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Interventions to improve antibiotic use among dentists: a systematic review and meta-analysis

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Objectives: To analyse the effectiveness of various strategies, such as audits, education and digital tools, in reducing inappropriate antibiotic prescription by dentists. This study provides a comprehensive overview of how such interventions can contribute to improving clinical practice and combatting antimicrobial resistance in the dental setting.

Methods: An electronic search of articles published until 2023 in the following databases was performed: MEDLINE, SCOPUS, EMBASE, COCHRANE CENTRAL, LILACS and BBO. Systematic data synthesis and meta-analysis was carried out. A total of 23 studies regarding interventions to reduce antibiotic prescription among dentists were included. The studies were mostly published in the UK between 1997 and 2023. Of the 23 studies, three were trials and 20 were pre–post studies.

Results: In general, interventions among dentists resulted in a 70% reduction in the inappropriate prescription of antibiotics (95% CI: 33.3% to 86.4%), which is an extremely high percentage. In the pre–post studies, the reduction was 71% (95% CI 28.8%–88.1%) I^2 99.2%. In randomized controlled trial studies, a 63.9% (95% CI 41%–78.1%) I^2 0% reduction was achieved. The greatest magnitude of effect was found in audit-based interventions with audit and education intervention at 73.3% (95% CI 44%–87.4%) and audit and feedback 75% (95% CI 33%–91.4%), respectively. However, the quality of the evidence is low, mostly due to the study design.

Conclusion: Given the magnitude of the effect found, it has been shown that dentists are receptive to improving their prescription of antibiotics. However, it is clear that there is ample room for improvement.

Introduction

Antimicrobial resistance (AMR) has emerged as a global public health threat and is the subject of increasing attention from organizations such as the WHO.[1] Antibiotic abuse and overuse compromise the effectiveness of these vital medications and play a major role in the growth of AMR.[2] Antimicrobial drugs should be reserved for those patients who would actually benefit from receiving such treatment.[3] According to the WHO, the inappropriate use of antibiotics not only puts people at immediate risk, but also creates a haven for resistant bacteria that could spread throughout communities and continents, potentially leading to deaths from once-treatable diseases. Thus, there is an urgent need for targeted interventions to optimize antibiotic use in all areas of healthcare, including dentistry.[4]

In the larger context of antibiotic stewardship, dentists play a vital role[5–8] since it is estimated that they prescribe 10% of all antibiotics consumed, with a rate of inappropriate prescription of between 50% and 80%.[9] This can lead to an unnecessary increase in resistance, making dentists essential partners in efforts

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to curb AMR.[10] The overuse of antibiotics contributes to a high risk of adverse effects,[11] out of pocket expenses and the higher cost of treatment.[12] Furthermore, the overuse of antibiotics can affect gut microbiota homeostasis and dysbiosis,[13,14] leading to an overgrowth of resistant pathogens that already exist in the patient's microbiota, leading to hard-to-treat superinfections.[15] The aforementioned problems caused by antibiotic overuse have been associated with serious complications such as infections, abnormal brain development, allergies, autoimmune disorders, obesity and an increase in mortality, as well as an increase in healthcare expenditure.[16] In particular, clindamycin has the highest rate of fatal and non-fatal risk of adverse drug reactions of any of the antibiotics commonly prescribed by dentists in relation to *Clostridium difficile*-associated disease.[17,18]

Addressing the issue of antibiotic usage in dentistry is of particular importance in understanding the dynamics of customizing interventions to the unique requirements and difficulties of oral healthcare. Our team has updated a review carried out in 2016,[19] as since that time: (i) numerous additional articles have been published as a result of the increase in concern in society as a whole and among healthcare professionals, health systems and international agencies regarding the consequences of the misuse of antibiotics; (ii) new studies use more up-to-date methodologies, thus providing a higher degree of evidence; (iii) new interventions may have been tested and (iv) a quantitative analysis was not carried out in the previous review.

The main objective of this systematic review is to assess current initiatives aimed at minimizing or improving the prescription of antibiotics by dentists and to evaluate their efficacy, including a meta-analysis. This study attempts to give policymakers and healthcare professionals useful information by combining data from several sources. The findings will not only contribute to the academic literature but will also serve as a practical guide for implementing evidence-based interventions that can mitigate the impact of antimicrobial resistance and, ultimately, protect the usefulness of antibiotics for coming generations.

Material and methods

Design

A systematic review with meta-analysis was carried out following the Preferred Reporting Items of Systematic Reviews and Meta-Analysis (PRISMA) guidelines. The protocol for this review was registered in Prospero (number CRD42023474664).

Information sources and search strategy

An electronic search of the following databases up to 2023 was performed: MEDLINE, EMBASE, COCHRANE CENTRAL, LILACS and BBO. Additionally, the references of the included studies or other similar systematic reviews were reviewed.[19] As a search strategy, the combination of the following keywords was used: dentist, prescription, intervention, antibiotics. The following combinations were used in the literature search:

[(prescription OR prescribing) AND (intervention OR programme OR 'health promotion' OR education OR audit) AND (dentist* OR odontolog* OR 'dental practitioner' OR 'dental practice' OR 'dental health professional') AND (antibiotic* OR antimicrobial)].

Both an ascending search, which consisted of searching the articles for references, and a descending search, which consisted of searching where the included articles were cited, were performed. Based on the findings of these searches, the original search strategy was reconsidered, and a new term, identified during the ascending and descending searches, was added.

Eligibility criteria

The following inclusion criteria were established: (i) epidemiological studies or original article; (ii) on interventions to optimize antibiotic prescription and (iii) aimed at dentists. Reviews, prescription guides, protocols, brief communications, books, letters to the editor, errata and conference abstracts were excluded. Studies involving non-dentist populations or focusing on different clinical settings, such as primary care or hospitals, where prescribing dynamics may differ significantly, were excluded. Studies that did not fit the research designs considered relevant to our review were discarded. Studies in all languages were considered.

For the meta-analysis, studies that did not report the outcome of 'appropriate prescriptions' were excluded as this was a key criterion for our assessment. In the context of this study, appropriate prescriptions were considered those that comply with established clinical guidelines and are justified by the available scientific evidence. This includes appropriate antibiotic selection, correct dosage, adequate treatment duration and consideration of factors such as patients' allergies and pre-existing medical conditions.

Selection and data collection process

All identified references were exported to Rayyan to facilitate their administration and to eliminate duplicates. The study selection process was carried out using the Rayyan QCRI software. (https://rayyan.qcri.org/welcome). Two reviewers (J.M., A.R.) independently examined first the titles and abstracts and subsequently the full texts of the studies retrieved through the search strategy. Any disagreement between reviewers regarding the eligibility of studies was resolved by discussion with a third reviewer (M.F.), with reasons for excluding studies recorded at the full text stage.

Data items

The main outcomes assessed were the number of prescriptions and appropriate prescriptions. In addition, the characteristics of the participants and interventions, primary and secondary outcomes and indications were assessed.

Study risk of bias assessment

J.M. and A.R. independently reviewed the risk of bias in the studies included according to The Evidence Project risk of bias tool, as it has a tool for assessing both randomized and non-randomized study designs.[20] Cases in conflict were reviewed by M.F.

Data extraction, synthesis and analysis

A qualitative synthesis of the included articles was performed according to their main characteristics. A standardized and previously piloted form was used to extract data from the included studies. The extracted information included: study design/setting, participant demographics and baseline characteristics,

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details of intervention and control conditions, outcome data of interest and follow-up times. J.M. and U.V. independently performed data extraction, with any discrepancies being resolved by discussion and consensus with a third author.

A quantitative synthesis for the outcome 'appropriate prescriptions pre–post intervention' was performed using the Comprehensive Metanalysis (CMA) software. Studies without the outcome 'appropriate prescriptions' were excluded from the analysis. Statistical analysis was performed, assessing the proportion of appropriate prescriptions. A random effects model was applied to account for heterogeneity across studies. Heterogeneity was assessed using the I^2 statistic.

To facilitate interpretation, the results were presented in terms of relative risk reduction, which is equivalent to vaccine efficacy expressed as a percentage. This approach is essential to understand the effectiveness of interventions in reducing inappropriate antibiotic prescribing, in a similar way to how vaccine efficacy is assessed in preventing infectious diseases.[21]

In addition, due to the high degree of heterogeneity observed in the included studies, sensitivity analyses were performed and stratified by type of intervention and study design. This heterogeneity, which refers to the variability in results between studies, may influence the generalizability of the findings and suggests that different approaches may have dissimilar effects in different clinical contexts.

Ethical aspects

The principle of value of validity was considered. None of the researchers reported any conflicts of interest. Only primary studies that met ethical criteria were included.

Results

Study selection

During the search, 1914 publications were identified in PubMed, Scopus, Embase, Cochrane, BBO and Lilacs, with one study being identified with other resources (the bibliography of an old systematic review on the same issue) (Figure 1). Following the elimination of duplicates, 1380 studies were reviewed by two researchers using the Rayyan software. Finally, 23 studies were included for qualitative synthesis.[21–42]

Study characteristics

A total of 23 studies regarding interventions to reduce antibiotic prescription among dentists were included.[22–44] These studies were published, predominantly in the UK,[22–26,29–31] between 1997 and 2023. Of the 23 studies, three were trials[25,31,40] and 20 were pre–post studies.[22–24,26–30,32–39,41–44] The intervention types included audit practices with education and feedback,[22,24,26,30,31,35–37,40,43] multimodal interventions[33,39,44] and online prescription tools.[38,39] The studies were mostly carried out in general dentistry with the exception of two studies that were performed specifically in the fields of oral surgery and endodontics.[36,42] The studies were not concerned with a specific antibiotic. Interventions were classified into several categories based on their format. These included presentations, which consisted of educational sessions at conferences or workshops where guidelines on the appropriate use of antibiotics were presented. In addition, online interventions were considered, such as training programmes, educational resources accessible through digital platforms and face-to-face sessions providing personalized training and direct advice to professionals. The intervention period ranged from 1 month to studies of 10 years post intervention (Table 1).

Description of interventions

Studies on a variety of effective interventions to optimize antibiotic prescribing by dentists were identified (Table 1). Educational strategies such as clinical audit and prescribing guidelines have been shown to be effective in reducing unnecessary prescription and improving rationality in the selection of antibiotics. Studies such as Seager *et al.* (2005), Kim *et al.* (2017) and Karaben *et al.* (2020) demonstrated the effectiveness of educational materials, visits and prescribing guidelines in reducing antibiotic prescriptions. Seager *et al.* (2005) found that visits and educational materials were more successful in reducing antibiotic prescriptions than evidence-based guidelines alone. Kim *et al.* (2017) found that antibiotic prescription rates decreased due to behavioural changes caused by the implementation of prescribing guidelines. Audit practices and feedback mechanisms proved to be most effective in the interventions. Thomas and Hill (1997), Palmer *et al.* (2001) and Chopra (2014) found that the effectiveness of audit interventions was related to a significant decrease in antibiotic prescriptions. Additionally, the study of Angarita *et al.* (2022) found that technological interventions such as online courses and virtual learning environments for antibiotic prescribing were instrumental in promoting better antibiotic prescription practices among dentists. The adoption of a virtual learning environment by Angarita *et al.* (2022) resulted in a rapid improvement in dentists' preparedness to prescribe antibiotics appropriately. Similarly, Teoh *et al.* (2020) found that the combination of targeted education and the use of prescribing tools resulted in an improvement in dental prescribing practices. There is also evidence that government policies can reduce antibiotic usage and prescription.[34] Government strategies may include regulating antibiotic prescription through clinical guidelines that limit their use in dental procedures and policies that promote responsible practices. Training programmes for dentists on the proper use of antibiotics and awareness campaigns regarding bacterial resistance have been implemented. Additionally, monitoring systems have been established to track prescriptions in dental clinics, along with periodic evaluations of the impact of these policies. Economic incentives have also been provided to reduce unnecessary prescriptions, with penalties being imposed on professionals who do not comply with the guidelines.

Efficacy of interventions

A meta-analysis was carried out on studies with the variable 'appropriate use of antibiotics before and after the intervention'. Two of these studies were randomized controlled trials (RCTs) while eight were pre–post studies. Seven of them have audit and feedback or education as intervention practices (Figure 2). Overall, the effect of the interventions of the studies included in our meta-analysis reduced inappropriate antibiotic prescription by 70% (95% CI: 33.3% to 86.4%). In the pre–post studies, this figure was 71% (95%IC 28.8%–88.1%) I^2 99.2%. In RCT studies

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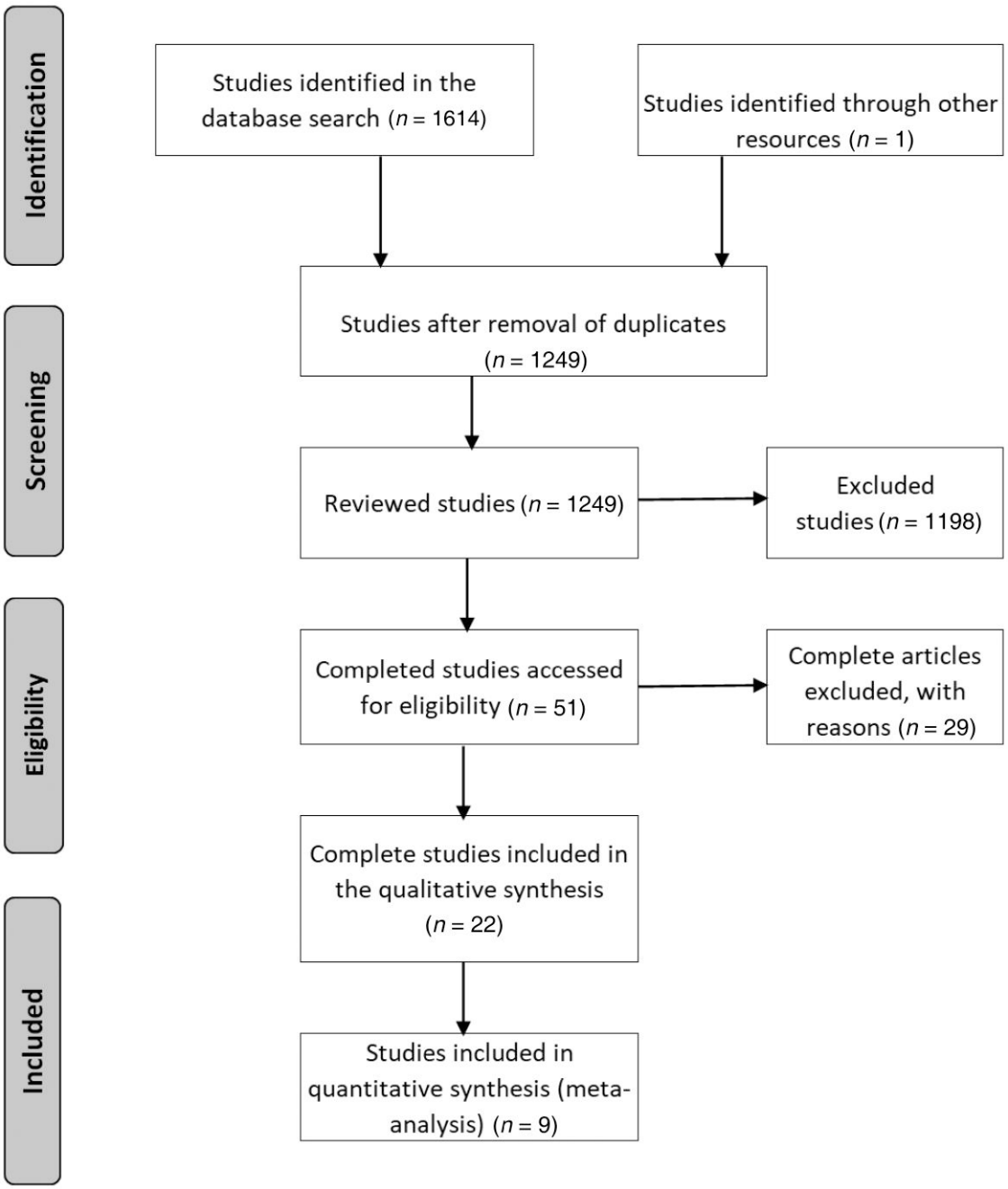

Figure 1. Flowchart of the inclusion of studies.

the percentage of reduction in antibiotic prescription was 63.9% (95%IC 41%–78.1%) I^2 0%. Although feedback involves educational components, it specifically refers to the provision of information regarding performance to the practitioners, which can enhance the educational aspect.

Figure 3 shows the studies grouped by intervention type. Audit and education intervention was effective at a percentage of 73.3% (95%IC 44%–87.4%), with audit and feedback being 75% effective (95%IC 33%–91.4%). However, heterogeneity in the audit and feedback group was I^2 99%, followed by audit and education, I^2 69%.

Analysis was also carried out by year of study, intervention period and dentist specialization (Supplementary material, available as Supplementary data at *JAC* Online Figures S1–S3).

Quality assessment of pooled studies

One issue with pre–post designs is that they do not have a control or comparison group. Furthermore, there was no random selection of participants for assessment. Therefore, the external validity of the studies is lost. In terms of methodological quality,

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Table 1. Characteristics of the included studies

Autor (year)	Country	Sample size[a]	Study design	Intervention type	Specialization	Intervention period	Pathology	Analysis	Primary outcome	Secondary outcome	Results
Thomas and Hill (1997)[22]	UK	132 S	Pre–post intervention	An Audit of antibiotic practices	General Dentists	1 month	Third Molar Surgery	Comparison of pre- and post-values	Number of Prescriptions	Type and route of administration of antibiotics	Usefulness of the audit process in oral and maxillofacial surgery
Steed and Gibson (1997)[23]	UK	320 P	Pre–post intervention	Consensus	General Dentists	4 months	All conditions	Comparison of pre- and post-values	Number of prescriptions		Antibiotic prescribing and the number of prescriptions fell by 50% as a result
Palmer (2001)[24]	UK	175 S	Pre–post intervention	Audit and feedback	General Dentists	6 weeks	All Conditions	Comparison of pre- and post-values	Number of prescriptions Adequate prescriptions	Type of antibiotics, indications	Clinical audit, with the issuing of guidelines and an educational component lead to a more rational and appropriate use of antibiotics in general dental practice. (57.4% versus 70.5%)
Seager (2005)[25]	UK	97 S	RCT	Educational material Pharmacist visit	General Dentists	3 months	All Conditions	Comparison of pre- and post-values within and between group	Number of prescriptions Appropriate prescriptions	Complains on patients	Evidence-based guidelines alone do not improve prescribing. However, visits by a pharmacist may be. (37% versus 67%)
Chate (2006)[26]	UK	212 S 2951 P	Pre–post intervention	Clinical Audit, Guidelines and educational component with feedback	General Dentists	2 months	All Conditions	comparison of pre- and post-values	Adequate prescriptions Number of prescriptions	Type of antibiotics prescribed, regimen, dose, frequency	during the audit the antibiotic prescription was reduced by 43.6%
Ocek (2008)[27]	Turkey	162 S	Pre–post intervention	Rational antibiotic usage course	General Dentist	2 years	All conditions	Comparison of pre- and post-values	level of improvement in knowledge		The knowledge was increased after the course and the difference between pre- and post-tests was found to be statistically significant
Rauniar (2012)[28]	Nepal	1200 P	Pre–post intervention	Feedback educational intervention	General Dentists	6 months	All Conditions	Comparison of pre- and post-values	Number of prescriptions	Mean number of drugs per prescription, most common prescription drugs	Feedback educational intervention of prescription audit is effective

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Table 1. *Continued*

Autor (year)	Country	Sample size[a]	Study design	Intervention type	Specialization	Intervention period	Pathology	Analysis	Primary outcome	Secondary outcome	Results
Zahabiyou (2015)[29]	UK	25 P	Pre–post intervention	Audit and Education	General Dentists	—	All Conditions	Comparison of pre- and post-values	Appropriate prescription	Appropriate antibiotic, correct dosage, frequency, duration	Antibiotic prescribing practices improved after intervention (30% versus 52%)
Chopra (2014)[30]	UK	60 S	Pre–post intervention	Audit and Education	General dentists	2 months	Acute Dental Pain and Infection	Comparison of pre- and post-values	Appropriate prescription		Clinical audit, in conjunction with education, and prescribing guidelines can change antibiotic prescribing patterns among general dental practitioners
Elouafkaoui (2016)[31]	UK	795 S	RCT	Audit and feedback A&F + Written Behaviour Change Message Current practice	General dentists	6 months, 9 months	All conditions	Comparison of pre- and post-values within and between group	Number of prescriptions	Number of amoxicillin 3 g dispensed, number of broad-spectrum antibiotics, daily dose prescribing rates	Audit and feedback derived to a significant reduction in the antibiotic prescribing rate of dentists
Kim (2017)[32]	Korea	22 098 P	Pre–post intervention	Prescription guidelines. Removal of prescription button	General Dentists	Three months	All Conditions	Comparison of pre- and post-values	Number of prescriptions	Patient, treatment and dentist factors	The interventions induced behavioural changes in the dentists and were effective in lowering the antibiotic prescription rates in a dental hospital
Gross (2019)[33]	United States	—	Pre–post intervention	Multimodal intervention	General Dentists	8 months	All Conditions	Comparison of pre- and post-values	Antibiotic prescribing rate		A 72% decrease in antibiotic Prescribing was observed in urgent care visits after implementation of multimodal intervention
Lund (2020)[34]	Sweden	1 276 203 P	Retrospective cohort	Governmental strategies	General Dentist	8 years	All conditions	Comparison of pre- and post-values	Number of prescriptions		Governmental strategies can reduce antibiotic prescriptions
Karaben (2020)[35]	Argentina	417 P	Pre–post intervention	Educational intervention (Audit and Feedback)	General Dentists	6 months	All Conditions	Comparison of pre- and post-values	Number of prescriptions	Diagnostic, medicine prescription dosage and frequency	An improvement was observed through an educational intervention

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Kusumoto (2020)[36]	Japan	742 P	Pre–post intervention	Educational intervention	Oral and maxillofacial surgery dentists	6 months	All Conditions	Comparison of pre- and post-values	Number of prescriptions	Patient characteristics, adverse effects	A remarkable reduction was noted in the prescription of oral third-generation cephalosporins, but increased use of penicillins
Teoh (2020)[39]	Australia	26 S	Pre–post intervention	Multimodal intervention: Education and online prescribing tool	General Dentists	3 months	All Conditions	Comparison of pre- and post-values	Number of prescriptions Appropriate prescriptions	Confidence of practitioners towards the prescribing website. Participants feedback	The intervention of targeted education and the prescribing tool was effective in improving dental prescribing (44.6% reduction)
Angarita (2022)[38]	Colombia	206 S	Pre–post intervention	Virtual learning environment for antibiotic prescription	General Dentists	6 months	All Conditions	Comparison of pre- and post-values	Awareness, attitudes, and intention to practice	Type of antibiotic, satisfaction with the learning environment	The use of a virtual learning environment designed for dentists contributed to a rapid improvement in awareness and intention to practice antibiotic prescription; however, their attitudes and information retention need reinforcement
Debra Goff (2022)[37]	United States	15 S	Pre–post intervention	Antibiotic stewardship education from Experts, Audit and Feedback	General Dentists	6 months	All Conditions	Comparison of pre- and post-values	Appropriate prescribing Number of prescriptions	Antibiotic duration, type, appropriate use	After the programme dentist rapidly optimized antibiotic prescribing (19% versus 88% appropriate)
Chehabeddine (2022)[40]	Lebanon	60 P	RCT	Educational intervention	General Dentists	5 months	All Conditions	Comparison of pre- and post-values within and between groups	Number of prescriptions Compliance with guidelines	Indication, type	There was a decrease in the overall antibiotic's prescription
George (2022)[41]	Malaysia	28 S	Pre–post intervention	C-Reactive Protein to reduce antibiotic prescriptions	General Dentists	—	All Conditions	Comparison of prescriptions with and without analysing C-reactive Protein	Number of prescriptions		The CRP rapid test aid in lowering antibiotic prescription

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Table 1. *Continued*

Autor (year)	Country	Sample size[a]	Study design	Intervention type	Specialization	Intervention period	Pathology	Analysis	Primary outcome	Secondary outcome	Results
Marrufo (2022)[42]	Spain	100 S	Retrospective cohort	European Society of Endodontology (ESE) awareness campaign and position statement on antibiotics in endodontics	Endodontics	Comparison with 10 years ago	All conditions	Comparison of pre- and post-values	Antibiotic prescription	Duration of treatment	Antibiotics prescription habits of Spanish endodontists have improved after the ESE awareness campaign and position statement on antibiotics in endodontics
Lim (2022)[43]	Malaysia	7 S 3009 P	Pre–post intervention	Audit and Education	General dentists		All conditions	Comparison of pre- and post-values	Number, appropriateness	Accuracy of prescriptions, type of antibiotics prescribed	Clinical audit in conjunction with targeted interventions resulted in improvement in the antibiotic prescribing patterns
Okihata (2023)[44]	Japan	161 834 P	Pre–post intervention	Pharmacist-led, multi-faceted intervention	General Dentists	5 years	All conditions	Comparison of pre- and post-values	Number of prescriptions		The proportion of prescriptions gradually decreased over the 7-year study period

[a]Sample size: S (Subjects), P (Prescriptions).

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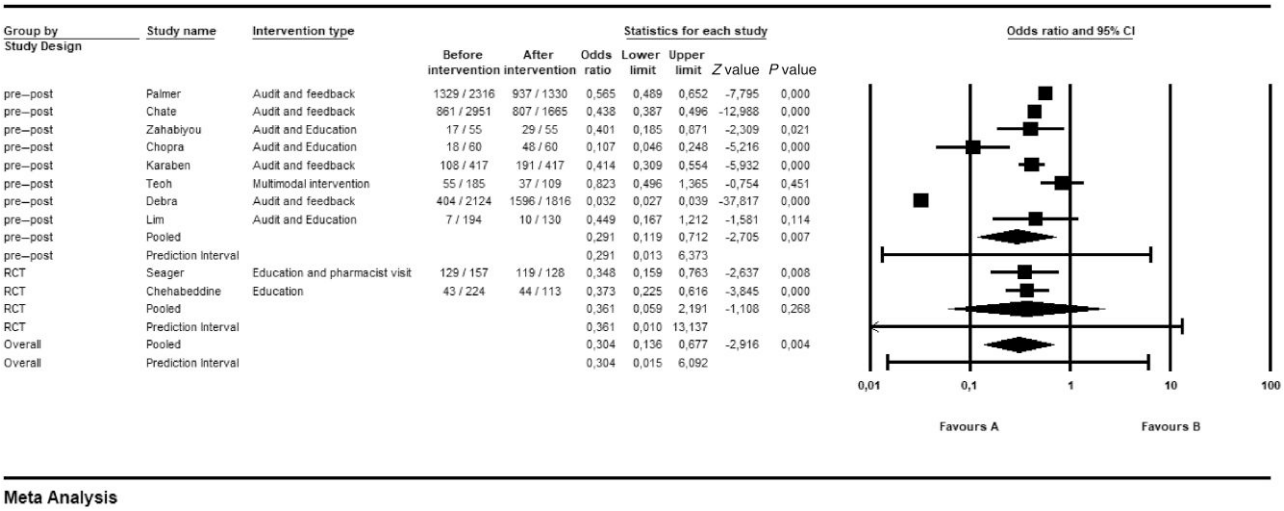

Figure 2. Metanalysis of studies included by study design.

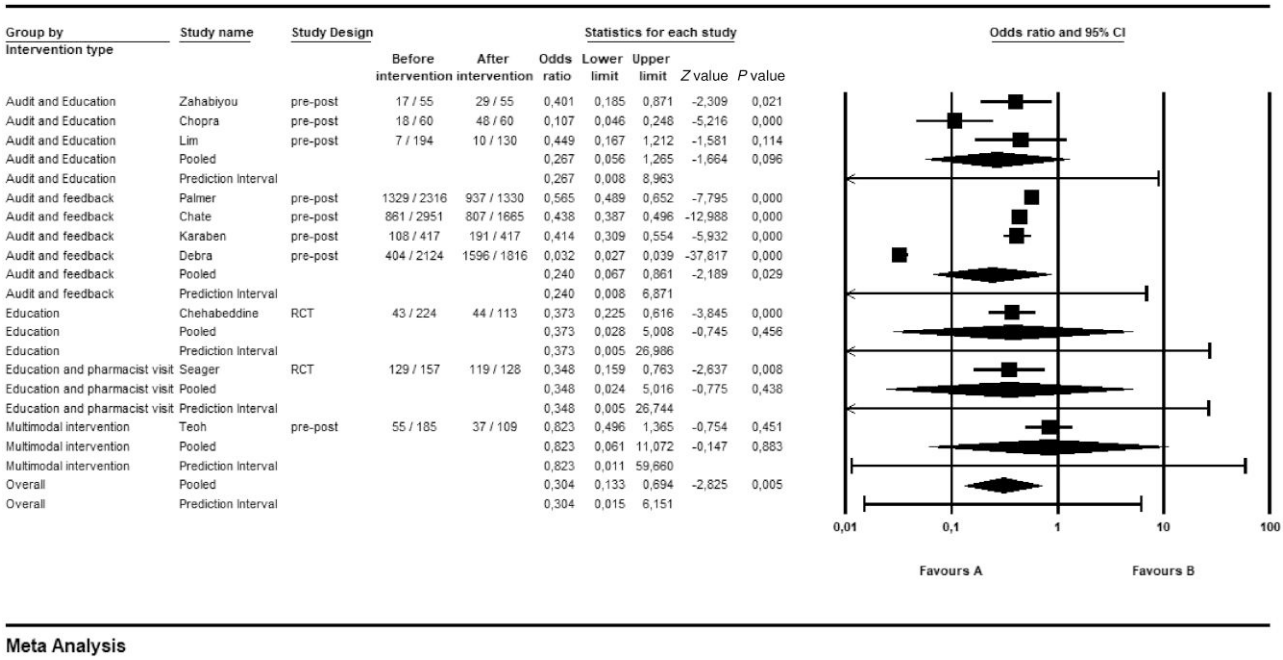

Figure 3. Metanalysis of studies included by intervention.

significant variability can be observed between the studies included in the review. Some studies employ robust designs such as random assignment of intervention groups, thus reducing the risk of selection bias. However, other studies lack a clear control group or do not provide sufficient details regarding participant selection. This could introduce selection bias and affect the internal validity of the results (Table 2).

Discussion

To our knowledge, this is the first meta-analysis evaluating the impact of different interventions to improve antibiotic prescription in dentists. The results indicate that interventions in general among dentists are extremely effective in reducing the inappropriate prescription of antibiotics (reduction of 70%; 95% CI: 33.3% to 86.4%). However, these results must be taken with caution as most of the studies included present methodological weaknesses, mainly due because most are pre–post studies with no concurrent control groups.

The results of our analysis reveal that audit-based interventions are the most effective in reducing antibiotic prescription among dentists. The greatest magnitude of effect was in the audit-based interventions with audit and education intervention at 73.3% (95%IC 44.0%–87.4%) and audit and feedback at

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Table 2. Quality assessment of pooled studies

Study	Cohort	Control or comparison group	Pre/post intervention data	Random assignment of participants to intervention	Random selection of participants for assessment	Follow-up rate of 80% or more	Comparison groups on sociodemographic	Comparison groups equivalent at baseline on disclosure
Thomas and Hill (1997)[22]	Yes	No	Yes	NA	NA	NA	NA	NA
Steed and Gibson (1997)[23]	Yes	No	Yes	NA	No	NR	NA	NA
Palmer (2001)[24]	Yes	No	Yes	NA	No	NR	NA	NA
Seager (2005)[25]	Yes	Yes	Yes	Yes	No	No	Yes	Yes
Chate (2006)[26]	Yes	No	Yes	NA	No	Yes	NA	NA
Ocek (2008)[27]	Yes	No	Yes	NA	NR	NR	NA	NA
Rauniar (2012)[28]	Yes	No	Yes	NA	Yes	Yes	NA	NA
Zahabiyou (2015)[29]	Yes	No	Yes	NA	No	Yes	NA	NA
Chopra (2014)[30]	Yes	No	Yes	NA	No	Yes	NA	NA
Elouafkaoui (2016)[31]	Yes	Yes	Yes	Yes	Yes	Yes	NR	Yes
Kim (2017)[32]	Yes	Yes	Yes	NA	NA	Yes	NA	NA
Gross (2019)[33]	Yes	No	No	NA	NR	NR	NA	NA
Lund (2020)[34]	No	No	Yes	NA	NR	NA	NA	NA
Karaben (2020)[35]	Yes	No	Yes	NA	NR	NR	NA	NA
Kusumoto (2020)[36]	No	No	Yes	NA	NA	NA	NA	NA
Teoh (2021)[39]	Yes	No	Yes	NA	No	Yes	NA	NA
Angarita (2022)[38]	Yes	No	Yes	NA	Yes	Yes	NA	NA
Goff (2022)[37]	Yes	No	Yes	NA	Yes	Yes	NA	NA
Chehabeddine (2022)[40]	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
George (2022)[41]	Yes	No	Yes	NA	No	No	NA	NA
Marrufo (2022)[42]	No	No	No	NA	No	NR	NA	NA
Lim (2022)[43]	Yes	No	Yes	NA	Yes	Yes	NA	NA
Okihata (2023)[44]	Yes	Yes	Yes	NA	NA	Yes	NA	NA

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75.0% (95%IC 33.0%–91.4%), respectively. The results indicate that dentists can use regular monitoring and feedback or education to reflect on their prescribing behaviour and adjust it according to evidence-based guidelines. The previous systematic review of dentists of Loffer *et al.* (2017) also mentioned the benefits of interventions. However, no meta-analysis was performed and no mention was made of which were the most effective interventions. These findings are similar to those of other systematic reviews carried out regarding general practitioners, which have found that interventions such as feedback and prescribing guidelines are effective in reducing the inappropriate prescription of antibiotics.[45]

In this review, feedback has been shown to be effective, although there are few details of the type of feedback. This is an important issue as there are a variety of approaches. It has been shown that personalized feedback provided face-to-face by experts on the subject can be particularly effective in optimizing antibiotic prescribing since it allows direct interaction that facilitates the discussion of specific cases and immediate feedback.[46] This is the method used by the pharmaceutical industry to modify drug prescription habits[47] and has been shown to be more effective than a single short educational session, particularly when feedback is presented together with written material.[48]

There is evidence that active clinician education strategies tend to be more effective than passive strategies.[49] For example, although feedback by email may shorten the time of the audits and prove less expensive,[50] active feedback could be more effective. However, no difference could be observed in the studies included. For example, Goff *et al.* (2022) gave professionals individual report cards of their prescriptions and then discussed them in one-to-one feedback. One aspect not mentioned in these studies, but which may be of particular interest, are low-cost passive interventions such as 'nudges' that influence decision making through subtle cognitive mechanisms. For example, poster-sized commitment letters can be displayed in examination rooms featuring photographs and signatures of clinicians, stating their commitment to avoid inappropriate antibiotic prescribing.[51] Although our review did not find studies in which this type of intervention was carried out, its evaluation is suggested.

Above all, it is important to bear in mind that the effectiveness of each type of feedback can depend on several factors, such as the frequency and quality of the feedback and the receptivity of the recipient. This auditing and active feedback must be carried out continuously as there is evidence that if it is discontinued, there may be a reversal in the improvement of prescription behaviours.[52] More research is needed to directly compare the effectiveness of these different approaches in the specific context of dental practice.

According to our results, the quality of the interventions analysed is suboptimal, since most of them are pre–post studies with no control group and no randomization. The difference between pre- and post-measurements may be due to the statistical law of regression. Therefore, it is necessary to improve the quality of the interventions and for them to be randomized controlled as is the case with doctors and pharmacists.[53] Our study has also identified publication biases, i.e. data that is not communicated. Seasonal variations in the frequency of diseases, commercial pressure from pharmaceutical companies and regulatory policies are some of the external variables that can affect temporal variations in drug prescriptions. However, following the quality assessment, it can be noted that some studies may present an overall higher bias risk. Because most of the studies were conducted in Europe, it may be difficult to make generalizations as they may not reflect the diversity of healthcare worldwide, especially in relation to North America and Latin America regarding clinical practice, prescription behaviours, and even policies on antibiotics. Indeed, it is striking that Latin American countries with overuse of antibiotics do not carry out interventions.

Although the results are positive, this review has several shortcomings. Initially, only 10 studies could be included in the meta-analysis, since not all of them have inappropriate prescriptions as an outcome. Furthermore, the heterogeneity of study designs and interventions made quantitative summaries of the data difficult. Owing to the limited number of RCTs in this review, further high-quality research is needed to strengthen the evidence base for interventions aimed at optimizing antibiotic use among dentists. In addition, it was not possible to explore some effect modifiers, such as years of study of the professionals, because the information was not stated in the studies. Owing to the low number of studies per category, it was not possible to stratify by sources of heterogeneity.

This analysis is limited by the variability inherent in the interventions studied. The observed heterogeneity is intrinsic to the nature of the interventions, which depend largely on human factors, such as staff motivation, communication skills and the size of the groups involved. This variability makes it difficult to replicate the results and limits the generalizability of our conclusions. Additionally, publication biases, inherent to the scientific research process, may have hindered a more exhaustive analysis of heterogeneity. The preference for publishing positive or significant results may lead to an underrepresentation of studies with negative or neutral results, distorting the overall perception of the impact of the interventions.

It should be noted that most of the studies included in this review have a pre–post design, in which the comparison is made with the same group of participants before and after the intervention. Although this design makes it possible to control the baseline characteristics of the participants, it is highly susceptible to the influence of external factors concurrent with the intervention, such as awareness campaigns or changes in clinical practice guidelines. This sensitivity to external factors may confound the results and make it difficult to attribute the observed effect solely to the intervention. A parallel control group design, in which the intervention is compared to a similar group that does not receive it, could mitigate this bias, although in this case, the presence of the intervention in both groups (albeit with different intensity or focus) could dilute the real effect of the intervention.

Another concern is the potential bias derived from the Hawthorne effect. It is plausible that participation in a study on antibiotic prescription generates greater awareness among dentists, which could lead to a temporary improvement in prescribing practices, regardless of the intervention itself. This limitation, inherent to behavioural intervention studies, could have an influence on the results, magnifying the real effectiveness of the evaluated strategies.

It is crucial to distinguish between the prophylactic and therapeutic use of antibiotics. While prophylaxis aims at preventing

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infections in patients at risk, treatment focuses on combatting existing infections. In procedures such as implant placement or extractions, the decision to prescribe antibiotics should be based on an individualized risk-benefit assessment, taking into consideration factors such as the patient's health and the complexity of the procedure.[54] Prophylaxis, when indicated, should follow dosage and duration recommendations, such as administration of 2 g of amoxicillin 1 hour before the procedure or 600 mg of clindamycin in case of allergy or intolerance to beta-lactams.

In summary, while our analysis provides valuable information on the impact of interventions on antibiotic prescription among dentists, it is essential to consider these limitations when interpreting the results. Future studies with more robust designs which adequately control for confounders and address publication biases are crucial in obtaining a more accurate understanding of the effectiveness of these interventions.

As far as the strengths of our study are concerned, a meta-analysis was performed, making it possible to make a comparison between different types of intervention and to identify the most effective. This meta-analysis presents several methodological strengths. First, the systematic search and clearly defined inclusion/exclusion criteria minimize selection bias and ensure a thorough review of the relevant literature. Second, the assessment of the quality of the included studies using standardized tools increases the internal validity of the analysis. Finally, the inclusion of studies with different intervention designs provides a broad perspective on strategies to improve antibiotic prescribing in dentistry.

Furthermore, other types of intervention (applications, courses, nudges) must be evaluated, along with multicomponent interventions. A limited number of studies were identified that apply new intervention designs of decision support systems based on e-health or artificial intelligence systems. We believe this could be a new field of study in the future via well-designed studies with control groups.

Conclusions

Dentists are key actors in the field of healthcare and, as such, they must be trained to combat AMR and the misuse of antibiotics. Given the magnitude of the effect found, it is clear that dentists are receptive to improving their prescription habits and that there is ample room for improvement. Since the interventions that have been tested have shown to be extremely effective, they should be generalized by adapting them to the characteristics of each environment through designs that provide a higher level of evidence (controlled, randomized, with a control group) and other types of interventions should be attempted. If these interventions are implemented worldwide, they will have a great impact on global public health.

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Transparency declarations

None to declare.

Author contributions

J.M., A.R., A.F. conceptualization. J.M., A.R., M.F., U.V. data curation, formal analysis, investigation. J.M., A.R., A.F., C.R., G.A. methodology. J.M., A.R., A.F. project administration, resources, software, supervision. J.M., A.R., A.F. writing original draft. M.F., U.V., C.R., G.A. writing—review and editing.

Supplementary data

Figures S1–S3 are available as Supplementary data at *JAC* Online.

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