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REVIEW ARTICLE

# Meta-research publications in dentistry: a review

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**Abstract**

The present scoping review has the objective of providing an overview of meta-research in dentistry. A search of the PubMed database was performed for the period 11 October 2014 to 10 October 2019. Study selection and data extraction were performed independently by one author; prior to this, a random sample of 10% of the retrieved titles and abstracts were independently screened by two authors, achieving agreement of >80% on eligibility for initial inclusion, corresponding to good agreement. The following information was extracted from the full text of each article: meta-research area of interest; study design; type of studies evaluated in the meta-research; type of methodology used in assessment of the primary research; conflicts of interest reported; sponsorships reported; dental discipline; journal of publication; country of the first author; number of citations; and impact factor. A total of 7800 documents were initially retrieved. After analysis of the title/abstract and the full text of each article, and a snowballing procedure, 155 meta-research studies were identified and included. The 'methods' and 'reporting' meta-research areas were the most prevalent, with 73 (47%) and 61 (40%) studies, respectively. General dentistry, and orthodontics and dentofacial orthopaedics were the dental specialties with the greatest number/proportion of included studies with 45 (29%) and 28 (18%) studies, respectively. These findings may help to prioritize future meta-research in dentistry, consequently avoiding unnessecary investigations, and increasing the value of oral and dental research.

**KEYWORDS**

biomedical research, methods, oral health, reporting, research design

## INTRODUCTION

Research plays a pivotal role for the improvement of oral health and care. It provides and advances insights into the mechanisms through which social, political, behavioural, psychological, and biological determinants, as well as risk factors, influence oral health and its correlates in terms of quality of life and well-being. Successes in achieving improvements in oral health are being driven by research in the humanities, natural sciences, and technology, and in biomedical and health research, in a spirit of (self-)critical thinking (1). For example, clinical research is one of the pillars of the evidence-based dentistry concept, together with other important approaches which are directly related to clinical decision-making (2).

The typical 'route' in the clinical research process involves testing of potential diagnostic and therapeutic approaches. Usually, this is performed initially at more basic levels (e.g., using *in vitro* and animal experiments) and then in clinical trials on humans. During this process, several biases and confounders may interfere with the accuracy of the

findings. For example, a methodologically unsound animal experiment may provide invalid and unreliable evidence to be further tested in clinical trials. This would put people at risk, as well as raise ethical issues on conducting animal experiments without proper planning (3,4). Such and similar limitations can occur at any stage of the research process: for example, when clinical studies are of low quality and produce possibly biased results. Other concerns include post hoc hypothesizing (HARKing), p-hacking, outcome switching, selective reading or citing of literature, salami-slicing, mass production of redundant/misleading/conflicted systematic reviews and meta-analyses, hyperprolific authors, poor conduct and reporting of economic evaluation studies , financial and non-financial conflicts of interest among researchers, as well as more explicit and indisputable forms of unethical behaviour, such as plagiarism and data fabrication (5-14). Challenges may also occur when authors report that they have received industry funding but declare no potential conflict of interest (COI). Such lack of transparency in reporting hinders accurate insights into the extent to which there might be a potential COI. Similar concerns exist for the (non-)reporting of non-financial COI (15,16). For example, this can occur when there is no detailed information about a non-financial relationship of an author and a third party who might have an interest in the results reported in the article, or when the background/personal views of the authors affect how the study is conducted, reported, and interpreted.

Meta-research is an emergent part of research that is used to evaluate how research is being planned and conducted (17). In other words, meta-research focuses on the research that has already been published in order to understand its quality and reliability, as well as the determinants associated with high-quality research. For instance, meta-research can explore the association between study characteristics, such as source of funding and associated levels of risk of bias and research outcomes (18). This type of research is important for understanding the methodological gaps in research and for identifying potential room for improving the quality of research. Scientific integrity is part of a broad ethical framework, which emphasizes the contribution of science to society (1).

The current state of meta-research in dentistry has not been examined systematically and is largely unknown. Therefore, the objective of the present study was to provide an overview of meta-research publications in dentistry to identify which meta-research areas are more and less prevalent in this field.

# MATERIAL AND METHODS

## Definitions

Following the proposal of Ioannidis et al. (17), meta-research was defined as 'scientific research on research itself'. More specifically, it was defined as the type of research that applies different methodologies to understand how research is carried out, ultimately to improve the overall quality of research. In the present study, a review was defined as a study compiling primary studies (for example, randomized clinical trials [RCTs]). An overview was defined as a review of reviews.

## Eligibility criteria

Studies included were classified by the authors of this study based on the suggestions made by Ioannidis et al. (17). Studies were included if they evaluated primary research or secondary research in the form of overviews of reviews, reviews with a meta-research aim, and overview studies of health economic evaluations published in any dental field. Studies were excluded if they were overviews or reviews with effectiveness/efficacy or harm as the primary focus; if they were other categories of study design without any type of evaluation, such as editorials and commentaries; or if they were studies reported in any language other than English.

## Search of articles

The search for potential meta-research articles was performed in the PubMed database by one author (KS) and covered the period from 11 October 2014 to 10 October 2019. The detailed search strategy was adapted from the Meta-Research Innovation Center at Stanford (METRICS) (19) and is reported in Table 1. Given that the search functionalities of PubMed for identifying publications in dental journals were considered more expedient in comparison with those of other databases, and that the screening of even larger numbers of titles/abstracts (beyond PubMed) was deemed unfeasible within the available time resources of the research team, we refrained from searching databases other than PubMed. Nevertheless, we aimed to increase the sensitivity of the search by applying the snowballing technique (20), which involves scrutinization of the reference lists of the articles retrieved from the PubMed database.

## Selection of articles

A randomly selected sample of titles and abstracts retrieved from PubMed, representing 10% of the overall sample, was independently screened by two authors (KS and SL) who achieved good agreement (>80%) on eligibility for initial inclusion. The sample was randomized through an online program (randomizer.org). Thereafter, one author (KS) screened the remainder of the titles and abstracts. Similarly, two authors

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**TABLE 1** Search strategy applied to PubMed

| | | |
|---|---|---|
| #8 | Search (#1 OR #2 OR #3 OR #4 OR #5) Filters: published in the last 5 years; Dental journals | 7,800 |
| #7 | Search (#1 OR #2 OR #3 OR #4 OR #5) Filters: Dental journals | 28,500 |
| #6 | Search (#1 OR #2 OR #3 OR #4 OR #5) | 1,419,150 |
| #5 | Search ("quality of reporting" OR "completeness of reporting" OR "reporting completeness" OR "risk of bias" OR "methodological quality" OR "methodologic quality" OR "meta epidemiological" OR meta-epidemiological) | 32,347 |
| #4 | Search ("peer review*" OR "post-publication" OR "pre-publication") | 20,252 |
| #3 | Search (reproducibility OR replicability OR "data sharing" OR "data deposition" OR "data repository" OR replication OR "reproducible research" OR "replicable research") | 660,529 |
| #2 | Search ("conflict of interest" OR "conflicts of interest" OR "conflicts of interests" OR consort OR prisma OR equator OR strobe OR stard OR entreq OR squire OR spirit OR coreq OR morecare OR brisq OR cobra OR clinpk OR ohca OR mibbi OR credeci OR tripod OR ragee OR eular OR camarades OR tevar OR quantec OR sampl OR strega OR rehbar OR cheers OR stricta OR grras OR arrive OR reporting OR "publication bias" OR metabias OR "meta-bias") | 465,360 |
| #1 | Search (misconduct OR integrity OR fraud OR falsif* OR fabric* OR plagiar* OR "questionable research practice" OR "questionable scientific practice" OR "confirmation bias" OR "optimism bias") | 287,993 |

(KS, CMF) scrutinized the full text of a random sample of 10% of the articles, after which one author (KS) continued with the remainder of the articles to determine whether the articles met all inclusion criteria. The snowballing approach was conducted independently by two authors (KS, CMF). The full list of articles excluded, with reasons for exclusion, was documented. Any uncertainties regarding the inclusion or exclusion of papers were discussed until consensus was reached.

## Data extraction and analysis

Two reviewers (KS, CMF) achieved good agreement (>80%) for extraction of data from a sample of eligible studies (representing 10% of the total sample)). Thereafter, extraction of data from the remaining articles was performed by one reviewer (KS) (21). In the event of disagreement, discussion between KS, CMF, and SL was performed to reach a final consensus. The following information was extracted from the selected articles into standardized forms: country of the first author; dental discipline (22); meta-research area of interest (Methods, Reporting, Reproducibility, Evaluation, and Incentives) (17) (Table 2); study design; type of studies evaluated in the meta-research; type of methodology used in the assessment of primary research; journal of publication; impact factor in 2019; number of citations (Google Scholar); sponsorship report; and COI reported.

## Assessor training

One author (CMF) tested the data-extraction form for lack of clarity using a sample of 10 randomly selected studies through an online program (randomizer.org). Consequently, two assessors (KS, SL) tested the refined form and extracted data from an additional 10 randomly selected studies. Between the rounds of testing, the standardized form was updated accordingly and, after reviewing the updated, refined data-extraction form in a pilot test (n = 10), full-scale data extraction was implemented.

# RESULTS

## Studies selected

Our initial search of PubMed identified 7800 documents (Figure 1). After assessment of titles and abstracts, 114 studies, potentially suitable for inclusion, remained. After scrutinizing the full text of these studies, five were excluded. Snowballing of the references of the 109 remaining studies retrieved a further 46 studies. Therefore, 155 meta-research studies were included in our final analyses (Table S1). The flow of the search and selection are described in Figure 1. The list of articles excluded, with the respective reasons for exclusion, is reported in Table S2.

## Study characteristics

Table 3 reports the characteristics of the meta-research studies published in dentistry. The studies included were published between 2014 and 2019 (median = 2017; interquartile range [IQR]: 2016–2018). The most prevalent type of study used in meta-research was the review ($n = 108$; 69.7%). Most studies focused on general dentistry ($n = 45$, 29.0%) or orthodontics and dentofacial orthopaedics ($n = 28$, 18.1%).

**TABLE 2** Meta-research areas (reference 17)

| Area | Detailed explanation |
|---|---|
| Methods: *performing research* (study design, methods, statistics, research synthesis, collaboration, and ethics | Biases and questionable practices in conducting research, methods to reduce such biases, meta-analysis, research synthesis, integration of evidence, cross design synthesis, collaborative team science and consortia, research integrity and ethics |
| Reporting: *communicating research* (reporting standards, study registration, disclosing conflict of interest, information to patients, public, and policy-makers | Biases and questionable practices in reporting, explaining, disseminating, and popularizing research, conflicts of interest disclosure and management, study registration and other bias-prevention measures, and methods to monitor and reduce such issues |
| Reproducibility: *verifying research* (sharing data and methods, repeatability, replicability, reproducibility, and self-correction | Obstacles to sharing data and methods, replication studies, replicability and reproducibility of published research, methods to improve them, effectiveness of correction and self-correction of the literature, and methods to improve them |
| Evaluation: *evaluating research* (pre-publication peer review, post-publication peer review, research funding criteria, and other means of evaluating scientific quality | Effectiveness, costs, and benefits of old and new approaches to peer review and other science assessment methods, and methods to improve them |
| Incentives: *rewarding research* (promotion criteria, rewards, and penalties in research evaluation for individuals, teams, and institutions | Accuracy, effectiveness, costs, and benefits of old and new approaches to ranking and evaluating the performance, quality, value of research, individuals, teams, and institutions |

Clinical trials/RCTs were the types of primary research most frequently evaluated ($n$ = 56, 36.1%). More than 20 different types of methodology were used to analyze the primary studies included in the reviews and overviews of reviews. A combination of two or more methodologies was used in 22 (14.2%) of the meta-research studies. The most commonly used methodologies were the Consolidated Standards of Reporting Trials (CONSORT) checklist for RCTs ($n$ = 20, 12.9%) and A MeaSurement Tool to Assess systematic Reviews (AMSTAR) I and II for systematic reviews of randomized and non-randomized studies ($n$ = 20, 12.9%). Potential COI for authors of meta-research studies was reported in 124 (80.0%) such studies, and sponsorship information was reported in 89 (57.4%) studies. The majority of meta-research studies were published in journals with an impact factor ($n$ = 141, 91.0%), and the studies were cited 1870 times (number retrieved on 3 July 2020) with a median citation rate of 8 (IQR = 3–16). The median impact factor of the journals was 2.43 (IQR = 2.07–3.12). The articles were published in more than 40 different journals; proportionally most were published in the *European Journal of Orthodontics* ($n$ = 13, 8.4%), followed by the *Journal of Dentistry* ($n$ = 12, 7.7%), and the *Journal of Evidence-Based Dental Practice* ($n$ = 11, 7.1%). In this sample of studies, Brazil and Germany were the countries with the highest proportions of first authors, with 20 (12.9%) first authorships each.

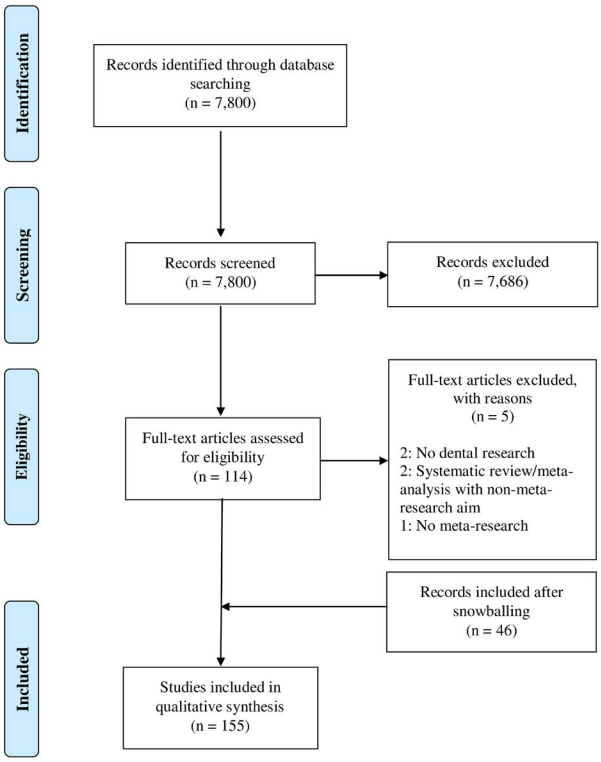


**FIGURE 1** Flow of the literature search and selection processes [Colour figure can be viewed at wileyonlinelibrary.com]

## Meta-research area

Figure 2 depicts the number of studies across the various dental disciplines grouped according to their meta-research area. The most prevalent meta-research areas in this sample were 'methods' and 'reporting', identified in 73 (47.1%) and 61 (39.4%) articles, respectively. Eleven (7.1%) studies included two types of meta-research areas simultaneously. Of the 73 meta-research studies focused on the meta-research area 'methods', 43 (58.9%) were reviews, and 29 (39.7%) were overviews; and of the 61 studies focused on the meta-research area 'reporting', 47 (77.0%)

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**TABLE 3** Characteristics of the studies included

| | | Meta-research area | | |
|---|---|---|---|---|
| | Total ($N = 155$) | Methods ($n = 73$) | Reporting ($n = 61$) | Other ($n = 32$) |
| **Characteristics** | *n* (%) | *n* (%) | *n* (%) | *n* (%) |
| Dental discipline | | | | |
| Dental public health | 1 (0.7) | 0 (0.0) | 0 (0.0) | 1 (3.1) |
| Endodontics | 16 (10.3) | 10 (13.7) | 5 (8.2) | 2 (6.3) |
| General dentistry | 45 (29.0) | 15 (20.6) | 24 (39.3) | 9 (28.1) |
| Geriatric dentistry | 1 (0.7) | 1 (1.4) | 0 (0.0) | 0 (0.0) |
| Implant dentistry | 12 (7.7) | 7 (9.6) | 4 (6.6) | 1 (3.1) |
| Oral and maxillofacial pathology | 6 (3.9) | 2 (2.7) | 2 (3.3) | 2 (6.3) |
| Oral and maxillofacial radiology | 3 (1.9) | 2 (2.7) | 0 (0.0) | 1 (3.1) |
| Oral and maxillofacial surgery | 13 (8.4) | 5 (6.9) | 5 (8.2) | 3 (9.4) |
| Oral oncology | 4 (2.6) | 3 (4.1) | 0 (0.0) | 1 (3.1) |
| Orthodontics and dentofacial orthopaedics | 28 (18.1) | 13 (17.8) | 11 (18.0) | 6 (18.8) |
| Paediatric dentistry | 5 (3.2) | 3 (4.1) | 3 (4.9) | 0 (0.0) |
| Periodontics | 13 (8.4) | 7 (9.6) | 4 (6.6) | 5 (15.6) |
| Prosthodontics | 1 (0.7) | 0 (0.0) | 0 (0.0) | 1 (3.1) |
| Implant dentistry/periodontics | 3 (2.0) | 3 (4.1) | 0 (0.0) | 0 (0.0) |
| Implant dentistry/prosthodontics | 3 (2.0) | 1 (1.4) | 2 (3.3) | 0 (0.0) |
| Orthodontics and dentofacial orthopaedics/periodontics | 1 (0.7) | 1 (1.4) | 1 (1.6) | 0 (0.0) |
| Meta-research area | | | | |
| Evaluation | 23 (14.8) | 0 (0.0) | 0 (0.0) | 23 (71.9) |
| Incentives | 2 (1.3) | 0 (0.0) | 0 (0.0) | 2 (6.3) |
| Methods | 63 (40.7) | 63 (86.3) | 0 (0.0) | 0 (0.0) |
| Reporting | 53 (34.2) | 0 (0.0) | 53 (86.9) | 0 (0.0) |
| Reproducibility | 3 (1.9) | 0 (0.0) | 0 (0.0) | 3 (9.4) |
| Evaluation/methods[a] | 2 (1.3) | 2 (2.7) | 0 (0.0) | 2 (6.3) |
| Evaluation/reporting[a] | 1 (0.7) | 0 (0.0) | 1 (1.6) | 1 (3.1) |
| Methods/reporting[a] | 7 (4.5) | 7 (9.6) | 7 (11.5) | 0 (0.0) |
| Methods/reproducibility[a] | 1 (0.7) | 1 (1.4) | 0 (0.0) | 1 (3.1) |
| Type of methodology[b] | | | | |
| AMSTAR | 10 (6.5) | 7 (9.6) | 2 (3.3) | 1 (3.1) |
| AMSTAR and other(s) | 10 (6.5) | 10 (13.7) | 1 (1.6) | 0 (0.0) |
| CONSORT | 11 (7.1) | 0 (0.0) | 11 (18.0) | 0 (0.0) |
| CONSORT and other(s) | 9 (5.8) | 2 (2.7) | 8 (13.1) | 1 (3.1) |
| PRISMA | 5 (3.2) | 0 (0.0) | 5 (8.2) | 0 (0.0) |
| RoB tool | 14 (9.0) | 10 (13.7) | 4 (6.6) | 1 (3.1) |
| AGREE | 7 (4.5) | 7 (9.6) | 0 (0.0) | 0 (0.0) |
| Bibliometric analysis | 18 (11.6) | 0 (0.0) | 0 (0.0) | 18 (56.3) |
| Others | 18 (11.6) | 13 (17.8) | 7 (11.5) | 1 (3.1) |
| No assessment | 53 (34.2) | 24 (32.9) | 23 (37.7) | 10 (31.3) |

(Continues)

Table 3 (Continued)

| Characteristics | Total ($N = 155$) | Meta-research area | | |
|---|---|---|---|---|
| | | Methods ($n = 73$) | Reporting ($n = 61$) | Other ($n = 32$) |
| | *n* (%) | *n* (%) | *n* (%) | *n* (%) |
| Years of publication | | | | |
| 2014 | 3 (1.9) | 0 (0.0) | 3 (4.9) | 0 (0.0) |
| 2015 | 33 (21.3) | 19 (26.0) | 13 (21.3) | 4 (12.5) |
| 2016 | 24 (15.5) | 11 (15.1) | 9 (14.8) | 4 (12.5) |
| 2017 | 31 (20.0) | 15 (20.6) | 10 (16.4) | 7 (21.9) |
| 2018 | 31 (20.0) | 12 (16.4) | 10 (16.4) | 12 (37.5) |
| 2019 | 33 (21.3) | 16 (21.9) | 16 (26.2) | 5 (15.6) |
| Study design | | | | |
| Review | 109 (70.3) | 43 (58.9) | 47 (77.0) | 26 (81.3) |
| Overview | 42 (27.1) | 29 (39.7) | 11 (18.0) | 6 (18.8) |
| Primary research | 2 (1.3) | 1 (1.4) | 1 (1.7) | 0 (0.0) |
| Unclear | 2 (1.3) | 0 (0.0) | 2 (3.3) | 0 (0.0) |
| Types of primary studies included | | | | |
| Clinical trials/RCTs | 56 (36.1) | 22 (30.1) | 30 (49.2) | 7 (21.9) |
| Epidemiological studies | 4 (2.6) | 4 (5.5) | 1 (1.6) | 0 (0.0) |
| Animal/*In vitro* | 6 (3.9) | 2 (2.7) | 3 (4.9) | 1 (3.1) |
| Qualitative | 1 (0.7) | 0 (0.0) | 1 (1.6) | 0 (0.0) |
| Economic evaluations | 5 (3.2) | 4 (5.5) | 3 (4.9) | 0 (0.0) |
| Combination | 44 (28.4) | 22 (30.1) | 7 (11.5) | 18 (56.3) |
| Other | 17 (11.0) | 9 (12.3) | 8 (13.1) | 1 (3.1) |
| Unclear | 22 (14.2) | 10 (13.7) | 8 (13.1) | 5 (15.6) |
| Conflict of interest reported | | | | |
| Yes | 124 (80.0) | 55 (75.3) | 54 (88.5) | 23 (71.9) |
| No | 31 (20.0) | 18 (24.7) | 7 (11.5) | 9 (28.1) |
| Sponsorship reported | | | | |
| Yes | 89 (57.4) | 44 (60.3) | 41 (67.2) | 14 (43.8) |
| No | 66 (42.6) | 29 (39.7) | 20 (32.8) | 18 (56.3) |

Other: evaluation, incentive, and reproducibility meta-research areas.

AGREE, Appraisal of Guidelines Research & Evaluation; AMSTAR, A MeaSurement Tool to Assess systematic Review; CONSORT, Consolidated Standard of Reporting Trials; PRISMA, Preferred Reporting Items for Systematic Reviews and Meta-Analyses; RCTs, randomized clinical trials; RoB tool, Risk of Bias tool;

[a]Some articles were categorized into two meta-research areas.

[b]Type of methodologies used in reviews/overviews to analyse primary data.

were reviews and 11 (18.0%) were overviews. Twenty-two (30.1%) meta-research studies that focused on 'methods' reported on clinical trials/RCTs as the primary research design, of which 10 reported the use of the Cochrane risk-of-bias tool. Thirty (49.2%) meta-research studies focused on 'reporting' included a clinical trial/RCT as the primary research design. Of these, 19 (63.3%) used the CONSORT checklist. Of studies focusing on the 'evaluation' meta-research area ($n = 23$, 14.8%), a high proportion ($n = 18$, 78.2%) used bibliometric analyses. Table 3 reports the characteristics of the meta-research areas in detail.

## DISCUSSION

The present study aimed to provide an overview of the meta-research conducted in the dental field. The most prolific areas of meta-research were 'methods' and 'reporting', comprising the majority of the currently existing meta-research studies in dentistry. The three other relevant areas of meta-research ('evaluation', 'reproducibility', and 'incentives') were represented in 32 studies. Eleven studies focused simultaneously on two different meta-research areas. Thematically, the greatest number of studies was focused

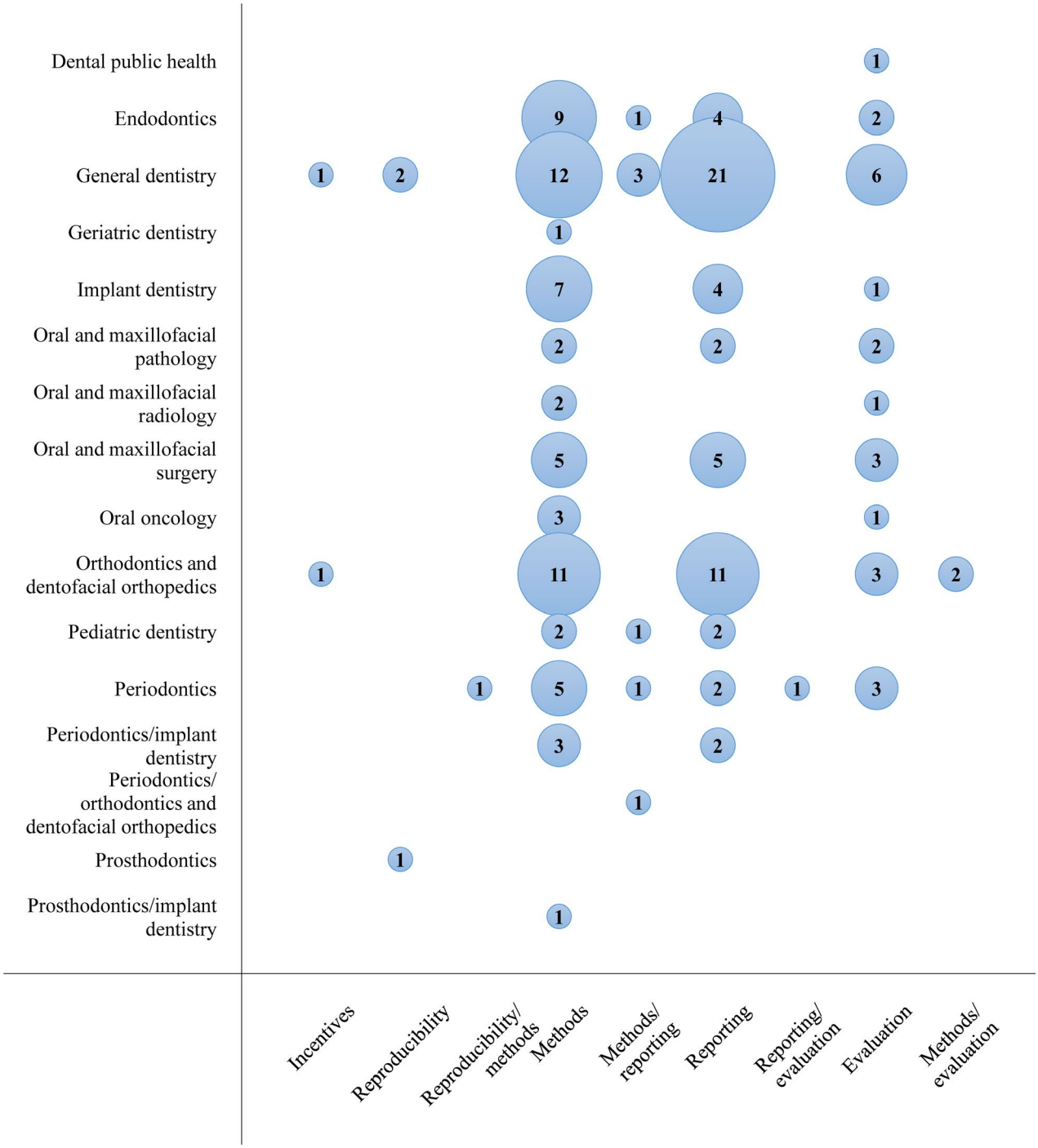


**FIGURE 2** Meta-research area and dental discipline of meta-research articles identified [Colour figure can be viewed at wileyonlinelibrary.com]

on general dentistry followed by orthodontics and dentofacial orthopaedics.

Our findings give an overview of the types of meta-research that are currently being conducted in the dental field. The majority of studies were classified into two meta-research areas – 'methods' and 'reporting' – which might be explained by the historical main focus of dental research. Over the last decades, dental researchers have focused extensively on understanding the prevalence/incidence of diseases and on testing therapeutic approaches for several dental conditions. Despite substantial struggles, the rise of the evidence-based practice (EBP) concept in recent decades has contributed to raising awareness of the importance of methodological robustness of studies to obtain accurate findings. Hence, it is reasonable to hypothesize that because of this increase in EBP, a substantial part of the meta-research focused on methods such as statistical approaches, methodological quality, and risk of bias of the evidence supporting

the identification, diagnosis, and therapies of several dental conditions. However, evidence-based medicine has also been "hijacked" by people with vested interests (23). Therefore, meta-research can also play an important role in identifying and addressing potentially misguided applications of the EBP methodology. One example is the use of meta-research to identify errors in reporting statistical and research design information published in scientific articles (24,25).

The 'reporting' area has also been intensively researched in dentistry in the last decade. The acceptance and endorsement, by several scientific journals, of reporting guidelines supported by the Enhancing the QUAlity and Transparency Of health Research (EQUATOR) Network (26) might explain this trend. Since publication, in 1996, of the first checklist supported by the EQUATOR Network (27), the scientific community has paid increasing attention to the importance of appropriate reporting of the different steps of an RCT. Following publication of the first checklist, other checklists have been developed to assist researchers in reporting other types of study design (28). The dissemination of these checklists seems to have influenced researchers to try to understand the associations between standards of reporting and study characteristics (29,30). Reporting bias, in the form of publication bias, can be detected by meta-research studies: for example, when evaluating the impact and extent of outcome reporting bias in studies included in systematic reviews (31,32). In this area, errors in reporting study designs can also be identified, such as when authors of systematic reviews state that they have included case–control studies as primary studies in meta-analyses but instead have incorrectly included cross-sectional studies as if these were case–control studies. The potential concerns of such a practice are that the inclusion of wrongly classified studies is willingly accepted as a means of increasing the number of included studies and the statistical power, and that the conclusions of these reviews are based on incorrect information.

The other three meta-research areas were rarely explored in this sample of studies. 'Reproducibility' is an important topic that might be necessary to validate the findings of an experiment (33). It has been suggested that more than 70% of researchers fail to reproduce another scientist's experiments and that 50% of the researchers fail to reproduce their own experiments (34). In dentistry, some research on the reproducibility of certain steps of a systematic review has recently been performed (35). However, this overview of meta-research clearly shows a lack of research in the reproducibility of dental studies.

'Evaluation' was mainly represented by bibliometric studies. Bibliometric studies are mainly focused on citation rates and potential association that can be found with study characteristics and outcomes. Other types of 'evaluation' meta-research were underrepresented in this sample. This area is important as it is used to monitor the procedures employed to link the production of knowledge through research and the delivery of this knowledge by the publications of scientific articles. For instance, the peer-review process may introduce bias through several mechanisms (36). Therefore, it is necessary to advance meta-research in dentistry, to identify various types of reviews in this field, and to guide future meta-research to reduce the likelihood of biased peer-reviews.

In the area of 'incentives', only two meta-research studies were identified. In dentistry, this area could be further explored by, for example, testing the level of adherence of patients to medicaments (37,38). Similarly, research could be conducted to understand the reasons for the withdrawal of patients in long-term interventions, and suggest strategies to reduce this. For instance, supportive periodontal maintenance is pivotal for the treatment of periodontitis. Yet, the majority of patients seem to leave the maintenance programme during the first or second year (39).

Meta-research plays an important role in raising awareness, facilitating (self-)critical reflection, and improving the quality of research – including through scientific integrity. The findings of the present study highlight the current state of meta-research in dentistry, thereby contributing to constructive deliberative discussions on improving the quality of research and scientific integrity in dentistry, as well as identifying gaps in knowledge. The findings presented in this paper may help future researchers to prioritize research and meta-research activities and facilitate deliberative (self-)reflection for strengthening the quality of dental research, scientific integrity, and all the ethical dimensions involved. This may also be relevant in relation to recent technological advancements in artificial intelligence (AI) where (commercial) algorithms are being calibrated against standards, the reliability of which crucially depends on the scientific rigour with which the baseline research (= reference for calibration) has been conducted (40).

Eventually, all research activities are potentially subject to human error and this also applies to meta-research. For example, spin or reporting practices that suggest more favourable findings have been found to occur also in research on spin itself (41). Hence, it is important to be mindful of the motives and potentially vested interests of researchers engaging in meta-research.

To our knowledge, this is the first study in dentistry to provide an overview of the current state of meta-research in dentistry. The findings are important for identifying research trends as well as for guiding future research on this topic. It is important, however, to report some limitations of our work. We included only studies published in English and therefore publication bias might be expected. We also searched in only one major electronic database, and this also might contribute to publication bias. However, it is important to emphasize that the sample size of articles included increased by 40% after the snowballing approach was applied. Some consider

the snowballing technique a reasonable alternative to the use of database searches (20). This may be the case in the present specific project, in which structured searches may lack sufficient sensitivity owing to the large variability in types of meta-research study. Finally, also as a result of logistics, we limited our search to recent publications (i.e., those published between November 2014 and October 2019), and we applied the PubMed filter 'dental journals' that could have limited the retrieval of articles on dental meta-research because meta-research on dental topics can also be published in non-dental journals.

It should also be noted that on some occasions it was difficult to classify the type of meta-research. We used the criteria proposed by Ioannidis et al. (17), which suggest some grey areas in the interpretation of the type of meta-research. For example, the authors of some studies do not clearly report whether the intention of the study was to evaluate the reporting or the conducting of the methodology. Hence, a few studies were classified to belong to two meta-research categories. In addition, some meta-research areas may overlap with each other, such as in the case of similar outcomes in the meta-research domains 'evaluation' and 'incentives'. All studies involving bibliometric analyses were classified as 'evaluation'; however, this may be a matter for future debate.

In conclusion, the present study identified several areas of meta-research – more specifically, 'evaluation', 'incentives', and 'reproducibility' – which should be explored further. Highlighting the limited extents of the research activity in these areas is a relevant first step to raise awareness of the importance of reducing waste in research and increasing the value of research in dentistry. An important next step on the research agenda would be to investigate the methodological rigour of existing meta-research studies in dentistry.

## AUTHOR CONTRIBUTIONS

C.M. Faggion Jr contributed to design, data acquisition, and interpretation, first drafted and critically revised the manuscript; S. Listl conceived the study, contributed to design, data acquisition, interpretation, drafted and critically revised the manuscript; K.P.J. Smits contributed to data acquisition and analysis, interpretation, drafted and critically revised the manuscript. All authors gave final approval and agree to be accountable for all aspects of the work.

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## CONFLICT OF INTEREST

The authors declare no potential conflicts of interest with respect to the authorship and/or publication of this article. The first author has meta-research publications included in the sample used for the present study.

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## SUPPORTING INFORMATION

Additional supporting information may be found online in the Supporting Information section.

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