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Use and misuse of mixed methods in population oral health research: A scoping review

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Background: Despite the known benefits of a mixed methods approach in health research, little is known of its use in the field of population oral health. ***Objective*:** To map the extent of literature using a mixed methods approach to examine population oral health outcomes. ***Methods:*** For a comprehensive search of all the available literature published in the English language, databases including PubMed, Dentistry and Oral Sciences Source (DOSS), CINAHL, Web of Science and EMBASE (including Medline) were searched using a range of keywords from inception to October 2017. Only peer-reviewed, population-based studies of oral health outcomes conducted among non-institutionalised participants and using mixed methods were considered eligible for inclusion. ***Results:*** Only nine studies met the inclusion criteria and were included in the review. The most frequent oral health outcome investigated was caries experience. However, most studies lacked a theoretical rationale or framework for using mixed methods, or supporting the use of qualitative data. Concurrent triangulation with a convergent design was the most commonly used mixed methods typology for integrating quantitative and qualitative data. The tools used to collect quantitative and qualitative data were mostly limited to surveys and interviews. ***Conclusion:*** With growing complexity recognised in the determinants of oral disease, future studies addressing population oral health outcomes are likely to benefit from the use of mixed methods. Explicit consideration of theoretical framework and methodology will strengthen those investigations.

Key words: *population oral health, mixed methods research, mixed methodology, scoping review*

Background

Population oral health is shaped by a complex interplay of factors ranging from biological to social, behavioural and environmental determinants (Sanders, 2007; Watt and Sheiham, 1999; Watt, 2012). These factors may independently or interactively affect individuals' oral health and therefore require due attention in research. If the already significant public health burden of oral disease is to be remedied, a holistic approach towards understanding the causes of disease may offer the most value (Kassebaum *et al.*, 2017).

The value of a mixed methods approach towards understanding health is gaining recognition, and its importance has been documented across a range of health sciences discipline (O'Cathain, 2009; O'Cathain *et al.*, 2007; Tashakkori and Teddlie, 2010). Mixed methods approaches integrate quantitative and qualitative data to provide a comprehensive understanding of the phenomenon under investigation. Even though several definitions exist for mixed methods research (Greene *et al.*, 1989; Johnson *et al.*, 2007; Tashakkori and Teddlie, 2010), their underlying philosophy remains the same, which is to harness the strengths of the two paradigms most associated with quantitative and qualitative methods i.e. post-positivism (quantitative) and interpretivism (qualitative) respectively (Creswell and Plano Clark, 2007; Jick, 1979; Morgan, 2006). The triangulation of data offers greater value than research using either suite of methods alone. Mixed methods can therefore provide a broader and deeper illustration of a research question.

The quantitative and qualitative dimensions may be used in various combinations and are delineated as 'concurrent' or 'sequential' designs (Creswell and Plano Clark, 2007). In concurrent designs the quantitative and qualitative data are collected simultaneously, either as separate entities with findings triangulated ('convergent') or with one type 'embedded' in the collection of the other, e.g. open-ended questions within a survey of quantitative data. In the sequential design, the data are collected one after the other. Where quantitative follows qualitative, such as in instrument development, studies are termed 'exploratory'; the reverse sequence is 'explanatory'. A combination of concurrent and sequential designs is referred to as a multiphase or iterative mixed methods design. Each type has its merits and demerits, thus the decision to choose a particular combination is critical and depends upon the research question (Maxwell, 2010).

A key feature of mixed methods approaches in health research is that they may offer context-specific insights for identifying and developing effective interventions (Creswell and Plano Clark, 2007). This is essential where policymakers seek feasible, effective and population-based solutions. For instance, within tobacco research, mixed methods have offered insights into why differences in smoking prevalence exist by gender, age, class and neighbourhood (Daykin, 1993; Frohlich *et al.*, 2002; Graham, 1987,1994) or why people still choose to smoke despite the good quality evidence of its ill effects. Qualitative data gathered on the lived experiences of women that might

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facilitate and impede smoking behaviour, when combined with quantitative data on smoking prevalence, have assisted in identifying potential points for future public health interventions (Daykin, 1993; Graham, 1987,1994).

Despite being largely preventable, oral health problems continue to be widely prevalent and to pose challenges at the population level. Caries, periodontal disease, tooth loss and oral cancer contribute most significantly to the global burden of disease (Kassebaum *et al.*, 2017). Quantitative methods have long been used to establish determinants of disease and assess the effectiveness of interventions (Blinkhorn, 1989). Qualitative methods are playing an emerging role in addressing the complexity of causes, with their capacity for in-depth description, e.g. in giving voice to patient and practitioners' perspectives on oral health (Asimakopoulou *et al.*, 2014; Bower and Scambler, 2007; Meadows *et al.*, 2003; Scambler *et al.*, 2015). While recognising the independent use of quantitative and qualitative methods, we have less insight into whether and how researchers have integrated them into single studies to understand population-level causes for oral health outcomes. Such an approach can be critical for advancing our understanding, aiding in targeting potential interventions and generating oral health prevention strategies. For example, what are the causes of the causes for the oral health problems in the population? Which oral health outcomes have been most studied using mixed methods? What types of mixed methods are commonly used, how and why? What was the underpinning rationale for each of the studies using mixed methods? These questions call for answers in order to understand the current state of practice and to identify research and knowledge gaps. A scoping review was therefore conducted to map the extent of literature using a mixed methods approach to examine population oral health outcomes.

Methods

Scoping reviews offer a comprehensive understanding of a topic by exhibiting the complex and heterogeneous nature of evidence (Arksey and O'Malley, 2007). This feature distinguishes them from systematic reviews, for which addressing study types (often limited to randomised trials) and quality assessment are essential components. A scoping review provides the liberty of mapping the extent and breadth of literature on a topic, while maintaining rigor and transparency throughout each step of the literature search and reporting of results (Arksey and O'Malley, 2007).

Identifying the Research Question

We included caries, periodontal diseases, tooth loss and oral cancer as these are top contributors to the increasing global burden of diseases. We expanded on the search terms to express mixed methods research by including both qualitative and quantitative terminologies within the broader umbrella of mixed methods. Furthermore, we also described when, where and how mixed methods designs have been used. The type of mixed method designs commonly used (including the rationale for using them) was also summarised, along with identifying commonly used study designs and data collection techniques for both qualitative and quantitative components. Defining these parameters, and considering their implications, we maintained a wide approach in order to generate breadth of coverage on our research question.

Search methods

Databases searched included PubMed, Dentistry and Oral Sciences Source (DOSS), Cumulative Index to Nursing and Allied Health Literature (CINAHL), Web of Science and EMBASE (including MEDLINE) to identify relevant peer-reviewed literature. To maximise our scope to identify all the relevant literature, the search was conducted from inception to October 2017. Following pilot testing of a range of keywords, the final search terms were combined using Boolean operators. In addition to incorporating the diverse terminology for describing mixed methods, oral health outcomes were addressed both generally and specifically for the four outcomes: caries, periodontal disease, tooth loss, and oral cancer. The generic syntax was: (((empirical research OR "mixed method*" OR multimethod* OR "multiple method*" OR "mixed research" OR pluralist* OR "mixed study" OR triangulation OR "integrative research" OR "hybrid research" OR "hybrid study" OR "blended research" OR "blended study" OR "mixed model research" OR "mixed model study") OR ((qualitative* OR interview* OR "focus group*" OR "participant observation*" OR ethnograph*) AND (quantitative* OR survey* OR questionnaire* OR "content analysis"))) AND (dental OR "oral health" OR caries OR periodont* or "tooth loss" OR "oral cancer*")) (Table 1). Specific searches were made of the *Journal of Mixed Methods Research* and the *International Journal of Multiple Research Approaches*, and searches were also made of the reference lists and journals of included articles (following full text screening, described below). A specialist librarian assisted with the development of the search string.

Inclusion and exclusion criteria

Only peer-reviewed, population-based primary or secondary studies addressing oral health outcomes, conducted among non-institutionalised participants and using mixed methods, (i.e. quantitative and qualitative data were reported in substantive proportions) were considered eligible for inclusion. All studies published from inception to October 2017 in the English language were included. Studies without oral health outcomes and not including mixed methods were excluded. Studies conducted among participants residing in institutional settings were excluded, to assist in the findings of the review being generalisable to the larger population. We also excluded studies focussed exclusively on instrument development. These studies were categorsied as not reporting on oral health outcomes; instead their outcome was primarily the validity and reliability of the instrument itself. Finally, we excluded studies that were neither primary, nor secondary research.

Table 1. Electronic Databases Search Strategies

PubMed

(((mixed method*[tiab] OR multimethod*[tiab] OR multiple method*[tiab] OR mixed research[tiab] OR pluralist*[tiab] OR mixed study[tiab] OR triangulation[tiab] OR integrative research[tiab] OR hybrid research[tiab] OR hybrid study[tiab] OR blended research[tiab] OR blended study[tiab] OR mixed model research[tiab] OR mixed model study[tiab]) OR ((qualitative*[tiab] OR interview*[tiab] OR focus group*[tiab] OR participant observation*[tiab] OR ethnograph*[tiab]) AND (quantitative*[tiab] OR survey*[tiab] OR questionnaire*[tiab] OR content analysis[tiab]))) AND (dental[tiab] OR oral health[tiab] OR caries[tiab] OR periodont*[tiab] or tooth loss[tiab] OR oral cancer*[tiab]))

Web of Science

(((“mixed method*” OR multimethod* OR “multiple method*” OR “mixed research” OR pluralist* OR “mixed study” OR triangulation OR “integrative research” OR “hybrid research” OR “hybrid study” OR “blended research” OR “blended study” OR “mixed model research” OR “mixed model study”) OR ((qualitative* OR interview* OR “focus group*” OR “participant observation*” OR ethnograph*) AND (quantitative* OR survey* OR questionnaire* OR “content analysis”))) AND (dental OR “oral health” OR caries OR periodont* or “tooth loss” OR “oral cancer*”))

CINAHL and DOSS

(((TI “mixed method*” OR multimethod* OR “multiple method*” OR “mixed research” OR pluralist* OR “mixed study” OR triangulation OR “integrative research” OR “hybrid research” OR “hybrid study” OR “blended research” OR “blended study” OR “mixed model research” OR “mixed model study”) OR ((TI qualitative* OR interview* OR “focus group*” OR “participant observation*” OR ethnograph*) AND (TI quantitative* OR survey* OR questionnaire* OR “content analysis”)) AND TI (dental OR “oral health” OR caries OR periodont* or “tooth loss” OR “oral cancer*”)

Medline and EMBASE

(((mixed method* OR multimethod* OR multiple method* OR mixed research OR pluralist* OR mixed study OR triangulation OR integrative research OR hybrid research OR hybrid study OR blended research OR blended study OR mixed model research OR mixed model study).ti,ab OR (qualitative* OR interview* OR focus group* OR participant observation* OR ethnograph*).ti,ab AND (quantitative* OR survey* OR questionnaire* OR content analysis))).ti,ab AND (dental OR oral health OR caries OR periodont* or “tooth loss OR oral cancer*).ti,ab

Study Selection

All the identified studies were imported to Endnote X7. Duplicates were removed and titles and abstracts were screened following the eligibility criteria. Further, the full text of articles meeting the eligibility criteria was retrieved and articles were assessed (Figure 1). The entire study selection process, from identifying potential studies to the title, abstract and full text screening, was conducted by two reviewers (AG and DK) independently to maintain validity. Both reviewers had research expertise in mixed methods research and oral epidemiology. A third reviewer (AS), with expertise in mixed methods research, scoping reviews and oral epidemiology was available to assist in the final full text review and resolve any disagreements during screening.

Data extraction and synthesis

Data from included articles were charted on study characteristics (including publication details, country in which the study was conducted, study aim, study population, oral health outcomes investigated, methods of data collection and analysis), and importantly, the process and typology of mixed methods used in the integration of data. AG initially carried out the data extraction, which was then verified by DK. We classified the mixed methods designs into concurrent (convergent or embedded) or sequential (explanatory or exploratory). A narrative synthesis was undertaken to critically synthesise and evaluate the available literature to provide insight into how the mixed methods approach was utilised in the field of population oral health.

Results

A total of 12,496 studies was identified, of which the full text of 54 studies was retrieved. After the full-text review, studies were primarily excluded for not reporting any health outcome, not applying mixed methods, not being population-based or not being primary/secondary research (Figure 1). Nine primary studies (Ariza *et al.*, 2012; Chatrchaiwiwatana *et al.*, 2012; Gibbs *et al.*, 2015; Gratrix and Holloway, 1994; Mahrous *et al.*, 2016; Maupome, 1998; Ogretme *et al.*, 2016; Templeton *et al.*, 2016; Vece *et al.*, 2016) were found to fulfil the inclusion and exclusion criteria and were considered eligible (Table 2).

Caries experience was the most commonly studied oral health outcome, and was mainly assessed among young children using the dmfs index (decayed, missing, filled surfaces) (Palmer *et al.*, 1984). Other oral health outcomes (clinical and non-clinical) included tooth loss, oral health status, oral health behaviours (including tooth brushing), knowledge and use of dental services, oral health needs and patient, organisation, and system level factors influencing delivery of care for prevention and management of caries. The participants were mostly purposively sampled. For instance, in a study conducted

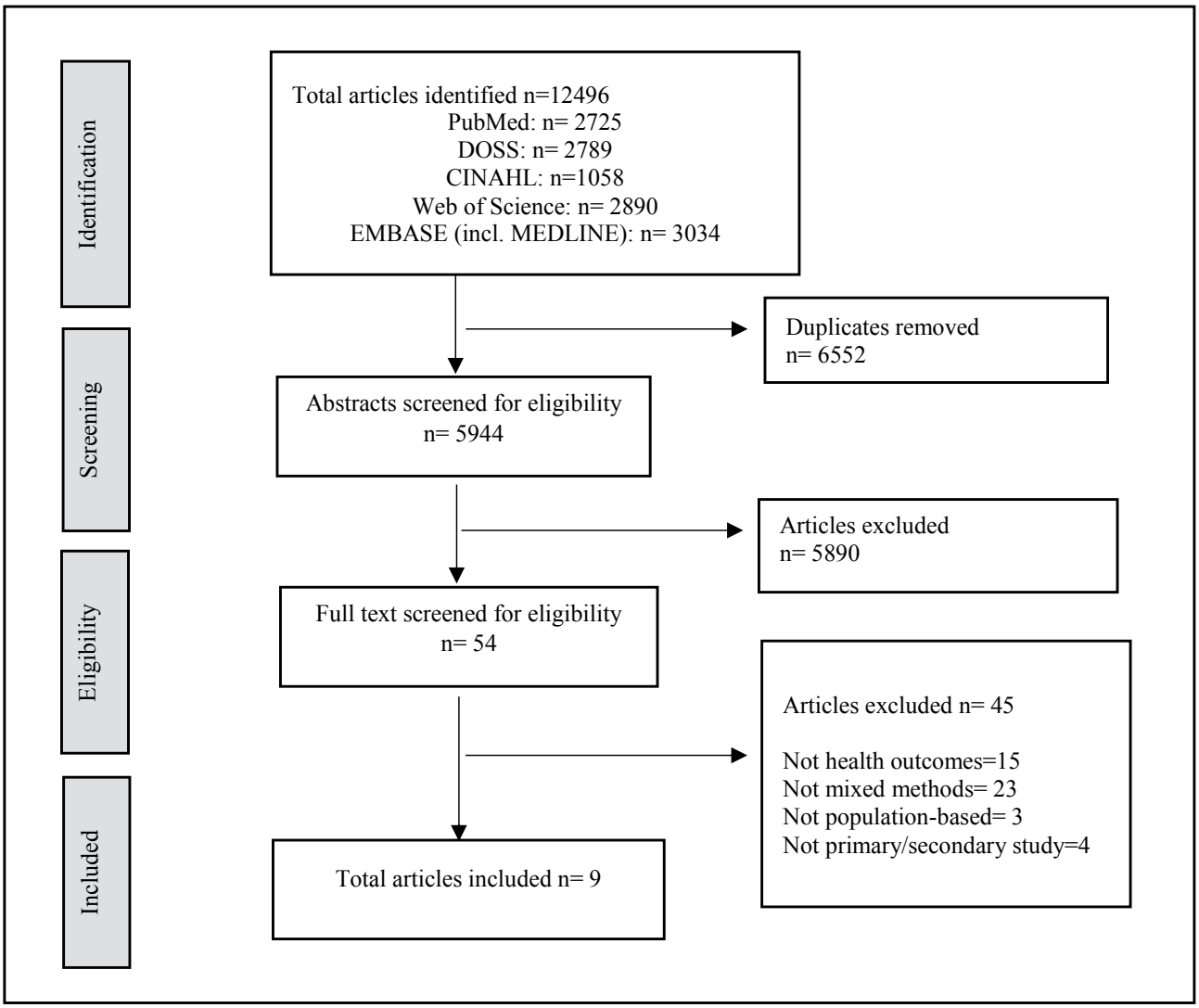

Figure 1. Research process flowchart

in Australia (Gibbs *et al.*, 2015), migrant families who were predetermined to be at risk of poor child oral health were selected for an oral health promotion intervention study. Other included studies identified and selected specific socio-economic groups such as participants in deprived socio-economic areas, and children attending schools, toy libraries and health centres.

At the data collection stage, the typology of mixed methods inferred for all but one study was concurrent triangulation with a convergent design, i.e. quantitative and qualitative data were collected simultaneously but separately. In the one exception (Maupome, 1998) data were collected sequentially using an exploratory approach i.e. qualitative before quantitative. In this study, participants who took part in focus groups were subsequently administered the survey and their children underwent a dental examination. However, no rationale was presented for using the sequential approach. Another study (Mahrous *et al.*, 2016) did not report any typology of mixed methods at the data collection stage. Neither could any inference be made as the quantitative survey included only a few open ended questions, which were referred to as producing qualitative data.

The quantitative data in the studies were mostly collected in surveys capturing participants' demographic data, oral hygiene behaviours, dental visiting behaviours, oral health knowledge/beliefs and dietary practices. Clinical examinations were performed in most studies (Ariza *et al.*, 2012; Chatrchaiwiwatana *et al.*, 2012; Gibbs *et al.*, 2015; Gratrix and Holloway, 1994; Mahrous *et al.*, 2016; Maupome, 1998). Most data were analysed only descriptively, with inferential analysis conducted for the remainder. The qualitative datasets were primarily collected through in-depth interviews, and in some cases through focus groups. The theoretical framework underlying the qualitative analysis was not described in any study. Further, no rationale for using either interviews or focus groups was mentioned. Only one study explicitly stated the analytical method used i.e. content analysis of transcripts to address the phenomenon under investigation (Maupome, 1998); the remaining studies appeared to use thematic analysis of qualitative data but were not explicit in naming it such.

Table 2. Summary of the included studies by year of publication (n=9)

Study (Author-Year) & country	*Aim*	*Outcome*	*Study Population, sample size and sampling*	*Data collection method and findings from components*	*Typology at data collection stage*	*Type of analyses*	*Process of integration*	*Typology at the integration stage*
Gratrix and Holloway 1994 UK	Identify potential indicators of dental caries	Caries experience	QUANT– Children (5 years) (n=344) attending primary schools with mixed socio-economic structure and high prevalence of caries	QUANT– Dental examination and area specific data provided information on mixed socio-economic groups and area specific risk factors of caries	Concurrent Triangulation (Convergent Design) QUANT+ QUAL	QUANT– Non-parametric test (Mann-Whitney U test)	Quantitative and qualitative data combined to reveal new indicators of caries risk and to provide information for policy relevance to tackle dental caries.	Concurrent Triangulation (Convergent Design) QUANT+ QUAL
			QUAL– health care and school informants *(n= not reported)* selected due to their knowledge about preschool children, their home background, their behaviour and community in which they lived	QUAL– Semi-structured open-ended interviews to obtain information on lifestyle risk factors of dental caries for high and low caries groups		QUAL– Data combined into descriptive profiles for each group and their associated communities		
Maupome 1998 Mexico	Probe the extent of the dental health problems and to establish the underlying behavioural causes of poor oral health	Caries experience	QUAL– Mothers of children ≤12 years (n=56) selected based on their availability to attend focus groups	QUAL– Focus groups to identify mothers' perceptions of oral health and disease as well as underlying mechanisms linking behavioural and dietary patterns to oral health	Sequential Triangulation (Exploratory Design) QUAL QUANT	QUAL– Content analysis of transcripts	Qualitative and quantitative data combined to reveal the underlying beliefs for poor oral health leading to tooth decay	Concurrent Triangulation (Convergent Design) QUANT+ QUAL
			QUANT– children ≤12 years (n=56) Children whose mothers took part in the focus groups were selected	QUANT– Dental examination of the children and baseline information collected from mothers on demographic factors, patterns of child rearing from 0-3 years, feeding practices for children, dental care and hygiene practices, and their interpretations of oral health and disease		QUANT– Means and standard deviations estimated		
Ariza *et al* 2012 Colombia	Create a place within a public library devoted to strengthening oral health habits and reinforcing oral health knowledge among children and their families	Caries experience in addition to knowledge and strategies for better oral health	QUANT- Children 4-12 years old (n=99) and their parents/ guardians attending a toy library	QUANT- Dental examination measuring dental caries and dental plaque and a survey to obtain oral health knowledge before and after the educational lectures and interactions with ludic materials	Concurrent Triangulation (Convergent Design) QUANT+ QUAL	QUANT- Descriptive analysis	Only quantitative findings were discussed to reveal that a toy library setting improved knowledge, allowed socialisation of the participants, promoted healthy oral habits and reinforced self-care among the participants	No Triangulation
			QUAL- Children 4-12 years old (n=99) and their parents/ guardians attending a toy library	QUAL- A focus group with teachers and children was conducted to obtain their opinions and perspectives on the ludic materials		QUAL- Thematic analysis *(inferred)*		

table 2 continued overleaf...

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Study (Author-Year) & country	*Aim*	*Outcome*	*Study Population, sample size and sampling*	*Data collection method and findings from components*	*Typology at data collection stage*	*Type of analyses*	*Process of integration*	*Typology at the integration stage*
Chatrchaiwiwatana *et al* 2012 Thailand	Evaluate factors related to tooth loss due to dental caries	Tooth loss due to caries experience	QUANT– Male and female industrial workers aged 19-53 years (n=457) QUAL– Of the participants, 11 were purposively selected based on number of years of employment (≥5 years) and number of teeth lost (≥4)	QUANT– Dental examination and survey of baseline demographic, socioeconomic and oral health-related characteristics QUAL– In-depth interviews about lifestyle, attitudes and habitual behaviours	Concurrent Triangulation (Convergent Design) QUANT+ QUAL	QUANT– Multivariate logistic regressions QUAL– Thematic framework analysis *(inferred)*	Quantitative and qualitative data were combined to reveal a range of socio-economic and oral health- related factors associated with tooth loss	Concurrent Triangulation (Convergent Design) QUANT+ QUAL
Gibbs *et al* 2015 Australia	Evaluate an oral health promotion intervention for children from migrant backgrounds	Frequency of child tooth brushing, oral health status, behaviour, knowledge and use of dental services. Facilitators and barriers to intervention	QUANT– Parents (n=319) with 1–4 year old children (n=341) with Iraqi, Lebanese or Pakistani backgrounds residing close to the study site and being at risk of poor child oral health. QUAL– study staff and participants to obtain process evaluation data *(n=not reported)*	QUANT– Dental examination and survey of child and parent demographic data, oral hygiene behaviour, dental visiting behaviour, self-reported health measures, child dietary practices and parent oral health knowledge. QUAL– Three focus groups to explore recruitment activity, participant attendance, barriers and facilitators of intervention implementation	Concurrent Triangulation (Convergent Design) QUANT+ QUAL	QUANT– Logistic regression QUAL–Thematic analysis	Quantitative and qualitative data combined to assess the feasibility, relevance and costs of the intervention as a model for child oral health promotion for culturally diverse groups	Concurrent Triangulation (Convergent Design) QUANT+ QUAL
Mahrous *et al* 2015 Saudi Arabia	Report on the caries status and dental service utilisation of 6- and 12-year-old children	Caries experience and utilisation of dental services	QUANT- School children 6 and 12 years old and the parents of 6 year olds only QUAL- School children 6 and 12 years old and the parents of 6 year olds only	QUANT- Dental examination and survey of oral hygiene practice, frequency of visits to dental clinics and preventive advice provided by oral health staff to the children. QUAL- Open ended questionnaires administered to the parents and self-administered to 12 year old children regarding oral hygiene practice, frequency of visits to dental clinics and preventive advice provided by oral health staff to the children	No Triangulation	QUANT- Descriptive analysis QUAL- No information available	Only quantitative findings were discussed describing the prevalence of caries experience similar to previous studies and low utilisation of dental services	No Triangulation

table 2 continued overleaf...

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Study (Author-Year) & country	*Aim*	*Outcome*	*Study Population, sample size and sampling*	*Data collection method and findings from components*	*Typology at data collection stage*	*Type of analyses*	*Process of integration*	*Typology at the integration stage*
Templeton *et al* 2016 UK	Identify patient, organisation, and system level factors influencing caries prevention and management	Prevention and management of caries	QUANT–Random sample of dentists in the National Health Service (n=651)	QUANT–Diagnostic survey assessing oral health behaviours, beliefs, child-focused behaviours (fluoride varnish, preventive fissure sealants) and practice characteristics included demographic information, practice structure and staff roles, enrolment, quality assurance systems, and perceived relevance of guidance	Concurrent Triangulation (Convergent Design) QUANT+ QUAL	QUANT–Logistic regression	Quantitative and qualitative data combined to obtain specific, theoretically based, testable interventions representative of interests within and across patient, practice and policy groups	Concurrent Triangulation (Convergent Design) QUANT+ QUAL
			QUAL–Case study practices (n=8); interviews with dental team members, stakeholders in policy, funding, education, and regulation (n=29)	QUAL– In-depth semi-structured interviews with dental team to explore use of recommended care, barriers and facilitators		QUAL– Thematic analysis *(inferred)*		
Ogretme *et al* 2016 UK	(1) Report on the profile of children requiring dental treatment under conscious sedation (2) Report from the children's parents/guardians on their experiences of oral health preventive services and the support they would like in order to improve their children's oral health	Caries experience	QUANT– Children 2-16 years scheduled to receive dental treatment under conscious sedation, and their parents (n=123)	QUANT– A survey with closed questions (patient's details, family's demographic data, status of the referring practitioner, ASA grade of the patient, dental diagnosis, caries risk assessment, type of treatment required under sedation, type of sedation, and previous history of general anaesthesia or conscious sedation for dental treatment)	Concurrent Triangulation (Convergent Design) QUANT+ QUAL	QUANT– Descriptive analysis *(inferred)*	Quantitative and qualitative data combined to propose a care pathway for high caries risk children requiring dental treatment under conscious sedation which included personalised education and support for behaviour change to improve oral and general health habits	Concurrent Triangulation (Convergent Design) QUANT+ QUAL
			QUAL– Children 2-16 years scheduled to receive dental treatment under conscious sedation, and their parents (n=123)	QUAL– A survey with open questions (impact of the child's poor oral health on the child and on the family, dietary advice received from their dentist, preventive treatment options, and parents' views on oral health education delivery)		QUAL– Thematic analysis		
Vece *et al* 2016 USA	Implement an evidence-based oral health care program into health centres.	Oral health needs (caries experience), and the impact of basic oral health teaching	QUANT- English or Spanish speaking parents aged ≥18 years with children presenting at the centre	QUANT- A survey to confirm demographic data (including age, race, ethnicity, primary language, and educational level) and oral health background information (including previous dental experiences, oral health habits, and the availability of toothbrushes, toothpaste, and floss within the home)	Concurrent Triangulation (Convergent Design) QUANT+ QUAL	QUANT– Descriptive analysis	Quantitative and qualitative data combined to reveal the population demographics, their unmet oral health needs, and the impact of basic oral health teaching on this vulnerable population	Concurrent Triangulation (Convergent Design) QUANT+ QUAL
			QUAL- English or Spanish speaking parents aged ≥18 years with children presenting at the centre	QUAL- A questionnaire to obtain data on engagement and satisfaction with the oral health program		QUAL– Thematic analysis		

Discussion

Our review suggested there was scant literature applying mixed methods in the field of population oral health. Furthermore, we found little theoretical rationale within the selected studies to justify their use, with limited integration of the study findings to make meaningful inferences. A limited number of tools (interviews and focus groups) to collect qualitative data was utilised. Concurrent triangulation with a convergent design was inferred as the mixed methods typology most commonly applied at the integration stage in all the studies.

Several reviews have suggested that the use of mixed methods has been growing consistently in health research, and more than in other domains (Andrew and Halcomb, 2006; Halcomb *et al.*, 2009; Ivankova and Kawamura, 2008). Those reviews have highlighted the importance of comprehending the rationale for using mixed methods, as not all research questions require this approach (Creswell and Plano Clark, 2007). None of the studies included in this review explicated their rationale for using mixed methods. However it was inferred to be mostly for complementarity. This could have been due to inadequate understanding of the scenarios in which mixed methods are applied or its significance to oral health research *per se*. In the included studies, the qualitative analysis was largely superficial and lacked theoretical depth. However, its application within the nine studies does indicate a growing use of combined quantitative and qualitative methods in oral health.

To assess the robustness of the mixed methods approach, it is important to consider which tools were used to gather the quantitative and qualitative data. Surveys were the most common choice for quantitative data, and interviews for qualitative data. Similar techniques have been used extensively in social research, health services and nursing research (Bryman, 2007; Doorenbos, 2014; O'Cathain *et al.*, 2007). As any particular tool may only be appropriate in certain contexts, restricting the research toolbox does not allow for the potential of other methods such as ethnography (Nicolau, 2017), or techniques such as participant observation, where pertinent to the research question. This subsequently impacts on the choice of analysis (Campbell *et al.*, 2017; Green and Thorogood, 2009; Neergaard *et al.*, 2009). For instance, observations may aid in assessing individuals' dietary habits or their oral hygiene practices, while documentary analysis may be chosen when analysing oral health related policies or health services-related documents.

Another important feature of mixed methods is the process of integrating the findings of the quantitative and qualitative components. This can occur during study design, data collection or interpretation (Fetters *et al.*, 2013). In the included studies, integration was limited to the data collection and interpretation stages. Consistent with previous meta-reviews in health sciences (Östlund, 2011; Plano Clark, 2010), the most common typology used at the data collection stage was concurrent triangulation with a convergent design. In the convergent designs, the qualitative and quantitative data are collected together at the same time. The preponderance of this typology here could indicate its application due to time constraints rather than based on the research question. However, for studies such as that which described the profile of children requiring dental treatment under sedation and obtained parents' views on their experiences of oral health services, it was logical to apply convergent design (Ogretme *et al.*, 2016). This approach is supported by other literature that profiles the study population then draws on participants' perspectives of the issue under investigation (Crabtree *et al.*, 2005). For studies that aim to gain a more comprehensive understanding, such as quality of care or the processes involved in catering for different medical conditions (Krumholz *et al.*, 2009; Popescu *et al.*, 2009), it is more appropriate to use the exploratory sequential design. Use of such a design was observed in only one study, which aimed to probe the extent of children's dental health problems and establish the underlying behavioural causes (Maupome, 1998). Researchers may not have been aware of the breadth of typologies used in the mixed methods approach.

Findings can be integrated at the study interpretation stage in varied ways, depending on the research design and question (Creswell and Plano Clark, 2007; Tashakkori and Teddlie, 2010). Often the best method for integration is when the researcher analyses quantitative and qualitative data separately and then compares and contrasts the findings in the discussion. This can be done narratively or by merging the findings on a theme-by-theme basis to draw novel insights beyond the information obtained from individual methods (Fetters *et al.*, 2013). Either approach makes the understanding of the topic under investigation more coherent. However, neither was used in the included studies. It was only in their concluding remarks where an attempt to collectively comment on the findings was presented. The lack of integration underscores the need for enhanced understanding of the principles and applications of mixed methods to help oral health researchers generate more novel and valuable evidence.

This review has several strengths and some limitations. The probability of omitting eligible articles was minimised by using a range of search terms and a thorough search, which included searches of the reference lists and journals of included articles. Studies published in languages other than English and those reporting only quantitative or qualitative methods were excluded as our primary interest was to understand the process of integration of findings from the two strands. This may have led to the exclusion of reports from mixed methods research where the results were published separately. Though the final search strategy was developed after several preliminary runs, it may be that not all mixed methods studies were captured. Studies using uncommon terms to describe mixed methods may have been omitted; some grey literature was covered by the searched databases but the search of this component of the literature was not exhaustive. Growing heterogeneity in the terminology used for mixed methods is a well-accepted limitation of the field (Johnson *et al.*, 2007).

Conclusion

Despite the importance of using mixed methods in health research, the value of truly integrating paradigms is yet to be fully realised in oral health research at the population level. Overall there appears to be a dearth of studies using mixed methods in population oral health. Those studies that were identified, were limited by a lack of theoretical rationale and framework underpinning the use of mixed methods, and merely descriptive integration of quantitative and qualitative components. The designs used to integrate study findings were also limited, mainly to concurrent triangulation with a convergent design. Some examples of a more thorough approach are emerging (Nicolau, 2017). With regard to oral health outcomes such as caries or periodontal disease, a valuable use of mixed methods in determining causes could be the integration of quantitative measurement of the condition with qualitative exploration of the contributing behaviours and their context.

To recoup the greatest benefit from mixed methods, future research of population oral health should involve fuller consideration of the rationale for using the approach. This should be conducted near the inception of the research, to identify which method will best address the research question. More rigorous integration of data will help produce more nuanced and meaningful findings. Based on this review, we suggest that a fuller explication of how mixed methods research can be applied to understand oral health outcomes, drawing on a range of disciplines to generate illustrative examples, would be a positive contribution to the literature. Regardless, oral health researchers could seek guidance directly from other fields, such as nursing, on the application of mixed methods. Research that results from such insight is likely to be of greater value and transferability, which will assist in identifying and developing appropriate preventive oral health strategies at the population level.

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