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Does orthodontic treatment under the age of 18 years improve the oral health related quality of life of young people? A systematic review & meta-analysis.

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ABSTRACT

Introduction: Orthodontics aims to improve oral health-related quality of life (OHRQoL). This systematic review examined the evidence for changes in OHRQoL following orthodontic treatment.

Methods: Participants: patients aged <18 yrs; Interventions: non-orthognathic/cleft orthodontic treatment; Comparisons: before- and after-orthodontic treatment, and/or non-orthodontic control; Outcomes: validated measures of OHRQoL; Study designs: RCTs, CCTs, prospective cohort studies, cross-sectional or case-control studies. Multiple electronic databases were searched, with no language restrictions, authors were contacted and reference lists screened. The Newcastle-Ottawa scale was used for quality assessments. Screening, data extraction and quality assessments were performed by two investigators independently.

Results: 1590 articles were found and 13 studies were included (9 cohort, 3 cross-sectional and 1 case-control), six in meta-analyses. All were judged low or moderate quality. A moderate improvement in OHRQoL was observed before and after orthodontic treatment (n = 243 participants; SMD = -0.75, 95% CI -1.15 to -0.36) particularly in the dimensions of emotional well-being (n = 213 participants; SMD = -0.61, 95% CI -0.80 to -0.41) and social well-being (n = 213 participants; SMD = -0.62, 95% CI -0.82 to -0.43).

Conclusions: Orthodontic treatment during childhood or adolescence leads to moderate improvements in the emotional and social well-being dimensions of OHRQoL, although the evidence is of low and moderate quality. More high quality, longitudinal, prospective studies are needed.

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INTRODUCTION

The impact of malocclusion on both individuals and populations has been explored extensively. Many of the traditionally held beliefs regarding the dental health implications of malocclusion, such as an increase in caries,¹ periodontal disease,² or temporomandibular disorders,³ are now considered ambiguous and are largely unsupported by the literature. However, it is now recognised that the impact of malocclusion on health must be explored beyond the mere influence that it may have on dental health.⁴ After all, the World Health Organisation (WHO) describes health as a ‘state of complete physical, mental and social well-being and not merely the absence of disease or infirmity’.⁵ It is therefore unsurprising that over the past decade, the use of patient-reported outcomes measures (PROMs), including measures of oral health related quality of life (OHRQoL), have been recognised as crucial in identifying the functional, emotional, and social impacts of malocclusion.⁶

As an outcome measure, one of the fundamental objectives of OHRQoL is to provide a subjective evaluation of oral health status. As a reflection of this, a universally accepted definition of OHRQoL is one that describes it as a measure which focuses on ‘the impact of oral diseases and disorders on everyday life that a patient or person values, that are of sufficient magnitude, in terms of frequency, severity or duration to affect their experience and perceptions of their life overall’.⁷

Recent systematic reviews have found evidence to suggest that malocclusion impacts negatively on OHRQoL.^{8,9} Where the individual dimensions of OHRQoL have been explored, malocclusion has been found to have no significant impact on functional limitations (FL) and oral symptoms (OS).⁹ Remarkably, it is the dimensions of emotional well-being (EWB) and social well-being (SWB) that have been found to be significantly influenced.⁹ Not only has the impact of malocclusion been explored, but recently published literature has also sought to establish the effect that wearing orthodontic appliances may have on OHRQoL.¹⁰ To date, studies have determined that such appliances have a negative impact, particularly on the OS and FL dimensions. It could be argued that perhaps these results are unsurprising; after all, one would expect most forms of dental intervention to have a negative impact on OHRQoL during treatment. Moreover, it is logical to assume that it is the subsequent improvement in one or more dimensions on completion of treatment, which drives individuals to seek and undergo such care.

To date, there is evidence to suggest that malocclusion, and its’ subsequent treatment with orthodontic appliances, have a negative impact on OHRQoL.¹⁰ It is only appropriate to now question whether completion of orthodontic treatment to correct a malocclusion will lead to an improvement in this multi-dimensional concept. Identifying whether orthodontic treatment has such a benefit is crucial if we are to safeguard against interventions that may be of little value, and to prevent the wastage of limited healthcare resources in countries where such treatment is state-funded. To date, this specific question has not been addressed in the context of a systematic review.

The aim of this review was to systematically review the current literature to identify changes in OHRQoL before and after orthodontic treatment, in children and adolescents.

METHODS

Protocol and registration, conflict of interest and funding.

The protocol for this systematic review was registered on the National Institute of Health Research Database (registration number CRD42014014825; <http://www.crd.york.ac.uk/PROSPERO>). The

source of funding for the review was a National Institute for Health Research Academic Clinical Fellowship for Hanieh Javidi. The authors report no conflicts of interest.

Eligibility criteria

The following selection criteria were applied for the review:

1. Participants: Patients aged 17 years or under at the start of their orthodontic treatment. Exclusions were patients with craniofacial syndromes and cleft lip or palate and those who had undergone previous courses of orthodontic treatment (if it was possible to identify these patients).
2. Interventions: Any form of orthodontic treatment provided in primary, secondary or tertiary care settings were included. This included orthodontic treatment that involved the use of extractions, surgical exposure of unerupted teeth or surgical removal of teeth. Studies involving orthognathic surgery were excluded.
3. Comparator: Studies had to include either assessment of OHRQoL before- and after-orthodontic treatment, and/or include a comparison group with subjects who had not undergone orthodontic treatment. This could include subjects who were not due to undergo orthodontic treatment, or patients who were on the waiting list but had not yet started treatment.
4. Outcome measures: The main outcome measure was OHRQoL at any time period following orthodontic treatment. The OHRQoL must have been determined using a validated measure such as the Child Perception Questionnaire (CPQ). Secondary outcome measures included the dimensions of OHRQoL comprising, but not limited to, FL, OS, EWB and SWB.
5. Study design: Randomized and controlled clinical trials, prospective cohort studies, cross-sectional or case-control studies, with data collection or follow-up periods following the completion of orthodontic treatment were to be included.

Information sources, search strategy, and study selection

The following electronic databases were searched: MEDLINE via OVID (1946 to March week 3 2016) (see Appendix A for the search terms used for the search strategy), the Cochrane Oral Health Group's Trials Register (March 2016), The Cochrane Central Register of Controlled Trials (CENTRAL) (Issue 3 of 12, March 2016), EMBASE (1974 to March 2016), PsychINFO (1806 to March week 4 2016), PubMed (Inception to March 2016), Scopus (All years to present- 25 March 2016), Web of Science (1900 to 2016). No language restrictions were applied. No search of the grey literature was undertaken.

Any systematic and narrative reviews on the topic were assessed and any studies referenced therein that met the inclusion criteria for this systematic review were included; however, the reviews themselves were not included. The reference lists of eligible studies were also screened for additional relevant research. In addition to this, authors who are known to have an interest in this field of research were contacted to identify unpublished or ongoing trials.

Assessments of studies for inclusion in the review were performed independently and in duplicate. One author (H.J) assessed all of the studies, and the other two authors (M.V., P.E.B.) each assessed half of the retrieved studies. The investigators were not blinded to the authors or the results of the research and any disagreements were resolved by discussion with a third author who was not involved with the original screening of that particular study (M.V., or P.E.B. as appropriate).

Data items and collection

Data were extracted independently and in duplicate in a similar method to that used for assessment of studies for inclusion. Pre-piloted data extraction forms were used and, where available, the following information was recorded: (1) year of publication, country and study setting; (2) study design; (3) participants: sample size, age before and after orthodontic treatment, sex, severity of

malocclusion treated; (4) intervention: type of orthodontic treatment provided; (5) type of control or comparison group; (6) outcomes: OHRQoL measure (including individual dimensions, where available) and the OHRQoL informant.

Authors were contacted to clarify data as required, including further information regarding the OHRQoL outcome measure used, or additional data on the OHRQoL outcome.

Quality assessment/ risk of bias in individual studies

The quality of the eligible trials was assessed independently and in duplicate, and disagreements were resolved, using the same methods outlined for study selection and data extraction. If appropriate RCTs were identified for the review, it was the intention of the authors to use the Cochrane Collaboration's risk of bias tool to assess the risk, and therefore quality of these.¹¹ An appropriately modified version of the Newcastle-Ottawa scale was used to assess the quality of non-randomized studies.¹² This included the scale designed for cohort and case-control studies, and an adapted version of the scale suitable for the assessment of cross-sectional studies. This tool evaluates studies based on eight domains, which are divided into three broad criteria: patient selection, comparability of study groups, and outcome assessment. A star system was used, whereby high-quality studies at low risk of bias could receive a maximum of 9 stars. Studies achieving 8, 7 or 6 stars were considered to be of moderate quality, and a rating of 5 stars or less signified low quality.

Summary measures and approach to statistical analysis

Studies were grouped based on their study design (e.g. cohort, cross-sectional or case-control). Clinical heterogeneity of the included studies was determined by assessing the study protocol, and in particular, the type of comparator used. Statistical heterogeneity was assessed using the I^2 test, and a threshold of less than 50% was assumed to demonstrate sufficient homogeneity. All studies that reported OHRQoL measures as scores (continuous outcomes) were combined to obtain the pooled mean values with 95% confidence intervals, using the inverse variance method and the random effects model. Many of the instruments used to assess OHRQoL, including the CPQ₁₁₋₁₄, are designed such that a higher score indicates a poorer level of OHRQoL. Based on this, a reduction in scores, demonstrated by a negative difference, was interpreted as an improvement in OHRQoL.

Where studies used different scales or instruments for the assessment of OHRQoL, the standardized mean difference (SMD) for each study was used in the meta-analysis. SMDs were interpreted using thresholds described by Cohen, where 0.2 represents a small, 0.5 a moderate and 0.8 a large effect.¹³ All analyses were carried out using RevMan (version 5) and a significance level of 5% was adopted for all analyses.

Risk of bias across studies

Publication bias could only be assessed where at least ten studies were included in the meta-analysis. The two statistical measures that would be used for this purpose were the rank correlation of Begg's test and the Egger's test.

RESULTS

Figure 1 is a flow diagram showing the retrieval, screening and selection of articles for the review. The search returned 1590 studies after removal of duplicates. Contact with authors for the retrieval of possible unpublished studies returned one further study for the review. All the titles and abstracts were reviewed, and 32 potentially relevant articles were retrieved in full. After a detailed assessment, which included contact with relevant authors for further clarification regarding the validation of one OHRQoL outcome measure (OASIS), as well as the translation of one article from

Dutch to English, 18 studies were excluded (see Appendix B for screening details of full text articles) and 14 studies remained. Of these 14 reported trials, two were considered to be duplicate reports of the same study.^{14, 15} For the purpose of this systematic review, these two were included, assessed and analyzed as one study. This resulted in a total of 14 articles (13 studies) appropriate for inclusion.¹⁴⁻²⁷ Table 1 summarises the characteristics of the included studies. No RCTs meeting the eligibility criteria were identified. The study designs for the 13 included studies were as follows: 8 studies were cohorts, 1 study was a cohort, but also included cross-sectional data, 3 studies were cross-sectional, and 1 study was a case-control. One cohort study included three distinct groups of patients; one group with cleft lip and/or palate, another group receiving orthognathic surgical treatment, and a final group who received orthodontic treatment alone and were aged 17 years or under at the start of treatment.²⁵ As this final group provided data that met the inclusion criteria for this review, this study was deemed appropriate for inclusion.

The methodological quality scores, derived from the Newcastle-Ottawa scale, are shown in Figure 2 (for full details of scores see Appendix C please see supplementary data file). Overall, seven of the studies were judged to be of low quality,^{16, 18, 19, 23-25, 27} and 6 were considered to be of moderate quality.^{14, 15, 17, 20-22, 26} No studies received the maximum of 9 stars and none were therefore assessed as being of high quality. Eight studies achieved 2 or less stars for selection of the study groups, with no studies achieving the maximum of 4 stars available for this domain. Most studies failed to justify their samples sizes, and in less than half of the studies was selection of the control group (or non-respondents for cross-sectional studies) deemed adequate. Only three studies achieved the maximum of 2 stars available for comparability of the study groups. Four studies were found to score the maximum of 3 stars available for ascertainment of the outcome of interest.

The OHRQoL outcome measure used in 7 of the studies was the CPQ₁₁₋₁₄, and the remaining studies used the Oral Health Impact Profile-14 (OHIP-14) and/or the Oral Impacts on Daily Performances (OIDP) instrument.

Figure 3 is a forest plot showing the overall change in OHRQoL before and after orthodontic treatment changes derived from 4 cohort studies, involving 243 participants.^{20, 25-27} The pooled SMD in the reduction of the total OHRQoL scores before and after orthodontic was -0.75 (95% CI -1.15, -0.36) (Fig. 3). This demonstrated a statistically significant improvement in OHRQoL and was indicative of a medium effect size; however the data should be interpreted with caution, because significant heterogeneity between the studies was detected ($I^2 = 75\%$). Two of the studies showed large effect sizes of -0.83²⁷ and -1.49.²⁵ These studies were of a similar design, collecting data from a clinical sample of orthodontic patients before and after orthodontic treatment. Agou also employed a before and after longitudinal design in a clinical sample; however the study by Benson and colleagues was a longitudinal study undertaken in seven UK schools, rather than a clinical setting and the participants who reported a history of orthodontic treatment were a relatively small proportion of the overall sample.

Figure 4 is a forest plot of the data for the individual dimensions of OHRQoL, as measured using CPQ₁₁₋₁₄ based on a total of 213 participants. The data from the study by Antoun and colleagues²⁵ was excluded because OHRQoL was assessed using OHIP-14, with different domains to CPQ. The OS domain showed a statistically significant improvement before and after orthodontic treatment, but the effect size could be considered small (SMD -0.32, 95% CI -0.51, -0.13). Improvements in both the EWB and SWB domains were moderate, with a SMD improvement of -0.61 (95% CI -0.80, -0.41) and -0.62 (95% CI -0.82, -0.43), respectively. There was no statistically significant change in the FL domain was found from before and after orthodontic treatment. Sensitivity analyses were carried out for both meta-analyses, excluding the two studies,^{25, 27} that were found to be of low quality when pooling overall OHRQoL scores and one study²⁷ that was of low quality when combining data based on dimensions of OHRQoL. For change in overall OHRQoL, this resulted in a SMD improvement of -0.42 (95% CI -0.69, -0.16). Although this was less than that observed with the data from all four studies, the improvement was still classed as moderate. Similarly, the analyses of dimensional data showed moderate improvements in EWB (SMD -0.54,

95% CI -0.85, -0.22) and SWB (SMD -0.51, 95% CI -0.78, -0.24). The small improvement observed in OS however, was found to no longer demonstrate statistical significance (SMD -0.22, 95% CI -0.49, 0.04).

Figure 5 is a forest plot showing the pooling of data from two studies comparing OHRQoL levels in a sample of non-orthodontic subjects and a group of orthodontically treated subjects, based on 442²¹ and 199 subjects¹⁸ respectively. This shows no statistically significant differences between the two groups (SMD 0.04, 95% CI -0.13, 0.21).

DISCUSSION

As far as the authors are aware, this is the first systematic review and meta-analysis that sought to assess the impact of orthodontic care on the OHRQoL of young people following treatment. On the basis of this systematic review, it appears that OHRQoL improves moderately following treatment, particularly in the dimensions of EWB and SWB. It could be argued that such a finding is reassuring; after all, the presence of malocclusion has been found to have a significant impact on these two specific dimensions. One would expect these to improve following treatment, and the results of this systematic review support this. Furthermore, the meta-analysis of cross-sectional data, suggests that there is no significant difference in the OHRQoL of those who have undergone orthodontic treatment and that of non-orthodontic subjects. As malocclusion has been shown to have a negative impact on OHRQoL, it could be argued that it is the subsequent improvement following orthodontic treatment, which causes levels in those treated, and that of non-orthodontic patients, to be at a similar level.

A systematic review published in 2014, sought to assess the impact of wearing orthodontic appliances on OHRQoL, as well as the changes observed on completion of treatment.¹⁰ The authors of the review concluded that orthodontic treatment can moderately improve the OHRQoL of patients, though the authors were unable to conduct a meta-analysis. The results of our systematic review and meta-analyses support this finding, though the limited quality of evidence on which these conclusions are based must be considered.

There are certain methodological limitations associated with this systematic review that must be taken into consideration when interpreting the results. Firstly, it was anticipated that most, if not all, of the studies eligible for inclusion in the systematic review would be observational in nature. Unfortunately, due to the specific methods used in RCTs, addressing many of our orthodontic-based research questions, using such methodology, is often fraught with ethical challenges, and the research question addressed in this systematic review is no exception. Randomly assigning subjects to 'orthodontic treatment' and 'no treatment' groups, and following these subjects for long periods of time, could be argued as unethical. It is therefore unsurprising that this systematic review found no evidence, in the form of RCTs, to address the research question. The lack of RCTs clearly limited the strength of evidence on which to base the results and conclusions of the systematic review. After all, the results of any systematic review or meta-analysis are only as good as the original studies they are based on.

Secondly, only six studies were found to be of moderate quality, and the remainder were considered to be of low quality. Although the Cochrane collaboration provides thorough and rigorous methodology for conducting systematic reviews of RCTs, this is less clearly defined for observational studies. This systematic review found cohort, cross-sectional and a case-control study for inclusion, and assessing the quality of these proved difficult. A systematic review of tools used for the quality assessment of observational studies, found that there is currently no agreed 'gold standard' appraisal tool.²⁸ The Cochrane collaboration discusses the application of the Newcastle-Ottawa Scale, that was used in this review, for assessing the quality of non-randomized studies¹² and concerns have been raised regarding the ability of the scale to identify studies with biased results.²⁹ The scale might also be considered unduly harsh on those studies that include patients before and after treatment, but do not have an untreated control. This is discussed later.

Thirdly, the inclusion/exclusion criteria for this systematic review were designed such that there was no time limit on the post-treatment assessment of OHRQoL. This was done to ensure that all potentially relevant studies would be identified and included, given that it was anticipated few studies addressing the aim of the systematic review may have been published. Unsurprisingly, this resulted in some studies that had measured OHRQoL at short periods of time after completion of treatment, whilst others measured at longer times. This variation is an important factor that must be considered, as the impact that orthodontic treatment may have on OHRQoL following treatment may only be short-term, or may last longer.

Finally, and arguably the most significant limitation of this systematic review, was that the pooling of cohort data, comparing OHRQoL before-and after-orthodontic treatment was based entirely on the changes that occurred in the orthodontically treated subjects, under the age of 18 years. The age range was chosen to represent the time, under most healthcare systems, when many individuals will experience non-surgical orthodontic treatment. It could be argued that these changes were merely due to natural fluctuations in OHRQoL that may occur in such age groups. Indeed some longitudinal studies have demonstrated an improvement in adolescent OHRQoL over time.^{26, 30} Although three of the studies in the meta-analyses had recruited control groups to account for this, these included a 'waiting list' group,²⁰ a group of school children who had not undergone orthodontic treatment during the three year study period,²⁶ a cleft lip and/or palate group and a group of subjects that had undergone orthognathic surgery.²⁵ Unfortunately, the clinical heterogeneity of these groups made pooling of these data inappropriate. Furthermore, pooling of such data would require not only the reporting of mean change in OHRQoL scores during the study period, but also the SD of the change, and this information was available for only one study. An ideal control group for such studies would involve participants, of a similar age, who have a malocclusion, but are not yet undergoing orthodontic treatment (i.e. a waiting list control), as this would allow assessment of OHRQoL changes if treatment were not provided. The research is undertaken in areas where there is a waiting time for treatment. Participants who agree to take part are randomly allocated to start treatment straight away or remain on a waiting list. This approach has been used successfully in other areas of dentistry.³¹ A control group was used in one study, which found that changes in OHRQoL scores within the control group did not reach statistical significance. This suggests that the improvement observed in the orthodontic treatment group was due to the treatment alone.²⁰

One of the challenges faced when conducting a meta-analysis of OHRQoL data is that studies used different measures of OHRQoL, which are based on different number of questions and scales. In this review the data were combined and summarised using the SMD, which is one method of determining an effect size. The use of effect sizes has been advocated because, unlike inferential statistical analyses, such as p-values, which supply information about the reliability of the result, an effect size provides an easily interpretable value concerning the size and direction of a treatment effect.³²

Another issue that has been raised in the past is concerns about the face and content validity of instruments, such as the 16-item short version of the CPQ₁₁₋₁₄, OHIP and OIDP, when used in young people with malocclusions,^{7, 33} as well as the responsiveness of the measures over time.^{34, 35} Questionnaires developed with adults are not appropriate to use with young people, who might have different issues that are not addressed. It has also been suggested that a condition-specific measure of OHRQoL is required to ensure that any problems specific to malocclusion changes that occur, however subtle, are detected.³³ Such an instrument, would be ideal for use in any future trials of OHRQoL and orthodontic treatment, and may even detect the impact that treatment of various types and severities of malocclusion has on OHRQoL. One such instrument has been devised and the details of this malocclusion-specific instrument have recently been published.^{36, 37}

Clearly, the impact of orthodontic care on OHRQoL following completion of treatment needs to be explored further using high quality research methodology. Such studies need to be prospective in

nature, with appropriately selected and sized study and control groups, using a malocclusion-specific and a generic OHRQoL outcome measure. This will ensure that future studies are compatible for conducting meta-analyses that are meaningful and provide results that extend beyond statistical significance, and establish whether changes are clinically significant and important to our patients.

The overriding purpose of this systematic review was to determine whether orthodontic treatment provided in young people, led to improvements in OHRQoL. Unfortunately, the review did not identify any 'high quality' studies for inclusion, and was therefore unable to generate conclusions with a high degree of certainty. However, the ability of this review to identify all the studies addressing the subject, to assess their quality, and more importantly, to use this information as a basis for providing a platform on which future research in the subject area can be conducted, cannot be refuted.

CONCLUSIONS

On the basis of this review, it is reasonable to conclude that there is some evidence, albeit of low and moderate quality, that orthodontic treatment provided during childhood or adolescence leads to moderate improvements in OHRQoL following treatment. This appears to be particularly true for the EWB and SWB dimensions of OHRQoL. There is an urgent need for high quality, prospective studies to explore this further, and to determine whether observed benefits in OHRQoL are short or long-term in nature, and whether specific types or severities of malocclusion are more likely to benefit than others.

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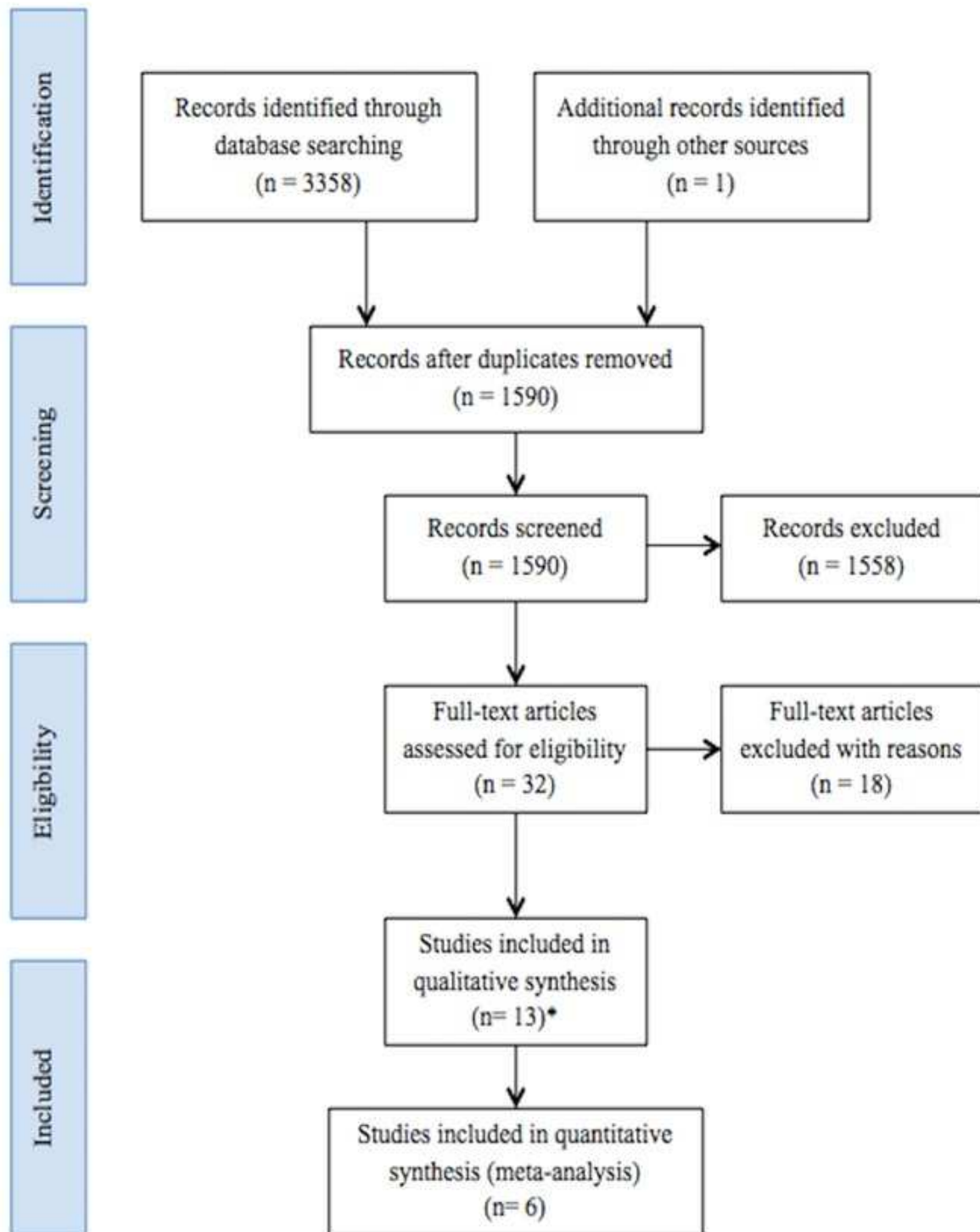
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FIGURES

Figure 1: PRISMA flowchart of article identification and selection



* Two articles were found to be reporting the results of the same study and were therefore analysed as one study.

Figure 2: Newcastle-Ottawa scores for included nonrandomized studies (n = 13)

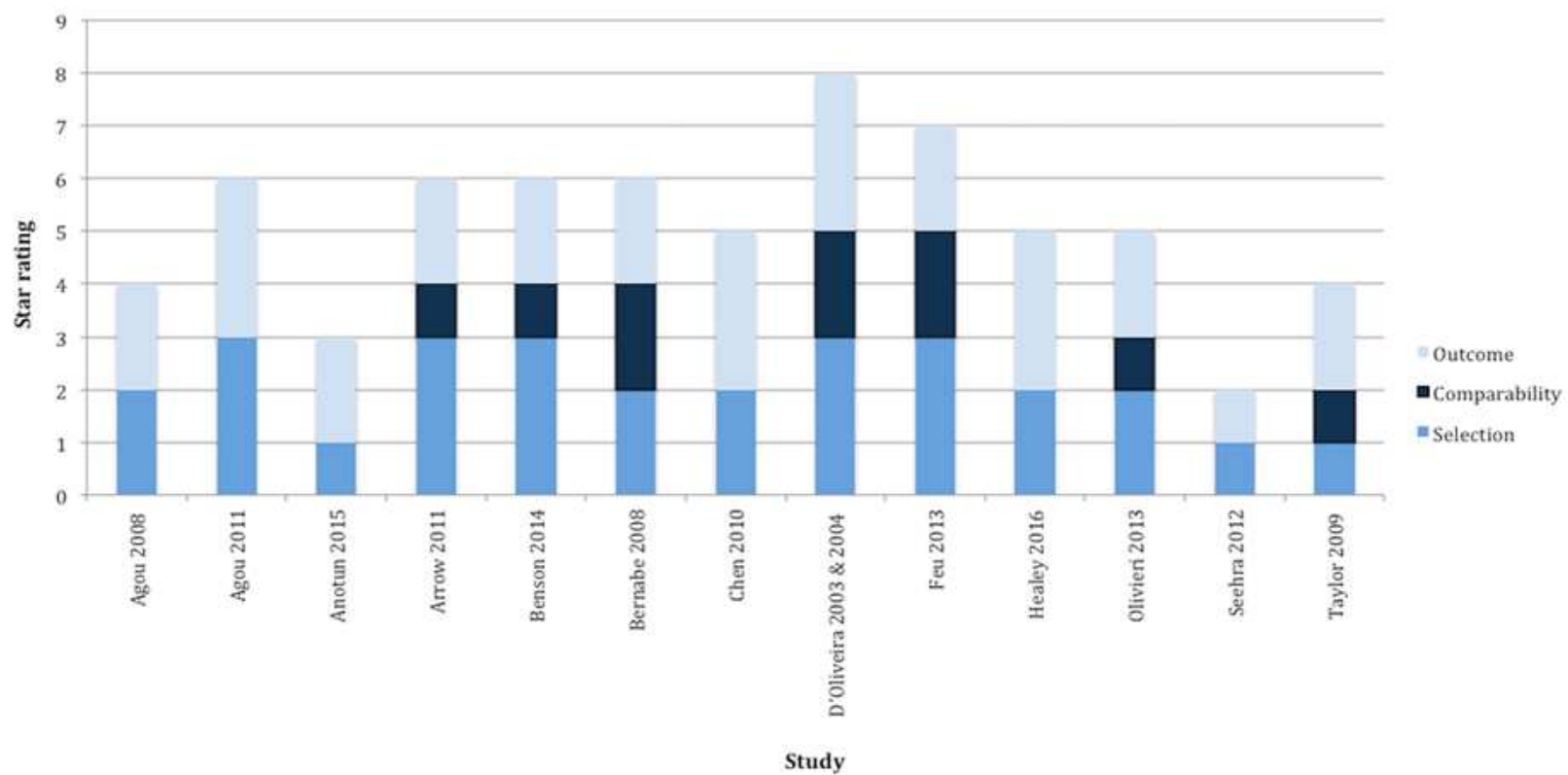


Figure 3: Forest plot for change in OHRQoL before and after orthodontic treatment.

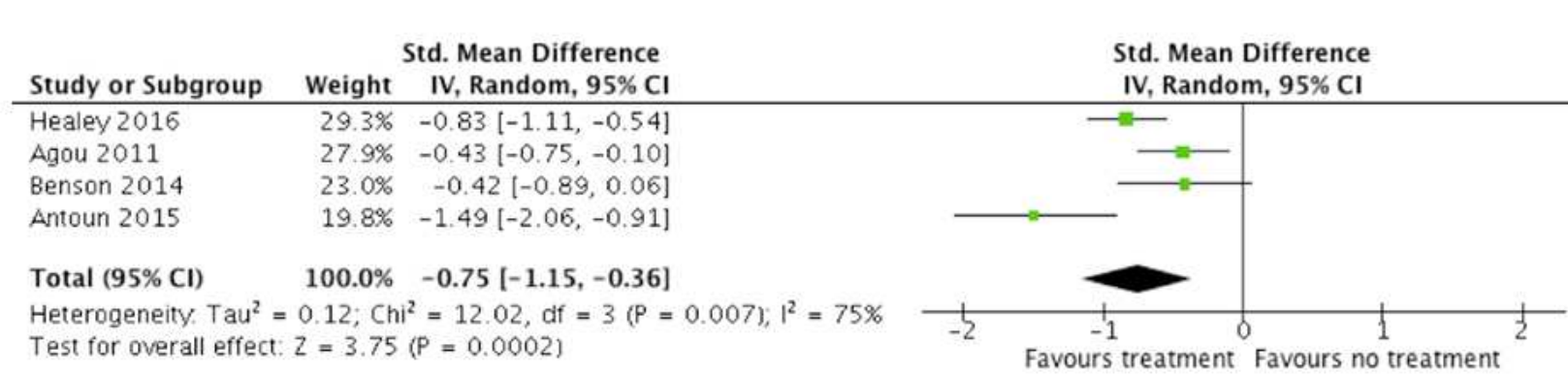


Figure 4: Forest plot for change in the dimensions of OHRQoL following orthodontic treatment.

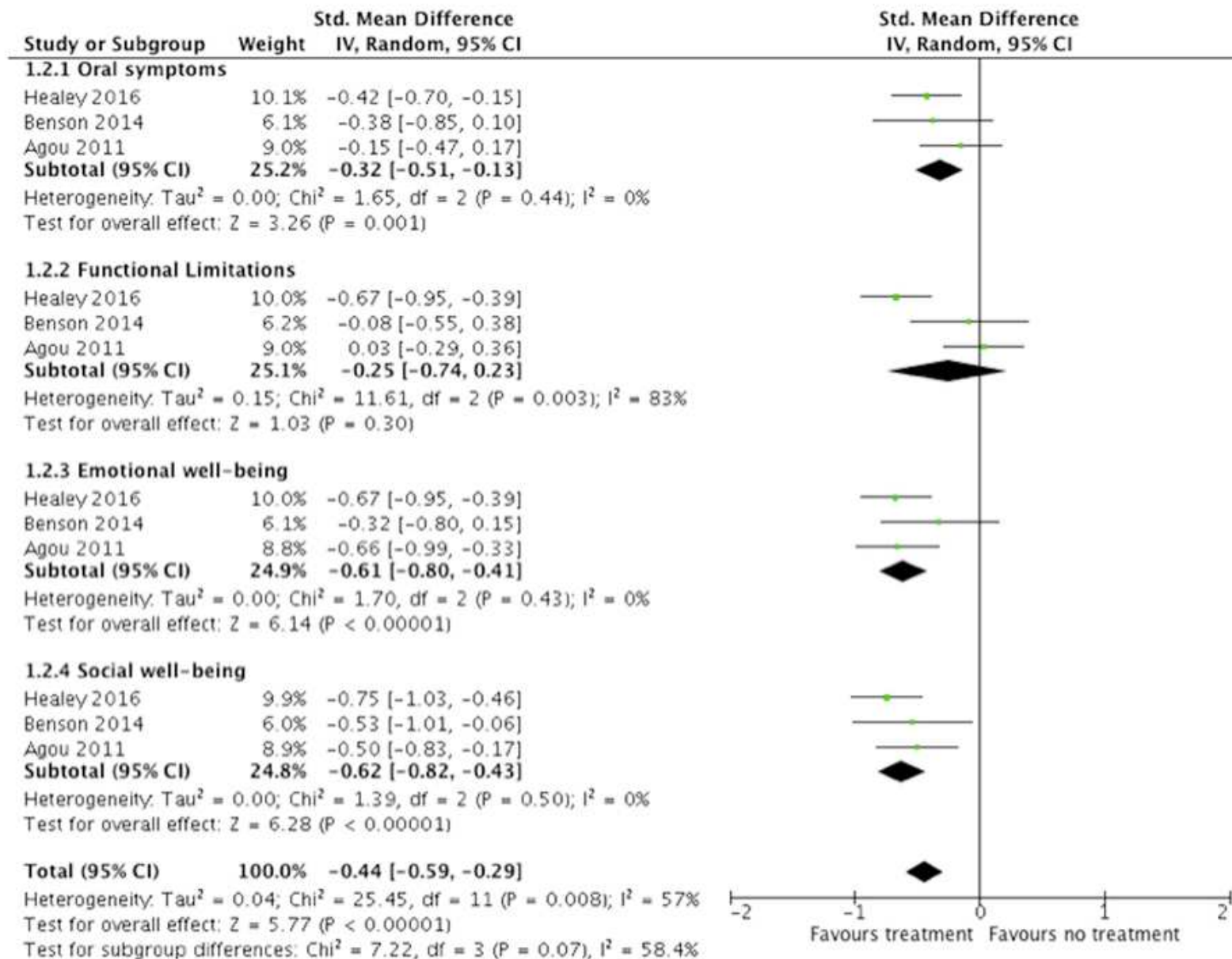
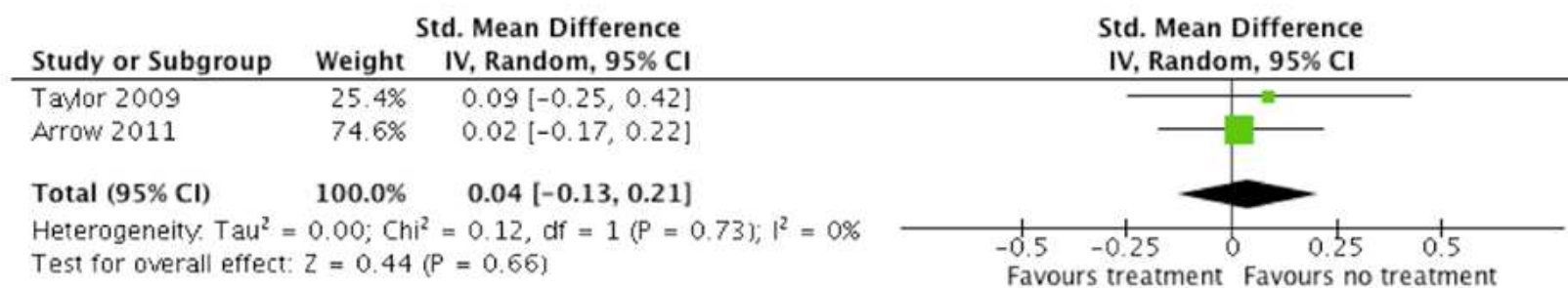


Figure 5: Forest plot of OHRQoL in a non-orthodontic sample versus an orthodontically treated group.



TABLES

Table 1: Characteristics of the included studies (N=13) (abbreviations used: F = Females; M = Males; SD = standard deviation; CL/P = cleft lip and palate).

Study	Study Design	Country	Setting (clinic/ population based)	Participants	OHRQoL measure	OHRQoL informant	Type of orthodontic treatment	Control/Comparison group
Agou 2008	Cohort	Canada	University teaching hospital (Clinic based)	Recruited (n = unreported); Follow-up at first re-call appointment (n = 45 children, 26 parents). Of those followed-up: 27 F, 18 M. Overall mean age of 12.6 years (SD, 1.4) Mean DAI score at baseline - 36.6, mean PAR score at baseline - 30.4.	CPQ 11-14	Self-reported and parent	Not stated	No control group
Agou 2011	Cohort	Canada	University teaching hospital (Clinic based)	Recruited (n = 199); Follow-up at first retention check appointment (n = 118) Of those followed-up: 59 F, 59 M. Overall mean age of 12.9 years (SD, 0.98) initially. Based on DAI, 44.2% handicapping, 25.7% severe, 23.9% definite, and 6.2% had minor malocclusions.	CPQ 11-14	Self-reported	Routinely prescribed fixed appliance therapy	Control subjects were consecutively recruited from same clinics during their first orthodontic screening visit
Antoun 2015	Cohort	New Zealand	Orthodontic unit of Christchurch Hospital (Clinic)	Recruited (not reported); At follow-up within 3-months of treatment completion -Standard orthodontic treatment group (n = 30); CL/P group (n = 24); Surgery group (n = 29) 37 F, 46 M. Pre-treatment mean age of standard group 14.5 years (SD, 1.9), CL/P 12.6 years (SD, 2.8), Surgery group 19.0 years (SD, 4.3). Pre-treatment DAI of standard group 45.5 (SD, 9.0), CL/P group 45.4 (SD, 13.4), Surgery group 56.6 (SD, 12.8).	OHIP-14	Self-reported	Single or double arched fixed appliances	2 groups of comparison: CL/P group and Orthoganthic Surgery group

Arrow 2011	Cohort (Follow-up) with cross-sectional elements	Australia	School Dental Service in South Australia (Clinic based for treated group; population based for control group)	Orthodontically treated (n = 155); Non-orthodontically treated (n = 286) Age of participants in both groups approximately 30 years. Orthodontically treated group vs. <i>Non-orthodontically treated group</i> - DAI ≤ 25 'No Need' (n = 53; n = 144), DAI 26–30 'Elective' (n = 32; n = 81), DAI 31–35 'Desirable' (n = 27; n = 35), DAI ≥ 36 'Mandatory' (n = 43; n = 26).	OHIP-14	Self-reported	Fixed orthodontic treatment	Random sample of adults the same age as the study cohort drawn from Adelaide's electoral register
Benson 2014	Cohort	UK	Seven publicly funded schools (Population based)	Recruited (n = 374); Follow-up at 3 years (n = 258) 252 F, 122 M. At baseline, all aged 11-12 years. IOTN DHC 'No need' (n = 96), 'Borderline need' (n = 138), 'Definite need' (n = 139).	CPQ 11-14 ISF-16	Self-reported	Not stated	Those who had no history of undergoing orthodontic treatment
Bernabe 2008	Case-control	Brazil	Secondary schools in Bauru (Population based)	Cases n = (279); Controls (n = 558) 485 F, 352 M. Aged 15 years n = 552, aged 16 years n = 285. Orthodontic treatment need of cases vs. <i>controls</i> - No need (n = 116; n = 360), Moderate need (n = 58; n = 122), Definite need (n = 105; n = 76)	OIDP	Self-reported	Any history of orthodontic treatment irrespective of the type of appliance used.	Adolescents who had never received, or had not completed orthodontic treatment
Chen 2010	Cohort	China	University teaching hospital (Clinic based)	Recruited (n = 250); Follow-up at post-treatment (n = 222) 148 F, 74 M. Overall mean age of 15.7 years	OHIP-14	Self-reported	Fixed appliance treatment	No control group
D'Oliveira 2003 & 2004	Cross-sectional	Brazil	Public and private schools (Population based)	Orthodontically treated (n = 258); Having orthodontic treatment (n = 357); Untreated (n = 1060) 951 F, 724. Participants aged 15 years (n = 1110), aged 16 years (n = 565). IOTN DHC 'No/slight need' (n = 1031), 'Moderate need' (n = 351), 'Need' (n = 293)	OIDP & OHIP-14	Self-reported	Not stated	2 groups: Adolescents undergoing orthodontic treatment and adolescents who have not undergone orthodontic treatment
Feu 2013	Cohort	Brazil	Dental School for treatment group (TG) and waiting list group (WG) (Clinic based). Public School for school group (SG) (Population based)	Recruited TG (n = 92); WG (n = 124); SG (n = 102); Follow-up at 2 years in TG (n = 87); WG (n = 101); SG (n = 96) 169 F, 149 M. Mean age in TG of 13.4 years (SD, 1.1), WG 13.7 years (SD, 1.1), SG 13.7 years (SD, 1.2). IOTN DHC mean TG 3.5 (SD, 1.1), WG 3.4 (1.2), SG 3.0 (0.9).	OHIP-14	Self-reported	Not stated	2 groups of comparison: The orthodontic WG & the SG included children from a public school who never undergone or sought for orthodontic treatment

Healey 2016	Cohort	New Zealand	Nineteen Private specialist orthodontic practices (Clinic)	Recruited (n = 174); Follow-up at end of orthodontic treatment (n = 152); Follow-up at end of study period approximately 21 months after end of treatment (n = 104). 112 F, 62 M. Mean age at baseline of 13.5 years (SD, 1.3). Mean DAI at baseline 35.8 (8.4).	CPQ 11-14	Self-reported	Upper and lower fixed orthodontic treatment	No control/ comparison group
Olivieri 2013	Cross-sectional	Italy	Adolescents attending the last year of middle school (Population based)	Undergone orthodontic treatment (n = 115); Not undergone orthodontic treatment (n= 444) 269 F, 292 M. All participants 14 years of age.	CPQ 11-14	Self-reported	Not stated	Those who had not already undergone orthodontic treatment
Seehra 2013	Cohort (Follow-up)	UK	Dental Hospitals - Kent & Canterbury Hospital, William Harvey Hospital, Guy's campus of King's College London Dental Institute (Clinic based)	Recruited at follow-up (n = 27) 14 F, 13 M. Mean age of sample was 14.6 years (SD, 1.5). Pre-treatment IOTN was grade 5 (n = 16), grade 4 (n = 9), grade 3 (n = 1), grade 2 (n = 1).	CPQ 11-14	Self-reported alone or with assistance from their caregiver.	Fixed appliances either alone or in combination with functional appliances	No control/ comparison group
Taylor 2009	Cross-sectional	USA	University of Washington School of Dentistry and Odessa Brown Children's Clinic (Clinic based)	Recruited Precomprehensive group (PC) (n = 93); Postinterceptive group (PI) (n = 44); Comparison group (C) (n = 156) PC- 45 F, 48 M, PI- 21 F, 23 M, C- 76 F, 80 M. Mean age in PC of 12.5 (+/- 1.1), PI 12.5 years (+/- 1.1), C 12 years 9 months (+/- 1.1). Pre- ICON total in PC 69.0 (+/- 21.5), PI 79.0 (+/- 20.1).	CPQ 11-14	Self-reported	Interceptive orthodontic treatment	2 groups of Paediatric dental patients- Precomprehensive group with no orthodontic treatment and a comparison group with no plans to have treatment