SYSTEMATIC REVIEW

AJO-DO

Do malocclusion and orthodontic treatment impact oral health? A systematic review and meta-analysis

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Introduction: Currently, there is limited evidence on the effects of malocclusion on oral health and whether the correction of malocclusion results in an improvement in oral health. In this review, we examined the evidence from randomized controlled trials and prospective cohort studies to provide information on any association between malocclusion and oral health and the effects of orthodontic treatment. **Methods:** We conducted this review in 2 parts: (1) we looked at the impact of malocclusion on oral health, and (2) we reviewed the evidence on the effect of orthodontic treatment on oral health. We searched for randomized controlled trials and prospective cohort studies. The searches were completed for articles published between January 1, 1990 and October 8, 2018 and covered Medline via Ovid, Embase, and the Cochrane Database of Systematic Reviews. References of included articles and previous systematic reviews were hand-searched. No language restrictions were applied. Two members of the study team assessed the quality of the studies using the Appraisal Tool for Cross-Sectional Studies to appraise the quality of studies in part 1. The assessment was performed at the study level. Two authors assessed each study independently, with a third author consulted when a disagreement occurred. For studies in part 2, we used the Newcastle-Ottawa scale to assess the risk of bias. When studies were included in a Cochrane review, we incorporated the risk of bias assessment. We developed data extraction forms for each area of oral health under investigation (trauma, quality of life, caries, and periodontal disease). Each author piloted the form, and we held discussions to inform any necessary refinements. We extracted data from studies into 2 × 2 tables, which provided a binary analysis of malocclusion vs the outcome of interest. If these data were not available from the published paper, then studies were not included in the meta-analysis. The authors were contacted when possible to request data in this format. **Results:** For part 1 of the study, we identified 87 studies. The overall quality was low. We could not include any of the data into an analysis because of a large variation in the nature of the studies, data collected, and outcome measures that were selected. For part 2 of the study, we found 7 studies; however, there were similar deficiencies in the data as in part 1, and thus, we could not reach any strong conclusions. **Conclusions:** Overall, there is an absence of published evidence regarding the effects of malocclusion on oral health and the impact of orthodontic treatment on oral health. (Am J Orthod Dentofacial Orthop 2020;157:738-44)

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All authors have completed and submitted the ICMJE Form for Disclosure of Potential Conflicts of Interest, and none were reported.
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Submitted, July 2019; revised and accepted, January 2020.
0889-5406/$36.00

https://doi.org/10.1016/j.ajodo.2020.01.015

Orthodontic treatment aims to correct malocclusion.[1] This type of dental care is widely provided throughout the world and there is a clear demand for treatment by patients. For example, in the United Kingdom, the demand for orthodontics is high, and waiting lists are long, with an estimated cost of £275 million to the National Health Service in England in 2015-2016.[2] There is evidence that orthodontic treatment is successful in the technical correction of malocclusion.[3] Unfortunately, investigators have evaluated the effects of orthodontic treatment by measuring normative, morphologic features

(eg, by using measures such as Andrew's 6 keys of occlusion and the Peer Assessment Rating).[4] As a result, they identify the correction of the malocclusion from the clinician's perspective. This approach is then perceived as a presumed benefit to the patient.[5,6] However, there is limited evidence on whether the correction of malocclusion results in an improvement in oral health.[7,8]

As a result, there is uncertainty about the effects of malocclusion on oral health and whether orthodontic treatment has a positive impact on oral health. This is relevant when we consider that the Fédération Dentaire Internationale defines oral health as,

> *The ability to speak, smile, chew, swallow and convey emotions through facial expressions with confidence and without pain, discomfort and disease of the craniofacial complex. Reflecting the physiologic, social and psychosocial attributes that are essential to the quality of life.*[9]

This means that if we want to consider the effects of malocclusion and orthodontic treatment with relevance to this definition, we need to gather information not only on caries, periodontal disease, and trauma but also on the patient's quality of life.

When we consider the patient's quality of life, we are uncertain if orthodontic treatment will have an impact.[10,11] For example, a review conducted over 35 years ago[12] highlighted the lack of evidence of the benefit to the patient's quality of life. A recent systematic review also reached the same conclusion.[13] As a result, we can only conclude that there may remain substantial uncertainty on whether any changes in the functional and esthetic components of malocclusion affect the patient's quality of life.

OBJECTIVES

We designed this review to answer 2 related questions: (1) What is the impact of malocclusion on oral health? (2) What is the effect of orthodontic treatment on oral health?

MATERIAL AND METHODS

We registered the protocol for this review on the international prospective register of systematic reviews (PROSPERO) from the National Institute for Health Research database (www.crd.york.ac.uk/prospero; protocol no. CRD42017057516) and followed the PRISMA statement when we reported our review.

The participants of this study were children (aged 18 years and younger) with malocclusion and/or who have been treated with orthodontics.

The following inclusion criteria were used for part 1 of the review (ie, What is the impact of malocclusion on oral health?): (1) any study investigating the association between malocclusion and oral health at a single time point; (2) a comparison group with no-malocclusion; and (3) a study in which malocclusion is measured using a verified tool, such as Index of Orthodontic Treatment Need (IOTN), Dental Aesthetic Index (DAI), or a well-described measurement of overjet. Potential data sources were the baseline records of randomized controlled trials, prospective cohorts with an untreated control, and cross-sectional studies with a no-malocclusion control.

The following inclusion criteria were used for part 2 of the review (ie, What is the effect of orthodontic treatment on oral health?): (1) studies that assessed the oral health of participants before and after an orthodontic intervention; and (2) a comparison group that received no orthodontic treatment. Therefore, relevant study designs were randomized controlled trials and prospective cohorts with 2 time points (before and after treatment) with an untreated control group.

For both parts of the review, we identified outcomes that fell into 2 broad categories, which included change in dental disease state and sociodental impact.[14] We recorded the following data: (1) caries outcomes: decayed, missing, and filled teeth; (2) periodontal outcomes: basic periodontal examination and loss of attachment; (3) plaque; (4) incidence of dental trauma; and (5) any oral health–related quality of life (OHRQOL) outcome.

The following exclusion criteria were used for each part of review: (1) outcome measures using any radiological measurements, ultrasound measurements, or bite registrations; (2) any assessments of bonding or evaluations of the adherence or techniques surrounding the implementation of orthodontic processes; (3) split-mouth studies; (4) studies assessing compliance of patients; and (5) orthognathic surgery studies.

We conducted separate searches for parts 1 and 2 (Supplementary Material 1 provides comprehensive search strategy). The searches were completed for articles published between January 1, 1990 and October 8, 2018 and covered Medline via Ovid, Embase, and the Cochrane Database of Systematic Reviews. References of included articles and previous systematic reviews were hand-searched. No language restrictions were applied.

All authors piloted a screening proforma on the first 100 studies to ensure consistency of approach during screening. The form encompassed the agreed inclusion and exclusion criteria. We used this form to screen the results of the searches in duplicate.

Two members of the study team assessed the quality of the studies using the Appraisal Tool for Cross-Sectional Studies to assess the quality of the studies selected for part 1.[15] This checklist has been designed for cross-sectional studies. The assessment was performed at the study level. Two authors assessed each study independently, consulting a third author when a disagreement occurred. We piloted this approach on a sample of 10 studies and then compared our results, which ensured that we were consistent in our appraisal.

For studies included in part 2, we found that most of the studies were not randomized. As a result, we used the Newcastle-Ottawa scale to assess the risk of bias. When the studies had been included in a Cochrane review, we incorporated the risk of bias assessment.

We developed data extraction forms for each area of oral health under investigation (trauma, quality of life, caries, and periodontal disease). Each author piloted the form, and we held discussions to inform any necessary refinements.

We extracted the following information for each study: (1) study design; (2) study methods: method of allocation to treatment, blinding of participants; (3) time and setting of the included research; (4) participant details: age, sex, country, sample size, inclusion and/or exclusion criteria; (5) interventions: orthodontic treatment, length of treatment, follow up; and (6) outcomes: as previously listed.

We extracted data from studies into 2 × 2 tables, which provided a binary analysis of malocclusion vs the outcome of interest. If data were not available from the published paper, then studies were not included in the meta-analysis. The authors were contacted when possible to request data in this format. This request required the authors of studies to define a threshold for malocclusion (ie, overjet >5 mm or point on a malocclusion scale, such as IOTN or DAI). We extracted data from the papers to a Microsoft Excel spreadsheet and then imported those data into RevMan software (version 5.3; Nordic Cochrane Center, Cochrane Collaboration, Copenhagen, Denmark) to undertake the meta-analysis.

Heterogeneity was assessed using the Cochran Q test (significant at $P < 0.10$), quantified with the I^2 statistic (range from 0% to 100%).[16] If more than 10 studies were available and heterogeneity was substantial ($I^2 > 60\%$ or $P < 0.10$ for Q test) we aimed to explore heterogeneity through sensitivity analysis or meta-regression according to the baseline year of study, quality of studies, measurement tools for malocclusion and outcome measure, and thresholds applied.

RESULTS

We identified 87 studies that evaluated the association between malocclusion and dental disease (Fig 1). These included 5 longitudinal and 82 cross-sectional studies. Forty-one studies assessed the quality of life, 39 included trauma, and 9 examined either periodontal disease or caries. The characteristics of included studies are presented in Supplementary Tables I-III. Forty-four of the studies were conducted in Brazil (49%), the remainder were spread across Europe (13), the Middle East, India (7), Africa (6), and North America (3). The most commonly used malocclusion tools were DAI (19) and IOTN (13), whereas overjet was measured in 38 studies, which primarily investigated the relationship between malocclusion and dental trauma. The threshold of 5 mm or higher was used in 13 of these trauma studies. When assessing the quality of life, Child Perceptions Questionnaire (CPQ) was used in 17 studies with both the 11-14 and 8-10 scales being adopted, Oral Impacts on Daily Performance (OIDP) was used in 6 studies, and Oral Health Impact Profile-14 (OHIP) was used in 5 studies.

The overall quality of the included studies was low because all studies had at least 1 quality domain that introduced bias (Supplementary Material 2). The most common reason for poor quality was the lack of clarity on participant sampling and the omission of nonresponder and response rate information. In addition, many failed to report a valid sample size calculation or lacked transparency in their reporting around ethical approval and conflicts of interest.

All studies defined their population and measurement techniques, but there was a lack of clarity on participant selection, and often, the primary data were not present or interpretable.

When we considered dental trauma, we decided on a cutoff point for the definition of an increased overjet as 5 mm. We chose this cutoff because it was the most commonly used cutoff in the literature that we identified. Of the 39 included trauma studies, 31 reported usable data and, of these, 13 provided data at the 5 mm threshold. We were able to perform a meta-analysis of these data (Fig 2). The results from these cross-sectional data, on a sample of 3522 children, suggest that if a child has an overjet of >5 mm, then the odds ratio of them suffering trauma to their incisors was 1.98 (95% confidence interval 1.8-2.17). We found considerable heterogeneity ($I^2 = 84\%$), a sensitivity analysis was performed which excluded the outlying study[17] and resulted in a reduction of I^2 to 40% and the suggestion that heterogeneity might not be substantial in these studies.[18]

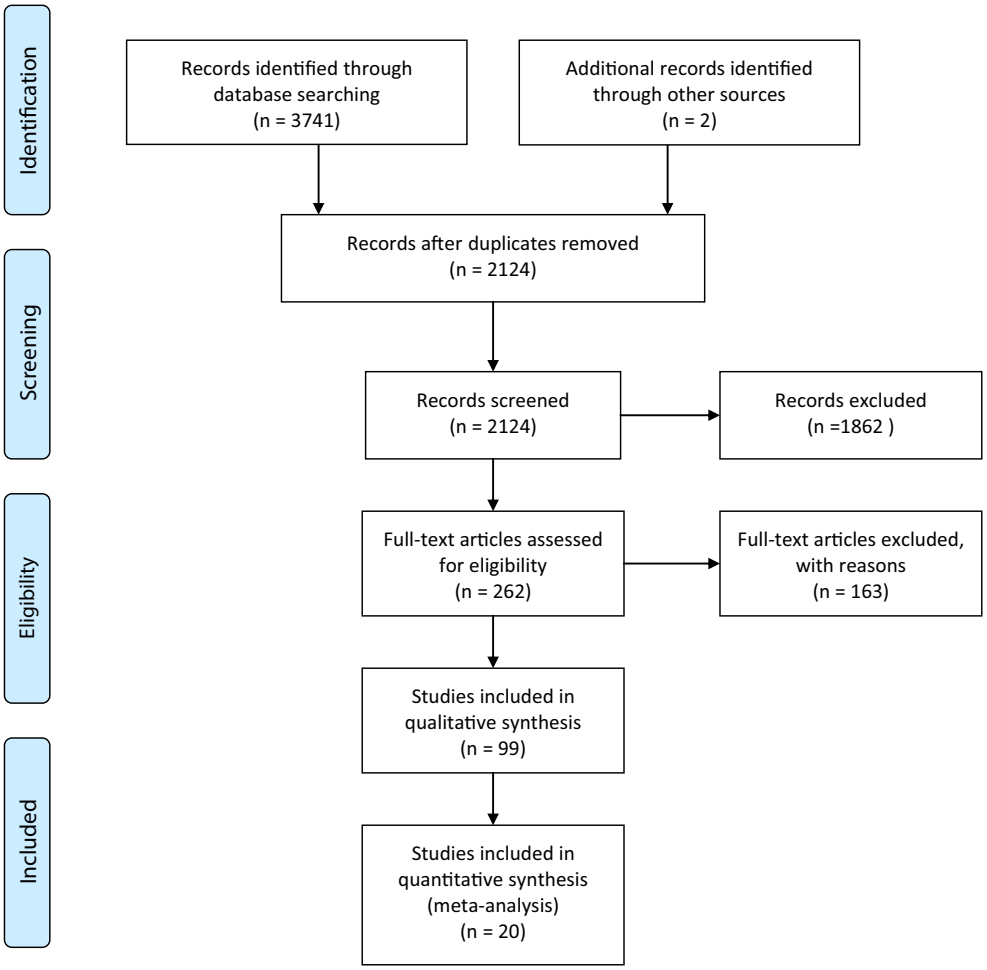

Fig 1. PRISMA flow diagram of study selection.

When we evaluated the data derived from studies concerned with caries and periodontal disease, we could not include the data for 8 of 9 studies that met our inclusion criteria, which was due to the investigators not recording tooth-level data. The investigators had recorded whole-mouth outcomes (ie, decayed, missing, and filled teeth and Gingival Index); although this is not relevant to malocclusion when individual components such as localized crowding, may influence the outcomes. It is clear that data should have been recorded on the teeth associated with the morphologic feature of malocclusion.

We only found 1 study that evaluated the association between individual tooth components and dental disease.[19] They recorded dental irregularity, gingivitis, and plaque accumulation of 213 children with a mean age of 12.7 years. Interestingly, they concluded that there was an association between irregularity and gingivitis. This finding was particularly true for patients with moderate and poor oral hygiene. However, there was no association between incisor irregularity and plaque accumulation. The overall conclusion of the study was that the crowding of the incisor is directly related to gingivitis. Nevertheless, this could not be explained by an effect of crowding on oral hygiene.

We found similar problems with the OHRQOL data. In 29 of the articles that evaluated the quality of life, the investigators collected composite scores. Unfortunately, we could not include this information in a meta-analysis for the following reasons:

(1) The composite scores included data that were not relevant to a malocclusion—for example, dental pain.
(2) Many of the authors simply presented the composite scores and then ran large regression models evaluating the association of many possible confounders. This resulted in an unsystematic "dredging" of data. Importantly, they did not

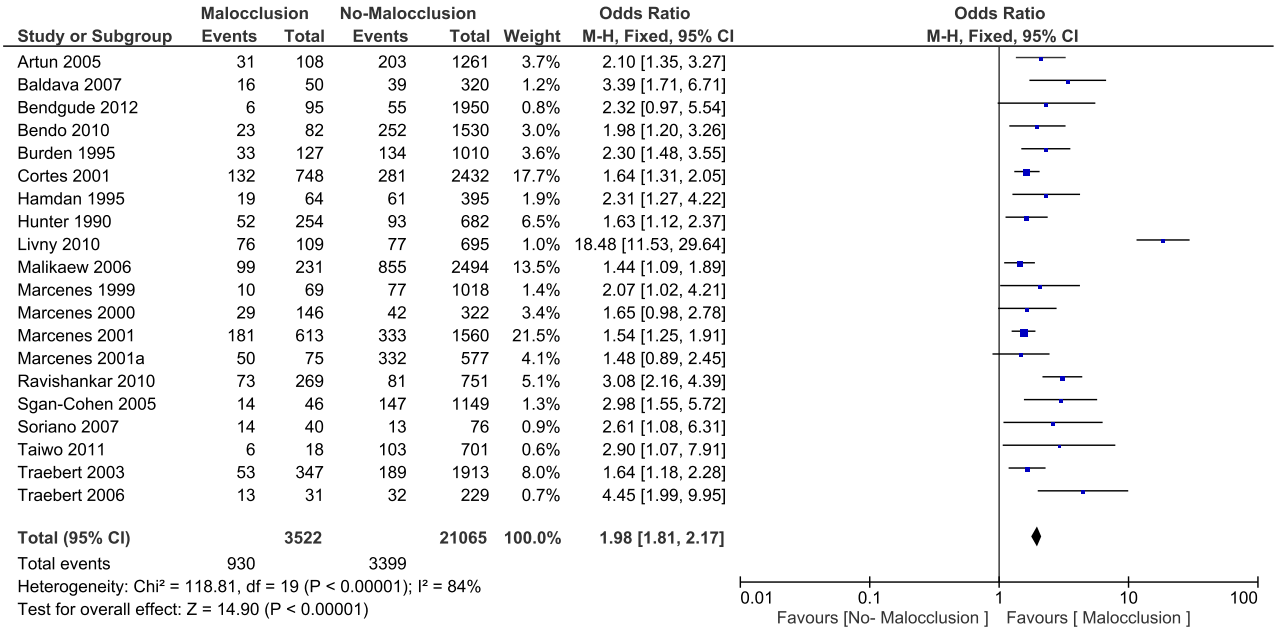

Fig 2. Forest plot, dental trauma experienced in children with malocclusion (overjet >5 mm) and no-malocclusion.

report the data in a manner that allowed the construction of a 2 × 2 table.

(3) There was no indication of the clinical significance of the sociodental impact. This was crucial if we were going to identify any effects of malocclusion.

(4) There was no uniformity in the selection of outcome measures. For example, 13 teams used CPQ, 5 used OIDP, 5 used OHIP, 3 used the Early Childhood Oral Health Impact Scale, and 3 used an unclear self-esteem measure and "specially designed questionnaires." This resulted in an unacceptable level of heterogeneity in the study methods.

(5) Finally, there was variation in the methods of measurement of malocclusion. For example, 13 investigators used the DAI with 4 different cutoff points to identify malocclusion, 12 used IOTN with 2 different cutoff points, 1 measured the Little's Irregularity Index (incisors only), and 6 recorded the morphologic features of malocclusion with limited validity and no uniformity in what constituted a malocclusion, apart from deviation from an ideal occlusion.

When we looked at the conclusions of the papers, 8 reported that malocclusion was associated with some sociodental impact, 10 concluded that there was no association, and 11 did not come to clear conclusions.

We identified 7 studies. We classified these into 4 cohort studies and 3 randomized controlled trials. We obtained data on the treatment of Class II malocclusion from a Cochrane systematic review,[20] all studies showed aspects of bias in their methods (Supplementary Tables IV and V). There were no other systematic reviews reporting on the effects of orthodontic treatment.

These data had similar deficiencies as those in part 1. Unfortunately, investigators did not collect caries and the periodontal disease data at the tooth level in any study that we identified. As a result, we could not reach any conclusions.

When we looked at quality of life, we found 5 articles and all reported in a way that prevented us from extracting data. For example, they used 4 different sociodental measures (1 Family Impact Scale, 2 OIDP, 1 Early Childhood Oral Health Impact Scale, and 1 OHIP). Therefore, it was not possible to use these data for meta-analysis. Importantly, there was no information on the clinically significant effect size for any of the sociodental measures that were used. This problem has been previously highlighted in a similar review of the literature.[21] However, our inclusion criteria were more stringent.

There was only 1 study that provided us with more information.[22] This study was a prospective cohort study. They enrolled 374 young people and followed them up for 3 years. They recorded CPQ 11-14 and self-esteem using CHQ-CF87 and IOTN and dental caries. At the end of 3 years, 258 remained in the study.

At baseline, they found an association between OHRQOL and gender, socioeconomic status, self-esteem and the self-assessed aesthetic component of IOTN. When

they looked at the longitudinal data, the Dental Health Component of IOTN improved in 35% of the sample, regardless of whether they had received orthodontic treatment. There was also a significant improvement in CPQ 11-14, suggesting that this also improves with time. Finally, there was no effect on orthodontic treatment on CPQ scores. However, the number of participants was low (35), and we could not give much weight to this finding.

The only useful data were those concerning trauma. We obtained this from a Cochrane systematic review of the effectiveness of orthodontic treatment for Class II Division 1 malocclusion.[20] This finding revealed that correcting prominent incisors resulted in a reduction in trauma from 31.7% to 19.7%. This was a reduction of 12%. Importantly, the orthodontic treatment did not eliminate the chance of injury.

DISCUSSION

We found from this review that there was an absence of evidence on the relationship between malocclusion and dental health, except for the apparent effect of increased overjet on the incidence of incisal trauma. Similarly, when we looked at the impact of orthodontic treatment, there was limited evidence that orthodontic treatment influenced oral health. There was also an effect of treatment on the incidence of trauma.

When we consider these results, we must remember that an "absence of evidence does not mean that there is evidence of absence." As a result, we cannot conclude that malocclusion and orthodontic treatment do not influence oral health. This is because most of the research that has been done has not been designed to address the questions specifically posed in this review. It appears that the outcome measures used were either not relevant to oral health or have been applied inappropriately. Tshlaki and O'Brien[6] highlighted this issue of orthodontic outcome measures when they concluded that there are many and varied outcome measures with no consistency in the outcomes selected. In effect, the research may have missed any effects of malocclusion or orthodontic treatment on oral health. Steps are currently being taken to develop a condition-specific measure to evaluate the effect of malocclusion on oral health impact.[23] Nevertheless, this research is still in its early stages and looks promising.

The only exception to this finding is incisal trauma. We can conclude with a degree of certainty that providing orthodontic treatment to correct an overjet for a young patient will reduce the chance of them experiencing incisal trauma, as highlighted by another recently published review.[24] Regardless, we also need to consider that orthodontic treatment will not completely avoid injury.

There is no doubt that these findings are disappointing. There is an urgent need to conduct studies that will answer questions on the effects of malocclusion and orthodontic treatment on oral health. Shaw et al[11] first posed these questions in 1984, and to date, they remain unanswered.[12]

This was a large and challenging review. The main strengths were that we adopted systematic review methods, identified the deficiencies and quality of the included papers, and attempted to perform relevant meta-analyses. The limitations were concerned with the need to be critical on the measures that have previously been used, the use of arbitrary or absent cutoff points by authors, and a general lack of uniformity in study design. This meant that we had to reject a large amount of data that may have been useful. However, this enabled us to identify significant deficiencies in the quality of information on this increasingly important area of dental health care.

Finally, we need to consider the type of investigations required to address this lack of knowledge of malocclusion and orthodontics. It is clear that studies that evaluate the effects of malocclusion should ideally be directed at the association between the morphologic features of malocclusion and oral health. For example, we should be evaluating the relationship between the crowding of individual teeth and any caries and periodontal disease directly associated with these teeth. Similarly, when we consider OHRQOL, this can be evaluated by the development of condition-specific instruments or adapting original measures to reflect the likely consequences of malocclusion. Finally, we should consider using qualitative measures, as studies using this methodology are revealing interesting findings from the patient's viewpoint.[25,26]

We could consider that the ideal study design may be a prospective cohort study using the appropriate outcome measures. Unfortunately, this may suffer from a problem with retention of participants, and it is unlikely to be successful. This means that any longitudinal study will be of short duration, and this may not provide us with sufficient certainty on the long-term effects of malocclusion.

An alternative could be a cross-sectional study. However, the sample of participants should be recruited consecutively or randomly and the methods should be clearly reported. Convenience sampling will lead to inherent selection biases. Furthermore, attention should be directed toward nonresponders to identify if their characteristics and reasons for nonparticipation were different from the responders.

If we want to evaluate the effects of orthodontic treatment, the ideal study would be a randomized trial of treatment vs no treatment, but it would not be ethical. Alternative designs such as cohorts could be considered. Unfortunately, this will not deal with the confounder of why some children are treated, and others are not, thus leading to bias in the study.

CONCLUSIONS

As a result, we can only conclude that, apart from trauma, there is an absence of evidence on the effects of malocclusion on oral health and the impact of orthodontic treatment on oral health. Unfortunately, it may not be possible to answer these questions with the degree of certainty that we are seeking because of the issues that we have discussed.

ACKNOWLEDGMENTS

Richard Macey was funded by Public Health England. The views expressed are those of the authors and not necessarily those of Public Health England or the National Health Service.

SUPPLEMENTARY DATA

Supplementary data associated with this article can be found, in the online version, at https://doi.org/10.1016/j.ajodo.2020.01.015.

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APPENDIX

Search strategy: MEDLINE Ovid:

1. Orthodontics/
2. exp Malocclusion/ or exp Orthodontics, Corrective/
3. exp Orthondotic Appliances, Functional/ or exp Orthodontics, Corrective/ or malocclusion, Angle Class ll/ or Open Bite/
4. Malocclusion.mp.
5. 1 or 2 or 3 or 4
6. exp Therapeutics/
7. exp Methods/is, mt [Instrumentation, Methods]
8. correct$.mp.
9. 6 or 7 or 8
10. 5 and 9
11. dental caries activity tests/ or dental caries/
12. periodontal disease/
13. "Wounds and Injuries"/
14. Exp "Quality of Life"
15. 11 or 12 or 13 or 14
16. 5 and 15
17. Limit 16 to yr "1990-Current"
18. Limit 17 to humans

Supplementary Table I. Trauma studies

Study, year	*Location*	*Setting*	*Male (%)*	*Age (y)*	*Recruited/reported (n)*	*Malocclusion tool*	*Malocclusion threshold (mm)*	*Trauma measure*	*Trauma reporting*
Abidoye, 1993[1]	Nigeria	School	51	12-12	574/574	Class I, II, III		Garcia Godoy	
Aldrigui, 2011[2]	Brazil	Preschool	53	2-5	305/260	TDI	≥3.1 mm	Glendor	Presence/absence
Altun, 2009[3]	Turkey	School	52	6-12	4956/472				
Antunes, 2015[4]	Brazil	Preschool	319	2-6	606/606	Overjet	≥3 mm	WHO classification	No trauma (0), treated (1), enamel fracture (2), dentine fracture (3), pulp (4), missing tooth because of trauma (5), other damage (6)
Artun, 2005[5]	Kuwait	School	50	13-14	1583/1572	Overjet	≤3.5, 4-6 mm, 6.5-9 mm	National Institute of Dental Research Index	Presence/absence, assumed >3.5 for overjet in data extraction
Baldava, 2007[6]	India	School		14-16	386/370	Overjet	≤3.5, 4-6 mm, 6.5-9 mm	Sgan-Cohen method	No trauma (0), enamel (1), dentin (2), pulp (3), treated (4), discolor (5), avulsed (6)
Bendo, 2010[7]	Brazil	School		11-14	1870/1612	Overjet	>5 mm		
Bendgude, 2012[8]	India	School	0	11-17	2045/2045	Overjet	≤3.5, 4-6 mm, 6.5-9 mm	Ellis & Dovey	
Bonini, 2009[9]	Brazil	Health center	51	0-1	1265/1265	Overjet	Not reported	Ellis	
Bonini, 2012[10]	Brazil	Health center	49	3-4	380/376	Overjet	>3 mm	Andreasen	
Borzabadi-Farahani, 2010[11]	Iran	School	49	11-14	502/502	ICON	≥ 44		No trauma (0), enamel (1), dentin (2), pulp (3), treated (4), discolor (5), avulsed (6)
Burden, 1995[12]	UK	School	48	11-12	1137/1107	Overjet & IOTN	≤3.5, 4-6 mm, 6.5-9 mm		Presence/absence
Cavalcanti, 2009[13]	Brazil	School	51	7-12	448/448	Overjet	>3 mm		Presence/absence
Cortes, 2001[14]	Brazil	School	47	9-14	3817/3702	Overjet	>5 mm	UK CDH Survey	
Feldens, 2010[15]	Brazil	Nursery	51	3-5	888/888	Not reported	>2 mm	Andreasen	
Francisco, 2013[16]	Brazil	School	41	9-14	850/765	Overjet	>3 mm	O'Brien	>0
Freire-Maia, 2015[17]	Brazil	School		8-10	1201/0	Overjet	>4 mm	Andreasen	
Hamdan, 1995[18]	Jordan	School	49	10-12	459/459	Overjet	>5 mm	Ellis Classification	
Hunter, 1990[19]	UK	School	46	11-12	1018/936	Overjet	>5 mm	Fractures	
Kania, 1996[20]	U.S.	School		7-12	4393/3396	Overjet		Sweet classification	
Kumar, 2011[21]	India	School	50	12-15	963/963	Overjet	>3 mm	Enamel, dentine, pulp, luxation	
Livny, 2010[22]	Israel	School	49	11-12	804/804	Overjet	>5 mm	UK CDH Survey	
Malikaew, 2006[23]	Thailand	School		11-13	4720/2725	Overjet	>5 mm	Cortes Classification	Presence/absence
Marcenes, 1999[24]	Syria	School	59	9-12	1087/1087	Overjet, lip coverage	>5 mm	UK CDH Survey	Yes/no

Supplementary Table I. Continued

Study, year	*Location*	*Setting*	*Male (%)*	*Age (y)*	*Recruited/reported (n)*	*Malocclusion tool*	*Malocclusion threshold (mm)*	*Trauma measure*	*Trauma reporting*
Marcenes, 2000[25]	Brazil	School	53	12-12	476/476	Overjet, lip coverage	>5 mm	UK CDH Survey	Yes/no
Marcenes, 2001[26]	UK	School	48	14-14	2684/2242	Overjet, lip coverage	>5 mm	UK CDH Survey	Yes/no
Marcenes, 2001a[27]	Brazil	School	50	12-12	652/652	Overjet, lip coverage	>5 mm	UK CDH Survey	Yes/no
Martins, 2012[28]	Brazil	School	46	7-14	590/590	Overjet	>3 mm	UK CDH Survey	Yes/no
Otuyemi, 1994[29]	Nigeria	School	53	12-12	1016/1016	Overjet, lip coverage			Any trauma
Petti, 1996[30]	Italy	School		6-11	824/824	Overjet, lip coverage	≤3 mm (overjet)	Garcia Godoy	Any trauma
Rajab, 2013[31]	Jordan	School	47	12-12	2560/2560	Overjet, lip coverage	>3 mm	WHO Classification	Yes/no
Ravishankar, 2010[32]	India	School	51	12-12	1020/1020	Overjet, lip coverage	>5.5	WHO Classification	
Schatz, 2013[33]	Switz	School	53	6-13	1900/1898	Overjet	>6 mm	NIDR	
Sgan Cohen, 2005[34]	Israel	School	50	9-13	1195/1195	Overjet, lip coverage	>7 mm		No (1); mild: enamel (2); severe: dentine, pulp (3)
Sgan Cohen, 2008[35]	Israel	School	60	10-12	480/453	Overjet, lip coverage	>4 mm (overjet)		No (1); mild: enamel (2); severe: dentine, pulp (3)
Soriano, 2004[36]	Brazil	School	52	12-12	1150/116	Overjet, lip coverage	>5 mm	Andreasen	
Taiwo, 2011[37]	Nigeria	School	57	12-12	719/719	Overjet	>6 mm	WHO Classification	Yes/no
Traebert, 2003[38]	Brazil	School	52	11-13	2493/2260	Overjet, lip coverage	>5 mm		Yes/no
Traebert, 2006[39]	Brazil	School		12-12	297/260	Overjet, lip coverage	>5 mm	UK CDH Survey	

Note. Empty spaces within the table mean that the data were not reported. *TDI*, traumatic dental injury; *WHO*, World Health Organization; *ICON*, index of complexity, outcome, and need; *UK*, United Kingdom; *CDH*, Children's Dental Health; *NIDR*, National Institute of Dental Research.

Supplementary Table II. Quality of life studies

Study, year	*Location*	*Setting*	*Male (%)*	*Age (y)*	*Recruited/reported*	*Malocclusion tool*	*Malocclusion threshold*	*QOL measure*	*QOL reporting*
Dann, 1995[40]	US	Secondary	51	9.3-11.4	104/104	Irregularity index	Not clear	Self concept	
Peres, 2009[41]	Brazil	School	54	6-12	359/339	DAI	Multiple features of malocclusion	OIDP	
Abanto, 2014[42]	Brazil	Other	53	1-4	1215/1215	Morph feature		ECOHIS	Continuous
Abreu, 2015[43]	Brazil	Secondary-ortho dept	49	11-12	125/123	DAI	1 (<25), 2 (26-30), 3 (31-35), 4 (>36)	FIS	Continuous (0-56), low impact (0-3), greater impact (4-26)
Anosike, 2010[44]	Nigeria	School	49	12-16	805/0	DAI	None (<25), elective (26-30), desirable (31-35), mandatory (>35)	OHIP 14	No impact (≤14), impact (≥15)
Araki, 2017[45]	Mongolia	School	47	10-16	420/420	Overjet, overbite, IOTN, DHC	IOTN 4 or 5, overjet >6mm	CPQ 11-14	Mean and SD reported
Barbosa, 2013[46]	Brazil	School	49	8-12	150/150	DAI	1 (<25), 2 (26-30), 3 (31-35), 4 (>36)	CPQ 11-14	All domains
Barbosa, 2016[47]	Brazil	School	29	8-14	550/167	DAI	13-25, 26-31, 32-35, >36	CPQ 8-10	
Bernabé, 2009[48]	UK	School	52	11-12	1126/1034	IOTN, DHC	No need (0-3), need (4-5)	OIDP-CS	Identified impact relevant to mal
De Oliveira, 2003[49]	Brazil	School	724	15-16	1675/1675	IOTN	No need (1-2), moderate need (3), great need (4-5)	OIDP	Dichotomous into 0 or any larger value = impact
De Oliveira, 2004[50]	Brazil	School	724	15-16	1675/1675	IOTN		OIDP	
De Paula, 2013[51]	Brazil	School		12-12	286/267	DAI	No need (<31), need (>31)	CPQ 11-14	Continuous
Dimberg, 2016[52]	Sweden	Secondary	46	9-13	277/257	IOTN	Need/no need	CPQ 11-14	Dichotomous using medians
Dos Santos, 2017[53]	Brazil	School	44	12-12	240/248	IOTN AC & DHC	Malocclusion (3-5), No (1-2)	CPQ 11-14	Overall score
Duarte-Rodrigues, 2017[54]	Brazil	School	39		300/300	DAI	Malocclusion present (>26)	CPQ 8-10 and child OIDP	Mean and SD reported across domains and total scores
Freire-Maia, 2015[17]	Brazil	School	45	8-10	1201/1201	Morph Features	Overjet (<3), overbite (<2), crowding (<2)	CPQ 8-10	Divided by conglomerates
Gomes, 2017[55]	Brazil	Preschool	52	5-0	769/769	None just presence of conditions	Increased overbite (>2 mm), increased overjet (>2 mm), AOB, anterior crossbite, and posterior crossbite	SOHO-5 and SOC-13	
Heravi, 2010[56]	Iran	School	100	14-17	120/120	ICON	Acceptable (>31), moderate (31-43), definite (>43)	CPQ 11-14	
Kaur, 2017[57]	India	School	43	10-17	1784/1140	IOTN AC & DHC	Standard groups	RSES	Score 10-40
Kok, 2004[58]	UK	School	44	10-12	208/170	IOTN AC	AC >6	CPQ 11-14	All domains
Locker, 2007[59]	Canada	School	56	11-14	370/370	IOTN AC	1-4, 5-7, 8-10	CPQ 11-14	Dichotomize at 80%
Machry, 2018[60]	Brazil	School			1134/0	DAI	"Presence of malocclusion" (moderate, severe, or disabling)		

Supplementary Table II. Continued

Study, year	*Location*	*Setting*	*Male (%)*	*Age (y)*	*Recruited/reported*	*Malocclusion tool*	*Malocclusion threshold*	*QOL measure*	*QOL reporting*
Manjith, 2012[61]	India	Secondary care	50		200/0	IOTN DHC	Little or no need, borderline, required	OHIP 14	No summary score
Marquez, 2009[62]	Brazil	School	35	14-18	448/403	DAI	No treatment (≤25), definite treatment (>25)	OIDP	With impact 1
O'Brien, 2007[63]	UK	Secondary care	43	11-14	147/0	IOTN DHC	No need (1-2), moderate need (3), great need (4-5)	CPQ 11-14	Medians
Onyeaso, 2007[64]	Nigeria	School	48	12-17	274/274	ICON	Need (>43), easy (<29), mild (29-50), moderate (51-63), difficuly (67-77), very difficult (>77)	OHIP 14	No impact (0-1), impact (2-4)
Paula, 2009[65]	Brazil	School	42	13-20	301/301	DAI	1 (<25), 2 (26-30), 3 (31-35), 4 (>36)	OHIP	Overall score
Paula, 2012[66]	Brazil	School		12-12	0/515	DAI	No need (<31), need (>31)	CPQ 11-14	
Scarpelli, 2013[67]	Brazil	School		5-5	1632/1412	Morph features	Any feature = malocclusion	B-ECOHIS	Continuous
Schuch, 2015[68]	Brazil	School		8-10	1086/750	DAI		CPQ 8-10	All domains
Silva, 2016[69]	Brazil	School		12-15	1050/1015	DAI <25 no need	Angles class: normal, Class I, Class II	OHIP 14	No impact (0-9), impact (10-28)
Sousa, 2014[70]	Brazil	School		3-5	732/732	Morph features		ECOHIS	Continuous
Tessarollo, 2012[71]	Brazil	School	53	12-13	704/704	DAI-quartiles	≤20, 21-24, 25-28, ≥29	Specially designed Qs	Appearance, self-perception of speech and mastication
Tomazoni, 2014[72]	Brazil	School	46	12-12	1134/0	DAI	Not described	CPQ 11-14	0-64
Vedovello, 2016[73]	Brazil	School	47	7-10	1256/0	Overjet >2, cross bite <2, overbite >2	Class I, II, III	CPQ	Division at median
Feu, 2013[74]	Brazil			12-15	0/318	IOTN	Mean measures	OHIP 14	Overall score
Kramer, 2013[75]	Brazil	School	52	2-5	1380/1036	Overjet, AOB	Present or absent	ECOHIS	FIS and CIS
Sun, 2017[76]	Hong Kong	School	52	12	668/589	IOTN	No need (1-2), borderline need (3), definite need (4-5)	CPQ 11-14	Mean
Sun, 2018[77]	Hong Kong	School	51	15	668/364	IOTN	No need (1-2), borderline need (3), definite need (4-5)	CPQ 11-14	Mean
Traebert, 2018[78]	Brazil	School	40	4-5	389/389	DAI	Normal (<25), mild (26-30), severe (31-35), very severe malocclusion (≥36)	OIDP	All domains

Note. Empty spaces within the table mean that the data were not reported. *ECOHIS*, Early Childhood Oral Health Impact Scale; *FIS*, Family Impact Scale; *DHC*, Dental Health Component; *SD*, standard deviation; *UK*, United Kingdom; *AC*, aesthetic component; *SOHO-5*, Scale of Oral Health Outcomes for Five-Year-Old Children; *SOC-13*, Sence of Coherence Scale; *ICON*, index of complexity, outcome, and need; *RSES*, Rosenberg self-esteem scale; *CS*, condition-specific; *AOB*, anterior open bite; *CIS*, Child Impact Section.

Supplementary Table III. Caries and periodontal studies

Study, year	*Location*	*Setting*	*Male (%)*	*Age (y)*	*Recruited/ reported (n)*	*Malocclusion tool*	*Malocclusion threshold*	*Outcome measure*	*Outcome reporting*
Buczkowska-Radlinska, 2012[79]	Poland			3.5-19				Caries	DMFT
Ashley, 1998[80]	UK	School	57	12.7	201/201	Irregularity of incisors	Overlap and space requirement	Plaque	Silness & Loe
Davies, 1991[81]	UK	School			417/0	Crowding		Plaque	
Eismann, 1990[82]	Germany	Secondary care	60	9-9	30/0			Gingival health	
Mtya, 2009[83]	Tanzania	School	40	12-14	1601/0	Overjet, AOB, open bite, crowding	Bjork & Bjork	WHO criteria	DMFT
Singh, 2011[84]	India	School	52	12-12	945/927	DAI		Caries	DMFT
Jordão, 2015[85]	Brazil	School		12-12	2962/2075	DAI		Perio	CPI
Felden, 2015[86]	Brazil	School		11-14	509/509	DAI		Caries	DMFT
Zhang, 2017[87]	Hong Kong	School	53	4-5	538/495	Cross bite/open bite		Caries	DMFT

Note. Empty spaces within the table mean that the data were not reported. *DMFT*, decayed, missing, and filled teeth; *UK*, United Kingdom; *AOB*, anterior open bite; *WHO*, World Health Organization; *CPI*, Community Peridontal Index.

Supplementary Table IV. Newcastle-Ottawa risk of bias assessments for phase 2 studies

Study, year	*Study design*	*Selection*	*Comparability*	*Exposure*
Dann, 1995[40]	Case control	**	**	**
Benson, 2015[88]	Nonrandomized cohort	****	**	***
Thomson, 2002[89]	Nonrandomized cohort	****	**	*
Feu, 2013[74]	Nonrandomized cohort	****	*	***

Supplementary Table V. Cochrane risk of bias for phase 2 studies

Study, year	*Design*	*Random sequence generation*	*Allocation concealment*	*Blinding of outcome assessment*	*Incomplete outcome data*	*Selective reporting*	*Other biases*
Chen, 2011	RCT	High risk	Unclear risk	Low risk	High risk	Low risk	Low risk
Tesco, 2010	RCT	High risk	Unclear risk	High risk	Low risk	Low risk	High risk
O'Brien, 2009	RCT	Low risk	Low risk	Low risk	Low risk	Low risk	Low risk

RCT, randomized control trial.

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