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Barriers and enablers to skill-mix in the oral health workforce: A systematic review

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Introduction: In dentistry, the term "skill-mix" is used to describe the combinations of dentists and dental care professionals in delivering activities that are commonly established by their level of education, training and scope of practice. However, the literature has indicated an under-utilisation of skill-mix in the oral health care team. Further work is required to understand the poor uptake of skill-mix in oral health care and what could be done to address this issue. ***Objective***: To identify and synthesise the available evidence on the barriers and enablers to skill-mix in the oral health workforce using a macro-, meso- and micro-level framework. ***Materials and methods***: The databases MEDLINE, CINAHL and Scopus between January 2010 to April 2020 were searched. Primary research studies published in English were included. ***Results***: Thirty-two articles were included. Key barriers and enablers at each level of analysis were identified. Macro-level barriers and enablers included structural, regulatory and policy conditions and dental health care needs of populations. Meso-level barriers and enablers defined the parameters of service delivery and included workplace characteristics, referral systems and patterns, and workplace productivity and efficiency. Micro-level barriers and enablers pertained to the perceptions, attitudes, and social acceptability of stakeholders that affected the delivery of services. ***Conclusion***: Understanding the barriers and enablers from a multi-level framework requires further high-quality research to fully appreciate its importance in addressing health care needs within populations and increase generalisability to oral health settings.

Keywords*: health workforce, dental health services, systematic review*

Introduction

In dentistry, the term "skill-mix" is used to describe the combinations of dentists and dental care professionals (DCPs) in delivering activities that are commonly established by their level of education, training and scope of practice (Brocklehurst and Macey, 2015; Gallagher and Wilson, 2009). Dental care professionals are non-dentist members of the dental team that include dental nurses, dental hygienists (DHs), dental therapists (DTs), oral health therapists (OHTs) (also termed dental hygiene-therapists in the United Kingdom [UK]), and dental prosthetists. These DCPs often perform a supplementary role (e.g., dental nurses) or substitution role in services otherwise provided by dentists (e.g., OHTs, DTs, DHs, and dental prosthetists). Role substitution has the potential to replace higher-paid dentists with lower-paid DCPs, thereby allowing dentists to utilise their time to undertake more complex dental treatments (Harris and Sun, 2012a).

The benefits of skill-mix have been discussed extensively in general medicine and have included increased cost-effectiveness, maintained quality in the delivery of medical services, and improved patient health outcomes (Laurent *et al.,* 2009; Laurent *et al.,* 2018). In dentistry, the evidence is also convincing: studies have demonstrated the benefits of skill-mix in dentistry to increase practice efficiency and effectiveness in service provision and increase workforce capacity (Brickle and Self, 2017; Brocklehurst and Macey, 2015; Freeman *et al.,* 2013). However, despite this, utilisation of oral health skill-mix remains behind that of their medical colleagues (Brocklehurst and Macey, 2015). There is an ongoing debate regarding the use of DCPs in the United States (US) with some experts noting their utilisation as a threat to dentists (Rodriguez *et al.,* 2013). In Australia, a debate concerns the scope of practice for OHTs and DTs to provide restorative dental services to adult patients precluding the oversight of dentists (Calache and Hopcraft, 2012). Furthermore, an inherent reliance on dentists as the primary professionals for all treatment (Calache and Hopcraft, 2012; Hopcraft *et al.,* 2008), reluctance for dentists to refer treatment to DCPs (Nilchian *et al.,* 2009), and remuneration models that favour more complex treatment (Knevel *et al.,* 2017) are some examples of reported barriers within the literature that may explain why skill-mix is under-utilised in oral health care (Gallagher and Wilson, 2009; Bohmer and Imison, 2013). Further work is required to understand the poor uptake of skill-mix in oral health care and what could be done to address this issue.

Thus, the purpose of this review was to examine and synthesise the available evidence to the question: What are the barriers and enablers to skill-mix in the oral health workforce?

Materials and methods

Search strategy

We developed a core search strategy based on an analysis of the Medical Subject Headings (MeSH), and text words of keys articles identified *a priori*. A single reviewer

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performed the searches in April 2020 on the following databases: MEDLINE, CINAHL and Scopus. The strategies for CINAHL and Scopus were adapted from the MEDLINE strategy. Limits were applied for language (English) and the publication year (after 2010). The main keywords in the search strategy were structured around two key concepts: "oral health workforce" and "skill-mix". The reference lists of reports were also scrutinised to identify further relevant papers. The resultant sources were imported into referencing software EndNote. Duplicates were removed using software and hand-searching. The detailed search strategy is outlined in Appendix 1.

Eligibility criteria

Inclusion criteria included English-language studies globally between 2010 and April 2020 (Table 1). The rationale for this start period was to limit the research to contemporary studies. Those that included DCPs or primary health care workforce were only eligible if they specified the inclusion of at least one dental professional group. In this study, an enabler referred to a factor or circumstance that facilitated the adoption of skill-mix in the oral health team. A barrier referred to a factor or circumstance that impeded or prevented this practice.

Table 1. Inclusion and exclusion criteria for systematic review

Criteria	*Inclusion*	*Exclusion*
Time period	2010 – April 2020	Prior to 2010
Language	English	Non-English
Place of study	Global	
Participants	Dental practitioners (dentists, dental hygienists, dental therapists, oral health therapists, dental prosthetists), dental nurses	Dental specialists (e.g., periodontists, endodontists, paedodontists, oral-maxillofacial surgeons, orthodontists, prosthodontists, special-needs dentists)
Study designs	Qualitative, quantitative and mixed methods research	Editorials, commentary, conference abstracts and proceedings, and reviews

Study selection

Two reviewers (AW and HH) independently screened titles and abstracts for eligibility. Full-texts of relevant articles were identified and independently reviewed for inclusion in accordance with PRISMA guidelines (Moher *et al.,* 2009). Conflicts were resolved through discussion or consultation with a third reviewer (TB).

Data extraction

Data were extracted for relevant study characteristics including country of origin, objectives, methods, the number of subjects, professional type (e.g., dentist, dental nurse, DH, DT, OHT, or dental prosthetist), and outcomes as they pertained to the research question.

Quality appraisal

Due to the combination of qualitative, quantitative and mixed-methods studies meeting our criteria, quality was appraised according to the Mixed Methods Appraisal Tool (MMAT) (Hong *et al.,* 2018). Two reviewers (AW and HH) independently assessed the methodological quality of included studies with conflicts resolved via consensus or third-reviewer consultation (TB). An overall quality score was determined for each study.

Data synthesis

Data were synthesised narratively using the macro-, meso-, and micro-level framework (Bullock *et al.,* 2018). Macro-level referred to structural, national or policy factors that were beyond the influence of individuals or groups. Meso-level referred to practice-level factors and influences that defined the parameters of service delivery. Micro-level referred to perceptions, attitudes or social acceptability of stakeholders that affected how services were delivered.

Results

Description of studies

The literature search identified 1,313 unique sources for inclusion. After screening titles and abstracts, 42 potentially relevant studies were identified. Full-text screening yielded a total of 32 studies that met the eligibility criteria (Figure 1). During the initial phases of eligibility screening, the most common reasons for exclusion were studies not related to oral health skill-mix or the enablers or barriers to oral health skill-mix. The included studies are characterised in Table 2. Twenty studies were conducted in the UK, ten in the US, and two in Australia. Overall, studies were deemed to be of good methodological quality with some variability. Quality analysis outcomes using MMAT criteria are shown in Table 3.

Macro-level barriers and enablers

At the macro-level were regulatory, economic considerations and implications, and population or community based dental health care needs. Included were studies about national policy and regulatory systems, such as the Child Dental Benefit Scheme (CDBS) in Australia (Nguyen *et al.,* 2019) and the National Health Service in the UK (Brocklehurst *et al.,* 2016; Robinson *et al.,* 2019). In five studies, the DCP scope of practice was reported to be constrained by regulations governing dental care funding (Brocklehurst *et al.,* 2016; Cowpe *et al.,* 2013; Robinson *et al.,* 2019; Sun and Harris, 2011; Turner and Ross, 2017). Lack of remuneration systems that hindered the utilisation of skill-mix was noted across three studies (Brocklehurst *et al.,* 2016; Cowpe *et al.,* 2013; Rainchuso and Salisbury, 2017).

Needs-led (or sociodental) approaches to dental service delivery were found to facilitate the utilisation of skill-mix within the dental team and to reduce population treatment needs and workforce requirements (Ab-Murat, 2015a; b). This was further supported by workforce patterns within rural and remote communities (Senturia *et al.,* 2018; Mehta and Erwin, 2018; Myers *et al.,* 2014), low-income families (Nicoll *et al.,* 2016), and school-based children (Rainchuso and Salisbury, 2017) where DCPs primarily undertook preventive services. Six studies (Gallagher *et al.,* 2010; Gallagher *et al.,* 2013; Harper *et al.,* 2013; Matthiesen, 2012; Nguyen *et al.,* 2017; Wanyonyi *et al.,* 2015), when modelling skill-mix

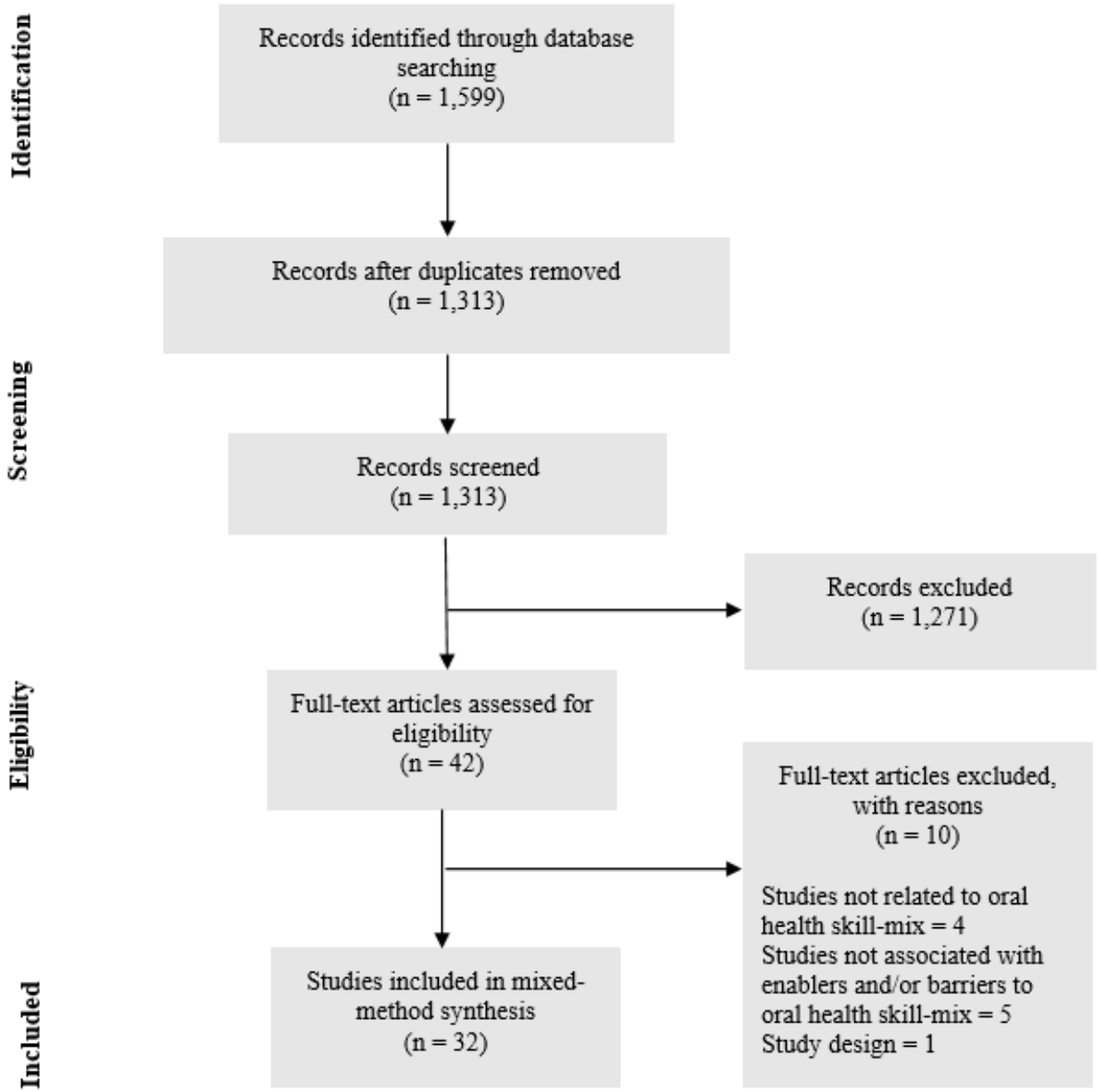

Figure 1. *Flow diagram of selected studies*

to future population dental health needs, demonstrated improvements to workforce capacity and economic savings to public funding. However, two studies (Bailit *et al.,* 2012; Beazoglou *et al.,* 2012c) demonstrated minimal economic savings when treatment was delegated to DTs using similar modelling methods.

Meso-level barriers and enablers

Meso-level determinants included practice productivity and efficiency, referral systems and patterns, and workplace characteristics reported across studies.

Across studies, practice efficiency was defined as the effectiveness with which a given set of inputs (such as annual work hours of dentists and DCPs) were used to produce specified outputs (such as number of patient visits and gross billings). Several studies identified benefits in utilising skill-mix for both practice productivity and efficiency based on clinical outcomes including volume of patients and treatment, salary cost-savings, optimum use of surgery time and management of workflow (Beazoglou *et al.,* 2012a; b; Gallagher *et al.,* 2010; Gallagher *et al.,* 2013; Harris and Sun, 2012a; b; Hill *et al.,* 2017; Wanyonyi *et al.,* 2015). A UK study found that the referral of routine treatment to DTs had an overall positive influence on practice productivity and efficiency but was under-utilised (Harris and Sun, 2012a). Costs for treatment, practice income, and salary distribution was influenced by the skill-mix in the oral health team (Dyer *et al.,* 2013; Gallagher *et al.,* 2013; Nguyen *et al.,* 2019; Wanyonyi *et al.,* 2015) with one study demonstrating increased gross annual income among primary dental practices when treatment was referred to DTs compared to practices that did not (Beazoglou *et al.,* 2012a).

Micro-level barriers and enablers

Micro-level determinants included social acceptability, attitudes, and perceptions of patients, dentists, and DCPs to skill-mix.

Table 2. Descriptive characteristics of studies included in the review

Author (year)	*Country*	*Objectives*	*Methods*	*Participants (n)*	*Dental professional types*	*Outcomes*
Ab-Murat *et al.* (2015a)	UK	To investigate prosthodontic treatment needs and workforce requirements for different skill-mix models	Survey	732	Dentists, prosthetists	Reduced treatment needs and workforce requirements when prosthodontic procedures (e.g., dentures) were delegated to dental prosthetists.
Ab-Murat *et al.* (2015b)	UK	To investigate periodontal treatment needs and workforce requirements for different skill-mix models	Survey	732	Dentists, therapists	Reduced treatment needs and workforce requirements when periodontal treatments were delegated to therapists.
Bailit *et al.* (2012)	USA	To examine the economic impact of dental therapists in FQHC-run school-based dental care programmes	Modelling analysis		Therapists	Estimated economic savings of utilising therapists in school-based dental care programmes were low.
Barnes *et al.* (2018)	UK	To explore the nature of treatment provided by dentists and therapists, and patients' satisfaction and confidence with the care received	Questionnaire	1,224 patients	Dentists, therapists	Dentists in practices with a therapist, undertook more extractions and complex treatment. Therapists undertook more preventive work than dentists. Patient satisfaction and confidence scores were similar for care received by dentists or therapists.
Beazoglou *et al.* (2012a)	USA	To examine the impact of expanded function dental nurses and hygienists in general dental practices	Historical data	154 dental practices	Dental nurses, Hygienists	Practices that delegated treatment to dental nurses and hygienists had higher productivity, financial gains, and capacity to treat a higher volume of patients than practices who did not.
Beazoglou *et al.* (2012b)	USA	To examine the economic impact of dental therapists in general dental practices	Modelling analysis		Therapists	Estimated economic savings of utilising therapists in general dental practices were negligible
Beazoglou *et al.* (2012c)	USA	To examine the economic impact of dental therapists in FQHC clinics	Modelling analysis		Therapists	Estimated economic savings of utilising therapists in FQHC clinics were low.
Brocklehurst *et al.* (2016)	UK	To explore the factors that influence utilisation of skill-mix in the NHS	Mixed methods	121 dental practices	Dentists, Therapists, Hygienists, Oral health therapists	Identified factors that influenced utilisation of skill-mix including current NHS remuneration systems and contracts, patient- and dentist-level attitudes and perceptions, and referral processes.
Cowpe *et al.* (2013)	UK	To examine the use of DCPs within general dental practices in Wales	Survey	131	Therapists, Hygienists, Oral health therapists, Prosthetists, Nurses	Majority of respondents perceived skills were fully utilised, but barriers to extending skills included resources, time, lack of support, and negative attitudes from patient and dentists.
Dyer *et al.* (2013)	UK	To explore the perceptions of patients and parents of patients' when treatment was delegated to dental therapists	Semi-structured interviews	18	Therapists	Parents and patients were accepting of treatment delegated to dental therapists. Social acceptability was influenced by type of dental service, collectivist or consumerist viewpoints, familiarity in the dental team, and continuity of care.
Dyer *et al.* (2010)	UK	To identify the social acceptability and awareness of the general public of treatment delegated to dental therapists	Survey	1,000	Therapists	Limited awareness of the role of dental therapists within the general public. Social acceptability was influenced by age of patient, type of dental service, and practice setting.

Table 2. Continued overleaf...

Table 2. Continued...

Author (year)	*Country*	*Objectives*	*Methods*	*Participants (n)*	*Dental professional types*	*Outcomes*
Gallagher *et al.* (2010)	UK	To explore future health services scenarios for the required skill-mix in the dental team to meet older population needs by 2028	Modelling analysis		Dentists, Therapists, Hygienists, Oral health therapists, Prosthetists	Increased utilisation of skill-mix resulted in increased volume of staff and capacity for meeting projected treatment needs for older populations.
Gallagher *et al.* (2013)	UK	To explore future health services scenarios for the utilisation of skill-mix in the dental team for meeting population needs	Modelling analysis		Dentists, Therapists	Increased utilisation of dental therapists resulted in reduced costs and volume of dentists required.
Gnich *et al.* (2014)	UK	To investigate the utilisation of extended duty dental nurses in general dental practice across Scotland	Survey	174	Dental nurses	Increased delegation of treatment to dental nurses resulted in increased job satisfaction. Barriers included patient and dentist attitudes, and lack of resources.
Harris and Sun (2012a)	UK	To investigate dentists' perceptions to use of dental therapists in general dental practices	Semi-structured interviews	26	Dentists, Therapists	Perceived dental therapists as improving practice efficiency in limited settings.
Harris and Sun (2012b)	UK	To investigate how changes to dental remuneration systems impact delegation of treatment to dental therapists in general dental practices	Semi-structured interviews	48	Dentists, Therapists, Hygienists	Identified disincentives to delegate treatment to dental therapists due to different remuneration systems based on practitioner-level productivity.
Harper *et al.* (2013)	UK	To explore future health services scenarios for utilisation of skill-mix in the dental team for meeting population needs	Modelling analysis		Dentists, Hygienists, Therapists, Prosthetists	Increased utilisation of skill-mix resulted in increased volume of staff, economic savings to public dental service funding, and capacity to meet projected treatment needs for future populations.
Hill *et al.* (2017)	UK	To evaluate impact of skill-mix to general dental practice efficiency	Questionnaire Historical data	121	Dentists, Hygienists, Therapists	No differences to general dental practice efficiency across practices after controlling for variables.
Macey *et al.* (2016)	UK	To assess the feasibility of a definitive trial to evaluate the impacts of utilising hygienists to undertake routine check-ups. A parallel qualitative study was undertaken	Mixed methods	60	Dentists, Hygienists	Outcome measures of recruitment, retention, and treatment fidelity rates were high when skill-mix was used, with overall positive acceptability and trust in treatment provided by hygienists reported by patients.
Matthiesen (2012)	USA	To assess the feasibility of DCPs to provide dental care to underserved communities	Modelling analysis		Therapists	Utilising DCPs increased access to services and economic savings for underserved communities.
Mehta and Erwin (2018)	USA	To determine the perceptions and attitudes of dentists on an expanded dental therapy program	Questionnaires	418	Dentists, Therapists	Dentists were supportive of the programme in delivering care to underserved populations. Negative perceptions of DTs included clinical competency, quality of care, and patient perceptions.

Table 2. Continued overleaf...

Table 2. Continued...

Author (year)	*Country*	*Objectives*	*Methods*	*Participants (n)*	*Dental professional types*	*Outcomes*
Myers *et al*. (2014)	USA	To examine the perceptions and experiences of ECP hygienists	Questionnaire	60	Hygienists	Perceived that ECP hygienists provided a solution to address access to dental services for underserved communities in Kansas. Barriers to the role included finances, resources, and lack of professional support.
Nicoll *et al*. (2016)	USA	To explore the social acceptability and perceptions of low-income parents on treatment provided by DCPs	Semi-structured interviews	20	Therapists, Hygienists	Parents were accepting of treatment provided by DCPs.
Nguyen *et al*. (2017)	Australia	To quantify the economic impacts of increased utilisation of oral health therapist workforce to the Child Dental Benefits Schedule	Modelling analysis		Dentists, Oral health therapists	Increased utilisation of oral health therapists resulted in greater economic savings to public dental service funding.
Rainchuso and Salisbury (2017)	USA	To explore the perceptions of public health hygienists on delivering preventive care services to underserved populations in Massachusetts, US.	Semi-structured interviews	10	Hygienists	Hygienists identified themselves as "agents of change" and improved access to dental services for underserved populations with overall high job satisfaction. Barriers reported included lack of professional support, remuneration and reimbursement issues.
Robinson *et al*. (2019)	UK	To explore stakeholder perspectives of a service delivery model in primary care dentistry to incentivise access, quality, and oral health outcomes.	Observations Interviews Focus groups	6 dental practices	Dentists	Perceived utilisation of a service delivery model that incentivised access, quality and oral health outcomes resulted in a greater emphasis on preventive treatment, utilisation of skill-mix, and patient satisfaction.
Senturia *et al*. (2018)	USA	To explore the factors and perceptions to dental care delivered by DCPs for children in remote Alaskan villages	Semi-structured interviews Focus groups	85	Therapists, Hygienists	Acknowledged key role in improving access to underserved communities. Reported barriers to care include lack of professional and administrative support, limited resources, and poor understanding of their role by patients in the communities.
Sun and Harris (2011)	UK	To identify factors that disincentivise delegation of treatment to dental therapists in general dental practices	Semi-structured interviews	35	Dentists, Therapists, Hygienists	Remuneration systems based on practitioner-level productivity negatively influenced delegation of treatment to dental therapists.
Tuesner *et al*. (2016)	Australia	To identify variations in DCPs workplace characteristics	Questionnaire	850	Therapists, Hygienists, Oral health therapists	Perceived variations in workplace characteristics and service provision did not allow for optimal use of skill-mix.
Turner and Ross (2017)	UK	To identify factors that influence direct access to dental therapists in the UK	Questionnaire	86	Therapists	Perceived barriers to direct access included social acceptability by patients, lack of resources, lack of professional support, treatment restrictions, and unfavourable attitudes from dentists.
Wanyonyi *et al*. (2014)	UK	To determine patterns of delegation by dental students to DCPs	Historical data	2,063	Students	Treatment delegated to DCPs included preventive services and restorative services in children and adult patients who smoked.
Wanyonyi *et al*. (2015)	UK	To explore future health services scenarios for the utilisation of skill-mix in the dental team in a primary care team training centre	Modelling analysis		Dentists, Therapists, Hygienists	Increased utilisation of skill-mix resulted in increased volume of staff and capacity for meeting projected treatment needs in a primary care team training centre.

DCPs = Dental care professionals; ECP = Extended care permit; FQHC = Federally Qualified Health Centres; NHS = National Health Service

Four studies reported overall acceptability by patients who were treated by DCPs (Barnes *et al.,* 2018; Dyer *et al.,* 2013; Macey *et al.,* 2016; Nicoll *et al.,* 2016). Preventive and periodontal treatment by DHs were generally well accepted by adult patients (Macey *et al.,* 2016). Negative acceptability by and patients and parents of young patients was identified if the nature of delegated treatment included deciduous extractions and pulp therapy, and if the parents of younger patients had existing dental anxiety (Dyer *et al*., 2010; Dyer *et al*., 2013). Factors that influenced acceptability included consumerist and collectivist perspectives, the familiarity of the dental team, communication, trust, continuity of care (Dyer *et al.,* 2013), and reduced treatment costs (Nicoll *et al.,* 2016). Routine check-ups had greater acceptance if delegation was alternated between dentists and DCPs and was clearly communicated to patients and parents of young patients (Macey *et al.,* 2016).

Overall, these studies demonstrated that DCPs were not practicing to the level of competency permitted within their scope of practice (Macey *et al.,* 2016; Tuesner *et al.,* 2016; Turner and Ross, 2018; Wanyonyi *et al.,* 2014). Lack of professional support (Gnich *et al.,* 2014) and poor acceptance by dentists were significant barriers to this (Mehta and Erwin, 2018). A telephone survey of 1,000 adults in the UK found that most respondents had poor awareness of the DT role (Dyer *et al.,* 2010). Elsewhere, even community members in remote Alaskan villages found the permitted scopes of practice of DCPs confusing (Senturia *et al.,* 2018). Lack of resources including clinical space, administrative and dental nurse support was also reported by DCPs to hinder professional practice (Brocklehurst *et al.,* 2016; Cowpe *et al.,* 2013; Gnich *et al.,* 2014).

Discussion

This review comprehensively assessed the current literature investigating the enablers and barriers to utilisation of skill-mix in the oral health workforce. Within the limitations of our search, the data highlighted several key themes.

Common enablers included: clearly defined regulatory, policy and remuneration systems that incentivised the utilisation of skill-mix and a focus on a needs-led approach to dental service models and funding (macro-level); improved productivity and efficiency and teamwork within the workplace (meso-level); or positive perceptions and support from dental professionals and patients, or awareness on the permitted duties of DCPs (micro-level).

Common barriers evident across several studies included: remuneration systems that disincentivised the utilisation of skill-mix (macro-level); underutilised referral systems or patterns to DCPs (meso-level); or negative perceptions from dental professionals and patients, or lack of awareness of DCPs roles (micro-level).

With these in mind, there is a need for better alignment between the financial incentives of remuneration systems and government contracts for the use of DCPs (Brocklehurst and Macey, 2015). However, the authors noted that such possibilities are constrained by current regulations and contractual arrangements that limit the ability of DCPs to undertake some services without the oversight of dentists (Brocklehurst *et al.,* 2016; Cowpe *et al.,* 2013; Robinson *et al.,* 2019; Sun and Harris, 2011; Turner and Ross, 2017). Understandably, underserved populations could significantly benefit from a growing skill-mix to reduce inequalities in accessing dental services. In particular, oral health workforce modelling in Australia and the UK had shown a significant demand for both DTs and OHTs and their effectiveness in reducing costs (Gallagher *et al.,* 2014; Nguyen *et al.,* 2019; Wanyonyi *et al.,* 2015). Furthermore, the State of Victoria in Australia was one example where higher OHT to dentist ratios resulted in discernible improvement to public funding and costs (Duckett *et al.,* 2019), suggesting the ability to reinvest these savings into other oral health initiatives. A reorganisation of service delivery incentives, such as a model that favours preventive care over restorations and capitation that rewards the treatment provider directly, are just some examples that could facilitate the better use of skill-mix at a macro-level.

Individual practice-led referral systems and patterns that support the role of DCPs as possible leaders of preventive services, and workplace characteristics that acknowledge the dentist as experts in the more complex aspects of general dentistry are some examples that may target these determinants at the meso-level (Rainchuso and Salisbury, 2017). Notably, dentists, as leaders and often employers of team members, are pivotal in the utilisation of skill-mix and should be acknowledged for their ability to facilitate and implement change. Therefore, payment systems at the practice-level that rewards the delegation of treatment to DCPs should be considered (Brocklehurst and Macey, 2015; Harris and Sun, 2012a).

Sources found that social acceptability by patients and parents of young patients towards DCPs were further enhanced when communication and support were maintained with the primary dentist (Dyer *et al.,* 2013; Dyer *et al.,* 2010). Patients or parents of young patients from underserved backgrounds were more likely to accept treatment by DCPs when it was understood that treatment would be of high quality, be relatively cost-effective, and reduce public waiting times for services (Nicoll *et al.,* 2016). Thus, professional education, increased societal and public awareness, and supportive collaboration amongst dental professionals should aim to breakdown negative perceptions and attitudes towards skill-mix. Further recommendations at the micro-level should seek to address DCP-led concerns, including perceptions of limited professional support and lack of resources (Brocklehurst et al., 2016; Cowpe *et al.*, 2013; Gnich et al., 2014).

To address barriers across macro-, meso- and micro-level categories, changes to professional education and clearer delineation of professionals' roles that recognise the need for preventive approaches to service delivery and funding models, collaboration between dental professionals, and a focus on population-based dental interventions are warranted. However, changes in skill-mix and redesign of professional roles have faced considerable opposition from professional bodies in the past (Bohmer and Imison, 2013). More promisingly, in Australia, a revised *Scope of Practice Registration Standard* to permit DCPs to practice in direct access settings is proposed to take effect mid-2020 (Dental Board of Australia, 2020). These changes aim to increase the capacity of services to increase access

Table 3. Mixed-Methods Appraisal Tool and quality scores of studies included in the review

Screening questions: *Do all studies in the review pass the screening questions?* Yes
Are there clear research questions? Do the collected data address the research questions?

1. Critical Appraisal Checklist QUALITATIVE

	1.1. Is the qualitative approach appropriate to answer the research question?	*1.2. Are the qualitative data collection methods adequate to address the research question?*	*1.3. Are the findings adequately derived from the data?*	*1.4. Is the interpretation of results sufficiently substantiated by data?*	*1.5. Is there coherence between qualitative data sources, collection, analysis and interpretation?*	*Overall quality score (%)*
Dyer *et al.* (2013)	Yes	Unclear	Yes	Yes	Yes	80
Harris and Sun (2012a)	Yes	Yes	Yes	Yes	Yes	100
Harris and Sun (2012b)	Yes	Yes	Yes	Yes	Yes	100
Nicoll *et al.* (2016)	Yes	Yes	Yes	Yes	Yes	100
Robinson *et al.* (2019)	Yes	Unclear	Yes	Yes	Yes	80
Senturia *et al.* (2018)	Yes	Yes	Yes	Yes	Yes	100
Sun and Harris (2019)	Yes	Yes	Yes	Yes	Yes	100

2. Critical Appraisal Checklist QUANTITATIVE DESCRIPTIVE

	2.1. Is the sampling strategy relevant to address the research question?	*2.2. Is the sample representative of the target population?*	*2.3. Are the measurements appropriate?*	*2.4. Is the risk of nonresponse bias low?*	*2.5. Is the statistical analysis appropriate to answer the research question?*	*Overall quality score (%)*
Ab-Murat *et al.* (2015a)	Unclear	Unclear	Yes	Yes	Yes	60
Ab-Murat *et al.* (2015b)	Unclear	Unclear	Yes	Yes	Yes	60
Bailit *et al.* (2012)	Yes	Unclear	Yes	NA	Yes	75
Barnes *et al.* (2018)	Yes	Unclear	Yes	Yes	Yes	80
Beazoglou *et al.* (2012a)	Yes	Unclear	Yes	No	Yes	60
Beazoglou *et al.* (2012b)	Yes	Unclear	Yes	NA	Yes	75
Beazoglou *et al.* (2012c)	Yes	Unclear	Yes	NA	Yes	75
Dyer *et al.* (2010)	Yes	Unclear	Yes	Yes	Yes	80
Gallagher *et al.* (2010)	Yes	Unclear	Yes	NA	Yes	75
Gallagher *et al.* (2013)	Yes	Unclear	Yes	NA	Yes	75
Harper *et al.* (2013)	Yes	Yes	Yes	NA	Yes	100
Hill *et al.* (2017)	Yes	Unclear	Yes	No	Yes	60
Matthiesen (2012)	Yes	Unclear	Yes	NA	Yes	75
Mehta and Erwin (2018)	Yes	Unclear	Yes	No	Yes	60
Nguyen *et al.* (2017)	Yes	Unclear	Yes	NA	Yes	75
Tuesner *et al.* (2016)	Yes	Unclear	Yes	No	Yes	80

Table 3. Continued overleaf...

Table 3. Continued...

Wanyonyi *et al.* (2014)	Yes	Yes	Yes	NA	Yes	100
Wanyonyi *et al.* (2015)	Yes	Unclear	Yes	NA	Yes	75
3. Critical Appraisal Checklist MIXED-METHODS						
	3.1. Is there an adequate rationale for using a mixed-methods design to address the research question?	*3.2. Are the different components of the study effectively integrated to answer the research question?*	*3.3. Are the outputs of the integration of qualitative and quantitative components adequately interpreted?*	*3.4. Are divergences and inconsistencies between quantitative and qualitative results adequately addressed?*	*3.5. Do the different components of the study adhere to the quality criteria of each tradition of the methods involved?*	*Overall quality score (%)*
Brocklehurst *et al.* (2016)	Yes	Yes	Yes	Yes	Yes	100
Cowpe *et al.* (2013)	Yes	Unclear	Yes	Unclear	Unclear	40
Gnich *et al.* (2014)	Yes	Yes	Yes	Yes	Yes	100
Macey *et al.* (2016)	Yes	Yes	Yes	Yes	Yes	100
Myers *et al.* (2014)	Yes	Yes	Unclear	Unclear	Unclear	40
Rainchuso and Salisbury (2017)	Yes	Unclear	Unclear	Yes	Yes	60
Turner and Ross (2017)	Yes	Yes	Yes	Yes	Yes	100

NA = Not applicable

and reduce waiting times among underserved communities (Dental Board of Australia, 2020). This may highlight the benefits and use of skill-mix within the oral health workforce and push to address barriers such as those identified within this review.

Limitations and strengths

Limitations in the design of the review are acknowledged. The search was broad to capture a wide range of studies and optimise the generalisability of the findings. This heterogeneous method of investigation precluded a meta-analytical synthesis of the results. The included study designs necessitated a narrative synthesis, which had several limitations. Quality appraisal and data extraction relied heavily on the reviewers' interpretation of the literature, which could have introduced bias.

Moreover, given the broad scope of skill-mix in dentistry (including, tangentially, direct access to DCPs, and workforce patterns of DCPs), the authors note that some relevant sources could have been missed leaving the possibility of lost or differing viewpoints that might restrict the global applicability of the review.

However, there are several important strengths to this review. The rigorous methodological approach to assess the confidence in the results improved the credibility, reliability, and transparency to the analysis. It helped to inform the interpretation of the results to understand and answer the research question.

Implications for future research

This review found limited quantitative evidence for the use of oral health skill-mix beyond operational and analytical modelling of the capacity to meet current dental health care needs. Furthermore, the complex relationships between regulatory constraints defining the permitted duties of DCPs, contractual and remuneration arrangements, health care provider behaviour and attitudes (such as referral and delegation patterns, acceptability of DCPs), and patients experiences in receiving care from DCPs need greater exploration to improve the quality and understanding of skill-mix in dentistry. The barriers and enablers identified in this review have the potential to be used to develop interventions to support oral health skill-mix, and to inform efforts to develop local, state and national workforce planning and development. Such efforts are imperative, not only to improve understanding of the importance of skill-mix in dentistry but also to promote a needs-led approach to the provision and experience of quality care and reduce poor oral health outcomes within underserved populations.

Conclusion

This systematic review presented a comprehensive, synthesis of the barriers and enablers to skill-mix in the oral health workforce using a macro-, meso-, and micro-level framework. Understanding the barriers and enablers from a multi-level, dynamic framework requires further high-quality research to fully appreciate its importance in addressing oral health care needs within populations and increase generalisability to oral healthcare settings.

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Appendix 1. Core search strategy developed from MEDLINE (via Ovid)

Limiters: English language; 2010 – April 2020
Searches:
"oral health", "dental health services", "delivery of health care", "patient care team", dentist*,"dental therapist*", "dental hygienist*", "oral health therapist*", "dental prosthetist*", "dental auxiliaries", "dental care professional*", "professional* complementary to dentistry", "dental nurse*", "dental practitioner*", "oral health practitioner*", "oral health team", "dental team", "skill mix", skill-mix, "role substitution", "role supplementation", "role delegation", substitution, supplementation, delegation, referral
Boolean operators: AND/OR
Results: 1, 599 records
Eligible articles for systematic review: 32