurchis MC, Di Pumpo M, Perilli A, Greco G, Damiani G (2023). "Nudging interventions on alcohol and tobacco consumption in adults: a scoping review of the literature". *International journal of environmental research and public health*, 20(3):1675. DOI: 10.3390/ijerph20031675. PMID: 36767077; PMCID: PMC9913966.

Paisi M, Baines R, Burns L, Plessas A, Radford P, Shawe J, Witton R (2020). "Barriers and facilitators to dental care access among asylum seekers and refugees in highly developed countries: a systematic review". *BMC Oral Health*, 20(1):337. DOI: 10.1186/s12903-020-01321-1. PMID: 33238954; PMCID: PMC7687682.

Perruchoud R, Redpath-Cross J. "Glossary on migration. Geneva". *International Organization for Migration* (2004).

Ponce-Gonzalez I, Cheadle A, Aisenberg G, Cantrell LF (2019). "Improving oral health in migrant and underserved populations: evaluation of an interactive, community-based oral health education program in Washington state". *BMC Oral Health*,19(1):30. DOI: 10.1186/s12903-019-0723-7. PMID: 30760255; PMCID: PMC6375135.

Ponce-Gonzalez I, Cheadle A, Parchman M (2020). "Impact of Oral Health Education for Migrants and Refugees by Community Health Workers: What do Participants Retain?". *Research Square.* DOI: 10.21203/rs.3.rs-49932/v1.

Reddy A, Huseman TL, Canamucio A, Marcus SC, Asch DA, Volpp K, et al (2017). "Patient and partner feedback reports to improve statin medication adherence: a randomized control trial". *Journal of General Internal Medicine*, 32:256–61. DOI: 10.1007/s11606-016-3858-0.

Ruggeri K, Folke T, Benzerga A, Verra S, Büttner C, Steinbeck V, et al (2020). "Nudging New York: adaptive models and the limits of behavioral interventions to reduce no- shows and health inequalities". *BMC Health Services Research*, 20:363. DOI: 10.1186/ s12913-020-05097-6.

Sabbah W, Folayan MO, El Tantawi M (2019). "The Link between Oral and General Health". *International Journal of Dentistry*, 7862923. DOI: 10.1155/2019/7862923. PMID: 31275387; PMCID: PMC6560319.

Sampson R, Mitchell G (2013). "Global trends in immigration detention and alternatives to detention: Practical, political and symbolic rationales". *Journal on Migration and Human*

Security.

Sokolov AR, Chichenkova BO, Stegacheva EA, Yumashev AV (2023). "Oral Hygiene Measures as a Preventive Measure in The Field of Maintaining the General Health of the Patient". *Complementary Medicine Research*,14(1):123-6. DOI: 10.5455/jcmr.2023.14.01.23.

Sypek S, Clugston G, Phillips C (2008). "Critical health infrastructure for refugee resettlement in rural Australia: case study of four rural towns". *Australian Journal of Rural Health*, 16(6):349-54. DOI: 10.1111/j.1440-1584.2008.01015.x. PMID: 19032207.

US Department of Health and Human Services, National Institute of Dental and Craniofacial Research (U.S.). *Oral health in America: a report of the Surgeon Genera* (2000).

WHO (2018). "*Report on the health of refugees and migrants in the WHO European region: no public health without refugee and migrant health"*.

WHO (2021). *World Health Organization.* "*Saving lives, spending less: The case for investing in noncommunicable diseases"*.

WHO (2023). "WHO's global oral health status report 2022: Actions, discussion and implementation". *Oral Disease*. DOI: 10.1111/odi.14516. PMID: 36680388.

Wouters JJ, Subba TB (EDS) (2022). *The Routledge Companion to Northeast India.* Migration.

Zinah E, Al-Ibrahim HM (2021). "Oral health problems facing refugees in Europe: a scoping review". *BMC Public Health*, 21(1):1207. DOI: 10.1186/s12889-021-11272-z. PMID: 34162351; PMCID: PMC8223339.

7. Acknowledgements

I extend my deepest gratitude to my supervisors, Prof. Guglielmo Campus and Prof. Marcella Esteves-Oliveira, for the invaluable opportunity to work under their guidance throughout my PhD studies. I am also thankful to my co-referee, Prof. Gail Douglas, whose constructive feedback has enriched my research journey significantly.

Special thanks to Dr. Ali Kazemian, our research collaborator in Iran, for his substantial support during my PhD journey. I appreciate the Graduate School of Health Sciences (GHS) for providing excellent courses and resources that have been crucial in my academic development.

I am grateful to all my coworkers and co-authors whose collaboration was essential in the publication of the articles included in this thesis. Without your collective efforts, this achievement would not have been possible.

Finally, a heartfelt thank you to my family for their unwavering support since I moved to Bern to pursue my PhD studies. Your encouragement has been a cornerstone of my success.

9. Declaration of Originality

Last name, first name: Banihashem Rad, Seyed Ahmad

Matriculation number: 21-112-024

I hereby declare that this thesis represents my original work and that I have used no other sources except as noted by citations.
All data, tables, figures and text citations which have been reproduced from any other source, including the internet, have been explicitly acknowledged as such.
I am aware that in case of non-compliance, the Senate is entitled to withdraw the doctorate degree awarded to me on the basis of the present thesis, in accordance with the "Statut der Universität Bern (Universitätsstatut; UniSt)", Art. 69, of 7 June 2011.

Place, date

Bern, 23-09-2024

Signature