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Extraction vs nonextraction of premolars for orthodontic treatment: A scoping review examining the extent, range, and characteristics of the literature

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Introduction: The debate about whether malocclusion can or should be treated with or without extraction of premolars continues. This scoping review quantifies the literature, summarizes the outcomes researched and methods, and proposes a way to reduce uncertainty in this area. **Methods:** Electronic and gray literature searches were undertaken without language restriction, but non-English language titles and abstracts were not translated. A minimum of 2 people independently screened the titles and abstracts. **Results:** Searches identified 9010 articles, of which 3851 were duplicates; 5159 were screened, and 4617 were excluded (1092 laboratory or animal studies, 1219 case reports or series, 2306 with no information). By consensus, 399 articles contained information concerning differences between orthodontic patients treated with or without premolar extractions (143 were unclear). The majority (n = 372) reported outcomes in 8 areas. Fifty-seven were review articles (32 systematic reviews and 25 nonsystematic reviews or opinions). The most common research design in the remainder was a cohort (n = 280, 82% of 342 articles reporting primary data), of which a very large majority were considered retrospective (n = 249, 89% of articles reported for subjects over ≥2 time points). Only 28 (8% of articles reporting primary data) were judged to involve prospective data collection (4 randomized controlled trials [RCTs], 23 cohorts, 1 unclear design). Excluding reviews and unclear articles, 99% (332 out of 336) were considered observational research and only 1% were interventional. **Conclusions:** There was limited low-quality evidence that extracting premolars in orthodontic patients have a possible negative effect in 2 outcome areas and a positive effect in 1 outcome area. Most study reports were of low methodological quality, and further reviews are unlikely to provide new information. Investigators should concentrate on collecting primary data of outcomes important to patients. A protocol has been made available to help reduce methodological differences, assist future meta-analyses and increase the generalizability of findings: https://doi.org/10.17605/OSF.IO/CQ49Y. (Am J Orthod Dentofacial Orthop 2023;164:368-76)

Because the modern era of orthodontic treatment began at the beginning of the 20th century, orthodontists have debated whether malocclusion can or should be treated with or without the extraction of permanent teeth, particularly premolars.[1,2] Over a century later, the debate continues without much sign or expectation that the issue will be resolved soon. We believe now is a good time to examine the literature, review the findings and propose a way forward for research in this area.

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Table I. A summary of PICOS definitions for the review

Element	*Definition*
Participants	Patients of any age, gender, ethnicity, or nationality with any malocclusion
Intervention	Orthodontic treatment with the extraction of premolar teeth. Exclusion criteria: patients undergoing orthognathic surgery or treatment for cleft lip and palate
Comparison	Orthodontic treatment without the extraction of premolar teeth
Outcomes	Any outcomes, including occlusal, cephalometric, esthetic, or patient-reported outcomes, including oral health related-quality of life, satisfaction with the outcome (including treatment time) or dental phobia because of extraction, any adverse effects on the dental tissues, airway changes, and breathing, as well as effects on the TMJ, eruption of second and third molars or bone growth
Studies	Clinical studies involving ≥20 participants of any design, including cross-sectional, cohort, case-control, randomized, prospective or retrospective, observational or interventional. In addition, any review undertaken in this area will aid identification of further studies and help summarize the findings

Scoping reviews have several purposes, but they are particularly useful in examining the size, variety and characteristics of evidence in the literature, summarizing the findings and helping plan future research.[3] A scoping review is undertaken using similar methods to a systematic review, but the intent is not to critically appraise the literature in detail and provide an answer to a specific question.

This scoping review aimed to examine study reports published in the scientific literature comparing orthodontic treatment undertaken with and without the extraction of premolar teeth. The specific objectives were to (1) quantify the extent of the scientific literature, (2) outline the main areas of primary outcomes reported, (3) summarize the study methods, and (4) propose a way forward.

METHODS

The protocol for the review is available on the Open Science Framework, a free, open-source service maintained by the Center for Open Science (https://osf.io/cvdx3/).

A summary of the PICOS descriptions is shown in Table I. Articles were excluded if they were laboratory or animal studies, were case studies or series involving <20 participants, did not contain information about a group of patients receiving orthodontic treatment with the extraction of premolars and a group of patients receiving orthodontic treatment without extraction of premolars, or the participants were treated with orthognathic surgery or treatment for clefts of the lip or palate. Longitudinal studies were considered cohorts even if they had an element of matching.

The following searches were carried out (see Supplementary Material for the full Ovid Medline search strategy): (1) Ovid Medline (1946 to February 4, 2022), (2) Web of Science Core Collection (various start dates to February 4, 2022[4]), Web of Science Medline (1950 to February 4, 2022), and Cochrane Library.

Gray literature searching included Google Scholar and reference lists of reviews and other articles identified. There were no restrictions on language in the searches, but non-English language titles and abstracts were not translated. Two assessors independently examined the title and abstract of each article, entering data into a customized Excel spreadsheet. All the authors of the article were involved in the initial reviews of titles and abstracts. In the event of disagreement between the first 2 authors, a third assessor (either P.E.B. or T.F.) examined the title and abstract independently.

RESULTS

The Figure shows a flow chart outlining the number of articles identified and screened. Database and other searches identified 9010 articles, of which 3851 were duplicates and were removed. Of the 5159 articles screened, 4617 were excluded for the following reasons: 1092 were either laboratory studies involving extraction of premolar teeth or animal studies; 1219 were considered case reports or series, with <20 participants; and 2306 were considered to have no information concerning the review objectives. Common reasons for a judgment of no information were that participants consisted only of the review intervention group, treated with premolar extractions or only the review comparison group, treated without the extraction of premolars or that the comparison was for teeth extraction other than premolars. There was a consensus among the assessors that 399 articles contained information concerning differences between orthodontic patients treated with or without premolar extractions, and 143 were unclear. Tables II and III outline the included research methods of studies according to the main areas of primary outcome researched. Most of the included articles reported outcomes in 8 areas of research (n = 392). Three articles were outcomes not covered by the 8 main areas, and in 4 articles, the outcomes were unclear. There was limited low-quality evidence that the extraction of premolars in orthodontic patients has a possible negative effect in 2 outcome areas (adverse effects to the

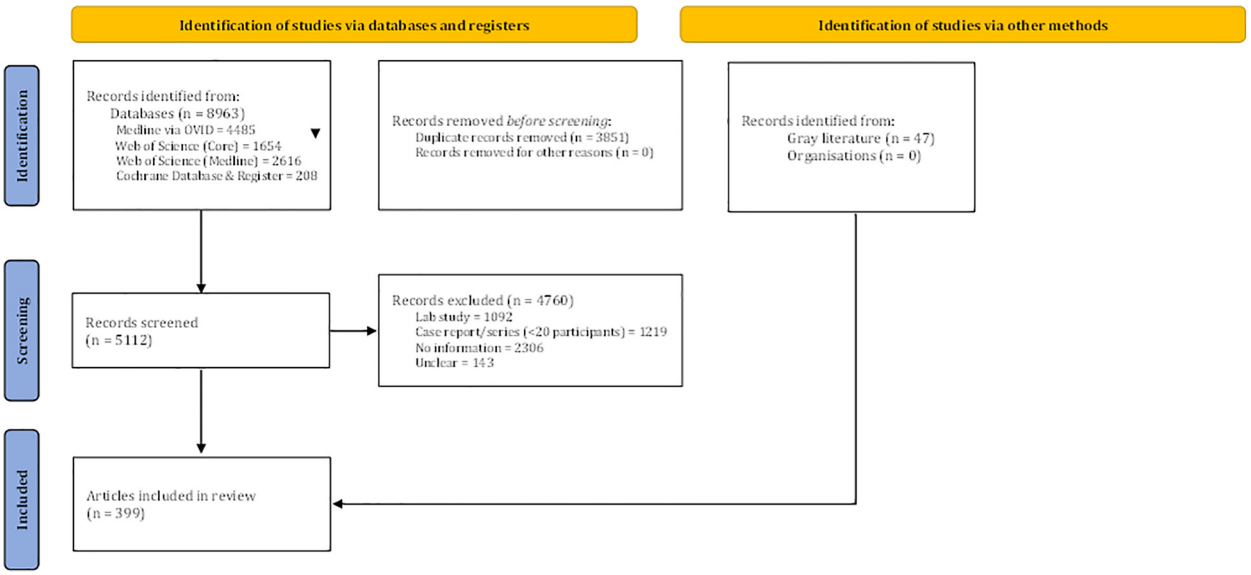

Fig. Flow diagram included searches of databases, registers, and other sources.

Table II. Research design of the included articles according to categories of reported outcomes (n = 399)

Area of research	*RCT*	*Cohort*	*Case-control*	*Cross-sectional*	*Review: systematic*	*Review: nonsystematic*	*Unclear*	*Totals*
Esthetics, including facial profile or cephalometric changes	3 (2%)	108 (73%)	4 (3%)	16 (11%)	11 (7%)	4 (3%)	1 (1%)	147
Occlusal changes, including stability	1 (1%)	77 (73%)	2 (2%)	10 (10%)	7 (7%)	6 (6%)	2 (2%)	105
Eruption of lower second and third molars	0 (0%)	43 (86%)	1 (2%)	0 (0%)	4 (8%)	1 (2%)	1 (2%)	50
Effect on TMJ and TMD	0 (0%)	23 (53%)	0 (0%)	5 (12%)	4 (9%)	11 (26%)	0 (0%)	43
Adverse effects to the dentition, including periodontal problems, gingival recession, root resorption	0 (0%)	14 (64%)	1 (5%)	6 (27%)	1 (5%)	0 (0%)	0 (0%)	22
Effect on airway	0 (0%)	6 (46%)	2 (15%)	0 (0%)	4 (31%)	1 (8%)	0 (0%)	13
Treatment process, including satisfaction and treatment duration	0 (0%)	6 (60%)	1 (10%)	3 (30%)	0 (0%)	0 (0%)	0 (0%)	10
Bone height and growth	0 (0%)	1 (50%)	0 (0%)	0 (0%)	1 (50%)	0 (0%)	0 (0%)	2
Other	0 (0%)	2 (67%)	0 (0%)	1 (33%)	0 (0%)	0 (0%)	0 (0%)	3
Unclear	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	2 (50%)	2 (50%)	4
Totals	4 (1%)	280 (70%)	11 (3%)	41 (10%)	32 (8%)	25 (6%)	6 (2%)	399

Note. Values are presented as n (%). *RCT*, randomized controlled trial.

dentition and treatment process) and a positive effect in 1 outcome area (eruption of second and third molars).

Fifty-seven review articles were identified (32 systematic reviews and 25 nonsystematic reviews or opinion articles). In the remaining 342 articles, which reported primary data, only 28 articles were judged to be reports of studies involving prospective data collection (4 RCT, 23 cohort, 1 unclear design). This was 8% of articles reporting primary data. Of those judged to be a randomized design, 2 were records of trials recently registered in a clinical trials database.[5,6] The remaining 2 reports of RCTs[7,8] will be discussed in the section discussing the esthetics category of the reported outcome.

The most common study design in the 342 articles reporting primary data was a cohort (n = 280), whereby outcomes were measured before and after treatment. This was 82% of articles reporting primary data. Most of these studies' reports were judged to have identified and selected samples retrospectively (n = 249). This was 89% of articles in which data were reported for patients over ≥2 time points. Excluding reviews and articles in which the design was unclear, 99% (332 out of 336 articles) were considered observational research and only 1% were interventional.

We also found several articles related to another relevant RCT.[9-12] After correspondence with 1 of the

Table III. Further information on research design of the included articles according to categories of reported outcomes (n = 399)

	Prospective/retrospective				*Interventional/observational*				
Area of research	*Prospective*	*Retrospective*	*NA*	*Unclear*	*Interventional*	*Observational*	*NA*	*Unclear*	*Totals*
Esthetics, including facial profile or cephalometric changes	7 (5%)	102 (69%)	35 (24%)	3 (2%)	3 (2%)	128 (87%)	15 (10%)	1 (1%)	147
Occlusal changes, including stability	4 (4%)	75 (71%)	25 (24%)	1 (1%)	1 (1%)	90 (86%)	12 (11%)	2 (2%)	105
Eruption of lower second and third molars	1 (2%)	42 (84%)	6 (12%)	1 (2%)	0 (0%)	44 (88%)	5 (10%)	1 (2%)	50
Effect on TMJ and TMD	16 (37%)	3 (7%)	20 (47%)	4 (9%)	0 (0%)	27 (63%)	16 (37%)	0 (0%)	43
Adverse effects to the dentition, including periodontal problems, gingival recession, root resorption	0 (0%)	13 (59%)	8 (36%)	1 (5%)	0 (0%)	21 (95%)	1 (5%)	0 (0%)	22
Effect on airway	0 (0%)	5 (38%)	7 (54%)	1 (8%)	0 (0%)	8 (62%)	5 (38%)	0 (0%)	13
Treatment process, including satisfaction and treatment duration	0 (0%)	6 (60%)	4 (40%)	0 (0%)	0 (0%)	10 (100%)	0 (0%)	0 (0%)	10
Bone height and growth	0 (0%)	1 (50%)	1 (50%)	0 (0%)	0 (0%)	1 (50%)	1 (50%)	0 (0%)	2
Other	0 (0%)	2 (67%)	1 (33%)	0 (0%)	0 (0%)	3 (100%)	0 (0%)	0 (0%)	3
Unclear	0 (0%)	0 (0%)	2 (50%)	2 (50%)	0 (0%)	0 (0%)	2 (50%)	2 (50%)	4
Total	28 (7%)	249 (62%)	109 (27%)	13 (3%)	4 (1%)	332 (83%)	57 (14%)	6 (2%)	399

authors, it was clear that this study had problems with recruitment and would not provide any useful information for the review. This study will be further considered in the Discussion section.

We will now report the findings of this review according to several broad categories of reported outcomes. Summaries of the study designs, numbers, and proportions are shown in Tables II and III. Details of all articles identified and screened, including those included, can be found in the Supplementary Material.

Esthetics, including facial profile or cephalometric changes: This was the most frequently reported primary outcome in articles comparing orthodontic treatment with and without the extraction of premolars (n = 147 or 37% of included articles). The most common research design was cohort (n = 108, 74% of articles reporting esthetic outcomes), of which the overwhelming majority were judged to have identified the participants' records retrospectively (n = 102, 94% of cohort articles). Three reports of RCTs with esthetics as a primary outcome were identified, including 2 completed RCTs[7,8] and a recently registered clinical trial.[5] One RCT, undertaken in Turkey,[7] randomized Class I borderline patients to be treated either with the extraction of 4 premolars or nonextraction with interdental stripping. They concluded that both forms of treatment were effective, and there were minor differences in the posttreatment profile with 1.0-1.5 mm more retrusion of the lips in the extraction group. Treatment was shorter in the nonextraction group by 8 months.

The second RCT, undertaken in Iran,[8] compared a fixed functional appliance with the extraction of maxillary premolars in patients with a Class II Division 1 malocclusion. The authors report many cephalometric measurements, some of which appear clinically significant; however, this might be due to the different effects of the appliances used rather than the extraction or nonextraction of premolars.

Four articles reporting the results of prospective cohort studies were identified,[13-16] 3 of which were from 1 site.[13-15] These explored the results of 3-dimensional facial scanning with quite small sample sizes (minimum, 24; maximum, 46).

We identified 11 systematic reviews in this area, most of which conclude that there are only minor differences in appearance between patients treated with and without premolar extractions. These differences do not significantly affect the esthetic outcomes of treatment (see Supplementary Material for details).

Occlusal changes, including stability: This was the second most frequently reported outcome in articles comparing the extraction vs nonextraction of premolars (n = 105 or 26% of included articles). Again, the most common research design was cohort (n = 77, 73% of articles reporting occlusal outcomes), and once again, the overwhelming majority were judged to have identified the sample retrospectively (n = 75, 97% of cohort articles). One recently registered RCT was identified[6] comparing the retraction of maxillary incisors in patients with a Class II Division 1 malocclusion and using zygomatic miniplates as anchorage compared with the extraction of maxillary first premolars.

Two articles reporting the results of 2 prospective cohort studies were identified. These examined occlusal

contacts and bite force after treatment with samples sizes of 74[17] and 85.[18]

Seven systematic reviews were identified. One review[19] concluded that there was more anterior open bite treatment relapse in patients treated with nonextraction compared with extraction, but the differences were <1 mm. Another review[20] indicated a slightly better Objective Grading System score after extraction treatment compared with nonextraction treatment, but the data were neither statistically nor likely to be clinically significant. Swidi and colleagues[21] reported long-term changes (10-20 years postretention) in the irregularity of the mandibular incisors of 1.7 mm (95% confidence interval [CI], 1.5-2.0) after extraction treatment and 1.4 mm (95% CI, 1.0-1.9) after nonextraction treatments. Therefore, minimal differences between extraction and nonextraction treatments were found (see Supplementary Material for details).

Eruption of lower second and third molars: This was the next most frequently reported outcome (n = 50 or 13% of included articles). Once again, the most common research design was cohort (n = 43, or 86% of articles reporting this outcome), and the majority were judged to have identified the sample retrospectively (n = 42, or 98% of cohort articles). No reports of RCTs were identified, and there was only 1 report of a prospective cohort study with a sample size of 56.[22] Although the report states that "extraction of first premolars in high anchorage cases does not lead to an improvement in the angulation of mandibular third molars; moreover, the angulation worsened…" the data were not statistically significant, and the clinical significance is unclear, as the patients were not followed up to determine if the third molars erupted or not.

Our searches identified 4 systematic reviews in this area. One review concluded that premolar extraction significantly improves the probability that the third molar would erupt, but the quality of evidence was low.[23] The other 3 reviews reported changes in the angulation of the third molar rather than the probability that it would erupt (see Supplementary Material for details).

Effect on TMJ & TMD: This was the fourth most frequently researched area (n = 43 or 11% of included articles). It was the only outcome in which most articles reported prospective cohort studies (16 out of 23 articles or 70%), although there were several reports from the same cohort at different time points. Four systematic reviews were identified, although 1 Cochrane review has been withdrawn.[24] Each review concluded no relationship exists between orthodontic treatment with or without extractions and disorders of the temporomandibular joint (TMJ).

Adverse effects to the dentition, including periodontal problems, gingival recession, root resorption: We identified 22 articles reporting outcomes in this research area (6% of included articles). Most articles were reports of cohort studies (n = 14 or 64% of articles reporting this outcome), and the overwhelming majority were considered retrospective (n = 13% or 93% of cohort studies). Sample sizes ranged from 22 to 153.

We identified 1 systematic review examining the extent of external apical root resorption after orthodontic treatment and comparing those treated with and without premolar extractions.[25] The authors conclude that extraction treatment leads to a statistically significant increase in external apical root resorption, but the mean difference was small (0.9 mm [95% CI, 0.6-1.1 mm]), and it is unclear if confounders such as length of treatment were accounted for by authors.

Gray literature searching identified several systematic and nonsystematic reviews examining the effects of orthodontic treatment on gingival recession. These reviews investigated the relationship between change in the angulation of the mandibular incisors with gingival recession and not specifically extraction or nonextraction of premolars, so they were excluded, although we understand that these 2 factors might be related (see Supplementary Material for details).

Effect on airway: We identified 13 articles (3% of included articles) reporting outcomes related to the relationship between orthodontic treatment with and without premolars extractions and airway dimensions. Five articles were considered reports of retrospective cohort studies, 2 case-control studies, 4 systematic reviews, and 1 nonsystematic review. None of the systematic reviews could reach any definitive conclusions because of the heterogeneity of the data, the quality of the studies, the limitations of the measurement methods and a lack of information about the relationship between upper airway size and respiratory function.

Treatment process, including satisfaction & treatment duration: Arguably, orthodontic patients would consider these outcomes the most important; however, we identified only 10 articles in this area. Six articles were judged to be reports of retrospective cohort studies, 3 were cross-sectional, and 1 case-control. There were no review articles, although 1 systematic review, summarized in the occlusal change section,[20] also found an increase in the treatment duration with extraction treatment (6.4 months [95% CI, 1.4-11.5 months]; $P = 0.013$).

One report, describing itself as a case-control design, had a large sample size (n = 400), and the investigators accounted for numerous potential confounding factors in their analysis.[26] They concluded that orthodontic treatment, involving the extraction of premolars, nearly doubled the probability that the treatment duration

would be long (>30 months; adjusted odds ratio, 1.8 [95% CI, 1.0-3.2]). In contrast, orthodontic treatment without extraction of premolars doubled the probability that the treatment duration would be short (<20 months; adjusted odds ratio, 2.3 [95% CI, 1.3-4.2]).

In the esthetic outcomes section, we have already reported that 1 RCT[7] found treatment duration was 8 months shorter in the nonextraction group. Therefore, we suggest this finding of increased treatment duration after extraction of premolars is reasonably robust.

Bone height & growth: Our searches discovered 3 articles investigating this outcome and directly comparing patients treated with the extraction of premolars and patients treated without the extraction of premolars. There were 2 reports of retrospective cohorts[27,28] and 1 systematic review.[29] One article was excluded as it contained data from only 12 subjects.

The systematic review summarized data from 29 studies, of which 14 were included in a meta-analysis. All the studies, except 1, were from single cohorts of patients treated with extractions or without extraction of permanent teeth. Some comparisons were with nonorthodontic subjects, and some were treated using corticotomy. None of these were eligible for inclusion in this review. The sample sizes of the studies ranged from 8-60. The authors did not directly compare the bony changes between extraction and nonextractions groups but summarized the findings separately. The review found losses of alveolar bone height with both extraction and nonextraction treatment, but the sizes of the mean changes were generally small (<1 mm).

Other outcomes: Three articles were judged to be other outcomes not within the categories above. These outcomes included skilfulness of masticatory jaw movements, changes in maximum lip-closing force and changes in the palatal form. Details of these articles and their findings can be found in the Supplementary Material.

Unclear outcomes: In 4 articles, the primary outcomes were unclear from the titles and abstracts. Details of these articles and their findings can be found in the Supplementary Material.

DISCUSSION

This review has attempted to summarize the currently available evidence for differences in outcomes between orthodontic patients treated with premolar extractions and those treated without premolar extractions. This subject has been widely debated, and no clear consensus exists. In common with other scoping reviews, we have not extensively examined the methodological quality of the included studies other than identifying features, such as the type of study design, whether it was retrospective or prospective, observational or interventional.[30]

There was limited low-quality evidence that the extraction of premolars in orthodontic patients has a possible negative effect in 2 outcome areas, with more root resorption (adverse effects to the dentition) and longer treatment times (treatment process, including satisfaction and treatment duration). There was also evidence that premolar extraction had a positive effect in 1 outcome area, with an increased probability that the third molar would erupt (eruption of lower second and third molars).

In 1 group of outcomes (effect on the temporomandibular disorder [TMJ] and TMD), the evidence is consistent that orthodontic treatment with or without extraction of premolars does not lead to problems with the TMJ or TMD. There is evidence of some differences in other outcome areas, but probably of minor clinical significance. However, significant methodological weaknesses in the current literature need to be addressed.

There were several issues with the designs of studies in this research area. First, too many participants are identified retrospectively after they have been treated, potentially providing a biased sample of successfully treated and satisfied patients. Potential participants should be identified at the treatment planning stage, recruited, consented and followed for the whole length of their orthodontic treatment. Second, participants must be followed up, probably many years beyond treatment, to identify possible long-term outcomes, such as the eruption of third molars and stability. This will lead to withdrawals, dropouts, and attrition, which must be rigorously documented and considered in sample size estimates. Third, sample sizes must be sufficient to account for confounding factors, such as the initial severity of the patient's malocclusion, treatment difficulty, and clinician differences. This can be done either during the selection and allocation of participants or with an appropriate statistical analysis. Finally, the outcomes of previous studies are not necessarily important to patients. For example, we found no studies exploring patient views or experiences of permanent tooth extraction for orthodontic treatment.

Given the weaknesses in the current literature, it is our view that further systematic reviews are highly unlikely to help resolve the premolar extraction or nonextraction debate. We suggest that academics and clinicians interested in advancing knowledge in this area should now stop undertaking systematic reviews and concentrate their time and efforts on studies that collect primary data to populate future reviews. Editors of academic orthodontic journals should strongly discourage anyone from submitting or publishing systematic reviews in this area.

So, what is an appropriate study design and what cohort of patients, with what range of malocclusions, should be invited to participate? Current thinking is that the most robust study design would be an interventional randomized trial. After an extensive discussion about the risks and benefits, patients with a predetermined set of criteria (and their parents) would agree to a 50% chance of having their premolars removed. The choice would not be theirs or their clinicians' but decided by the toss of a coin or computer program. After this discussion, you can imagine most patients and parents might opt to be treated with nonextraction.

As outlined earlier, we did find 1 randomized trial comparing a fixed functional appliance with the extraction of maxillary premolars in the correction of Class II Division 1 malocclusion. The study was undertaken in Iran and successfully recruited 45 participants.[8] We are also aware of a similar multicentred RCT undertaken in the United Kingdom that did not recruit sufficient participants.[31] This study compared patients with Class II Division 2 malocclusion treated nonextraction with a removable functional appliance and those treated with fixed appliances with the extraction of maxillary first premolars.

Perhaps the more interesting group of patients are those with a so-called borderline Class I malocclusion that could be managed with or without premolars extraction. We cited 1 RCT involving this group of patients undertaken in Turkey.[7] The investigators recruited 26 patients and randomized them to either extraction or nonextraction of premolars. We also know of another RCT involving patients with borderline Class I malocclusion, undertaken in the United States.[9-12] The study used an unusual design of RCT involving clinician treatment preferences to avoid potential issues with clinician equipoise. The first step in recruiting participants, as with any clinical trial, was to determine the patient's eligibility to enter the trial, using various inclusion and exclusion criteria. The next step was identifying and excluding eligible participants with whom clinicians likely agreed about the preferred malocclusion treatment. The remaining participants were then assessed independently by a panel of 2-4 clinicians who were ready and able to treat the patient. When there was disagreement between clinicians, the patient was randomly allocated to be treated by a clinician using their preferred approach. Steps were taken to ensure that equal numbers of participants were treated using either extraction or nonextraction approaches. This study used an unusual and innovative approach to recruitment; however, it failed to identify a sufficient number of patients in the borderline, disagreement category to recruit to the trial.

We propose a study design that could overcome some of the ethical and practical difficulties of an interventional RCT. This is an observational prospective cohort study. In this design, patients and parents would decide on the best approach to treat their malocclusion in discussion with their clinicians. The patient would agree to be observed for the full length of their treatment and beyond. At various stages throughout treatment, the investigator would be expected to account for all patients who agree to participate. Patients who started nonextraction treatment but might have premolars extracted for various reasons would be of particular interest. Some clinicians call this a therapeutic diagnosis. To increase generalizability, the study should involve several clinicians in different settings, including specialist practices. Korn et al[32] undertook the above RCT, which did not recruit sufficient participants. They proposed a possible method of overcoming selection bias in retrospective studies. This method involves using a clinician's treatment preferences derived from a patient's pretreatment records to identify patients with similar predetermined occlusal and facial criteria in which clinicians disagree on whether to treat them with extractions or nonextraction. The authors argue that because there is no consensus among clinicians about treating these patients, the choice of actual treatment undertaken is essentially random. The outcomes from these patients can then be used to estimate any treatment effects.

The scope of the review was such that it covered a wide area of the literature, and we are aware that not all articles were picked up by the terms used in the electronic searches. Most articles were screened using only the titles and abstracts, and the details of the article were not always explicit. Some subjective judgments were necessary about whether the participants included those treated by either extraction or nonextraction and whether they were identified and selected retrospectively or prospectively. By having up to 3 independent judgments, the potential for errors has hopefully been reduced.

We only included studies that directly compared those treated with or without premolar extractions. A significant number of articles were excluded as they contained data from patients treated exclusively with premolar extractions or exclusively without premolar extractions. Some studies compared these groups with a nonorthodontic cohort, and there were 2 reports of RCTs in which extraction or nonextraction were outcomes rather than interventions or comparisons.[33,34] We also excluded studies that did not have a title and or abstract in English. By excluding data from all these studies, potentially useful data were lost. However, we believe

that the fundamental findings of the review that the overwhelming majority of studies had low-level study designs will not change because of including these data.

A recent guest editorial expressed the view that the increasing number of systematic reviews published in the orthodontic literature is not assisting orthodontists in carrying out evidence-based treatment, as the primary data on which the reviews are based are so weak.[35] Until the absence of good-quality primary data is addressed, reviews will continue to reach similar, uncertain and unsatisfactory conclusions. Another problem is the lack of agreement between studies on the outcomes of interest and time points when they are collected. Developing a core outcome set for orthodontic studies is designed to address this problem.[36] The guest editorial suggested that the authors of each review should make a study protocol freely available, with a suggested best approach to collecting primary data. This will enable orthodontic investigators in different settings and countries to undertake studies using the same outcomes and time points, to address the lack of primary data, reduce differences in methods and increase generalisability. The authors of this review have made available a protocol for a prospective cohort study here: https://doi.org/10.17605/OSF.IO/CQ49Y.

CONCLUSIONS

There is limited evidence that premolar extractions have either a negative or a positive effect on orthodontic treatment outcomes compared with nonextraction treatment. The majority of studies have significant methodological weaknesses. Given these weaknesses, further systematic reviews in this area are highly unlikely to provide new information and editors of academic orthodontic journals should discourage further reviews from being submitted and published. Investigators should concentrate on collecting primary data of outcomes important to patients, and to aid this, a protocol has been made freely available for orthodontic investigators to use.

AUTHOR CREDIT STATEMENT

Philip E. Benson contributed to conceptualization, methodology, validation, investigation, data curation, original draft preparation, visualization, supervision, and project administration; Ebrahim Alshawy contributed to conceptualization, methodology, investigation, and manuscript review and editing; Gavin D. Fenton contributed to investigation and manuscript review and editing; Tom Frawley contributed to investigation and manuscript review and editing; Sangeeta Misra contributed to investigation and manuscript review and editing; Teresa Ng contributed to investigation and manuscript review and editing; Paul O'Malley contributed to investigation and manuscript review and editing; and Gillian Smith contributed to investigation and manuscript review and editing.

SUPPLEMENTARY DATA

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