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Socioeconomic disparities in orthodontic treatment outcomes and expenditure on orthodontics in England's state-funded National Health Service

Price, Juliet; Whittaker, William; Birch, Stephen; Brocklehurst, Paul; Tickle, Martin

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BMC Oral Health

Socioeconomic disparities in orthodontic treatment outcomes and expenditure on orthodontics in England's state-funded National Health Service: A retrospective observational study --Manuscript Draft--

Manuscript Number:	OHEA-D-17-00149R2
Full Title:	Socioeconomic disparities in orthodontic treatment outcomes and expenditure on orthodontics in England's state-funded National Health Service: A retrospective observational study
Article Type:	Research article
Section/Category:	Delivery, management, and promotion of oral health and dental care
Funding Information:	
Abstract:	<p>Background: This study aimed to assess whether there are potential areas for efficiency improvements in the National Health Service (NHS) orthodontic service in North West England and to assess the socioeconomic status (SES)-related equity of the outcomes achieved by the NHS.</p> <p>Methods: The study involved a retrospective analysis of 2008-2012 administrative data, and the study population comprised patients aged ≥ 10 who started NHS primary care orthodontic treatment in North West England in 2008. The proportions of treatments that were discontinued early and ended with residual need (based on post-treatment Index of Orthodontic Treatment Need [IOTN] scores that met or exceeded the NHS eligibility threshold of 3.6) and the associated NHS expenditure were calculated. In addition, the associations with SES were investigated using linear probability models.</p> <p>Results: We found that 7.6% of treatments resulted in discontinuation (which was associated with an NHS annual expenditure of £2.3 m), and a further 19.4% (£5.9 m) had a missing outcome record. Furthermore, 5.2% of treatments resulted in residual need (£1.6 m), and a further 38.3% (£11.6 m) had missing IOTN data (due to either a missing outcome record or an incomplete IOTN outcome field in the record), which led to an annual NHS expenditure of £13.2 m (44% of the total expenditure) on treatments that are a potential source of inefficiency. Compared to the patients in the highest SES group, those in the lower SES groups were more likely both to discontinue treatment and to have residual need on treatment completion.</p> <p>Conclusions: Substantial inefficiencies were evident in the NHS orthodontic service, with 7.6% of treatments ending in discontinuation (£2.3 m) and 5.2% ending with residual need (£1.6 m). Over a third of cases had unreported IOTN outcome scores, which highlights the need to improve the outcome monitoring systems. In addition, the SES gradients indicate inequity in the orthodontic outcomes, with children from disadvantaged communities having poorer outcomes compared to their more affluent peers.</p>
Corresponding Author:	William Whittaker, Ph.D. University of Manchester Manchester, Greater Manchester UNITED KINGDOM
Corresponding Author Secondary Information:	
Corresponding Author's Institution:	University of Manchester
Corresponding Author's Secondary Institution:	
First Author:	Juliet Price, Ph.D.
First Author Secondary Information:	
Order of Authors:	Juliet Price, Ph.D.

	William Whittaker, Ph.D.
	Stephen Birch, Ph.D.
	Paul Brocklehurst, Ph.D.
	Martin Tickle, Ph.D.
Order of Authors Secondary Information:	
Response to Reviewers:	<p>Dear Editor</p> <p>My co-authors and I would like to thank BMC Oral Health for the consideration of our revised manuscript. We were happy to see the revised manuscript has addressed the reviewer comments. We have edited the revised manuscript to address the two comments noted by the editorial board. The changes made to the manuscript are detailed below.</p> <p>Best wishes William Whittaker</p> <p>Revision requests:</p> <p>1.Unfortunately we are unable to access the web link for reference 12. Please ensure that you have provided the correct web link for this reference.</p> <p>Author response: we have replaced the reference with the latest FP170 form:</p> <p>References: Page 21 line 9 to line 11: "NHSBSA. FP17O revision 6. 2016 https://www.nhsbsa.nhs.uk/sites/default/files/2017-04/20160216_FP17O_Proof_SAMPLE.pdf Accessed 5 September 2017."</p> <p>2.Please list each individual author and their contributions in the Authors' Contributions section (e.g. Authors AB, CD, EF and GH participated in data acquisition, analysis, and interpretation). We note that the contributions of authors SB and PB have not been individually listed in this section.</p> <p>Author response: we have expanded the authors' contributions to include each author's initials where 'all the authors' were mentioned:</p> <p>Authors' contribution: Page 19 line 15 to line 18: "Authors JP, WW, SB, PB and MT contributed to the conception and design of the study, data interpretation, manuscript revisions and approved the final manuscript. MT acquired the data. JP and WW drew up the detailed analysis plan. JP carried out the analysis and drafted the manuscript."</p>

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2 1 **Socioeconomic disparities in orthodontic treatment outcomes and expenditure on**
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4 2 **orthodontics in England's state-funded National Health Service: A retrospective**
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6 3 **observational study**
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10 4 Juliet Price¹, William Whittaker^{2,*}, Stephen Birch³, Paul Brocklehurst⁴ and Martin Tickle⁵
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12 6 ¹ Division of Dentistry, School of Medical Sciences, University of Manchester, Manchester, UK; email:

13 7 juliet.price@cantab.net
14

15 8 ² Manchester Centre for Health Economics, School of Health Sciences, University of Manchester, Manchester,

16 9 UK; email: william.whittaker@manchester.ac.uk
17
18

19 10 ³ Department of Clinical Epidemiology and Biostatistics, McMaster University, Hamilton, Canada; email:

20 11 birch@mcmaster.ca
21
22

23 12 ⁴ Institute of Medical and Social Care Research, Bangor University, Bangor, UK; email:

24 13 p.brocklehurst@bangor.ac.uk
25
26

27 14 ⁵ Division of Dentistry, School of Medical Sciences, University of Manchester, Manchester, UK; email:

28 15 martin.tickle@manchester.ac.uk
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31 16 *Corresponding author
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1 **Abstract**

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3 2 **Background:** This study aimed to assess whether there are potential areas for efficiency
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6 3 improvements in the National Health Service (NHS) orthodontic service in North West
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8 4 England and to assess the socioeconomic status (SES)-related equity of the outcomes
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10 5 achieved by the NHS.

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14 6 **Methods:** The study involved a retrospective analysis of 2008–2012 administrative data, and
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16 7 the study population comprised patients aged ≥ 10 who started NHS primary care orthodontic
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18 8 treatment in North West England in 2008. The proportions of treatments that were
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21 9 discontinued early and ended with residual need (based on post-treatment Index of
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23 10 Orthodontic Treatment Need [IOTN] scores that met or exceeded the NHS eligibility
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25 11 threshold of 3.6) and the associated NHS expenditure were calculated. In addition, the
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28 12 associations with SES were investigated using linear probability models.

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32 13 **Results:** We found that 7.6% of treatments resulted in discontinuation (which was associated
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34 14 with an NHS annual expenditure of £2.3 m), and a further 19.4% (£5.9 m) had a missing
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37 15 outcome record. Furthermore, 5.2% of treatments resulted in residual need (£1.6 m), and a
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40 16 further 38.3% (£11.6 m) had missing IOTN data (due to either a missing outcome record or
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42 17 an incomplete IOTN outcome field in the record), which led to an annual NHS expenditure of
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44 18 £13.2 m (44% of the total expenditure) on treatments that are a potential source of
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47 19 inefficiency. Compared to the patients in the highest SES group, those in the lower SES
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50 20 groups were more likely both to discontinue treatment and to have residual need on treatment
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52 21 completion.

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55 22 **Conclusions:** Substantial inefficiencies were evident in the NHS orthodontic service, with
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57 23 7.6% of treatments ending in discontinuation (£2.3 m) and 5.2% ending with residual need
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60 24 (£1.6 m). Over a third of cases had unreported IOTN outcome scores, which highlights the

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1 need to improve the outcome monitoring systems. In addition, the SES gradients indicate
2 inequity in the orthodontic outcomes, with children from disadvantaged communities having
3 poorer outcomes compared to their more affluent peers.

4 **Keywords:** orthodontics; malocclusion; treatment outcomes; socioeconomic status

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1 **Background**

2 In England, NHS expenditure on the primary care orthodontic service amounts to
3 approximately £250 m per year [1,2], which makes ensuring maximum value for money in
4 the NHS orthodontic service critical. Moreover, the expenditure may continue to increase as a
5 result of increases in social acceptance of fixed orthodontic appliances and expectations
6 regarding dental appearance [3,4]. However, the NHS is currently under a great deal of
7 pressure to reduce expenditure because NHS commissioners and providers ended 2015/2016
8 with an aggregate deficit of £1.85 billion (a threefold increase on the previous year) [5].

9 A number of studies, which were largely hospital-based studies, have highlighted the
10 potential for suboptimal outcomes in the NHS orthodontic service in England and Wales.
11 These studies have focused on both discontinuation (i.e., failure to complete a course of
12 active treatment) [6,7] and suboptimal outcome scores based on occlusal indices such as the
13 Index of Orthodontic Treatment Need (IOTN) [8], the Index of Complexity, Outcome, and
14 Need (ICON) [8,9], and the Peer Assessment Rating (PAR) index [8,10] (the PAR index was
15 developed as a simple tool for assessing the orthodontic outcomes of groups of patients,
16 rather than individual patients and, as part of the NHS orthodontic outcome monitoring
17 system, providers are required to report PAR scores for 20 patients plus 10% of the additional
18 patients [11]).

19 In addition, several studies have explored the associations between socioeconomic status
20 (SES) and suboptimal orthodontic outcomes in the NHS. For example, a hospital-based study
21 in England of 144 orthodontic patients aged between 9 and 19 reported that SES was not
22 associated with discontinuation [6]. In contrast, a study based on 1990–1991 Dental Practice
23 Board data from England and Wales reported a positive association between deprivation and
24 discontinuation [7]. Moreover, a hospital-based study in England found a positive association

1 between deprivation and ‘low or no improvement in occlusion’ (defined as a score lower than
2 the sample median ICON improvement score of a modified version of the ICON), based on
3 an analysis of 135 12- to 16-year-olds treated for 1 year with fixed orthodontic appliances [9].
4 In this study, we aimed to identify the scale of potential efficiency improvements in the NHS
5 primary care orthodontic service. To do this, we quantified the proportion of, and NHS
6 expenditure on, treatments that were discontinued early and those that ended with residual
7 post-treatment need. Secondly, we aimed to analyse whether the proportions of treatments
8 ending in discontinuation and residual need differed by SES in order to assess the equity of
9 the outcomes achieved by the NHS and whether initiatives to improve the efficiency of the
10 service should be targeted at specific populations.

11 **Methods**

12 The study involved a retrospective analysis of data from 1 January 2008 to 31 December
13 2012 from all orthodontic activity records (i.e., FP17O records) submitted by primary care
14 dentists who were working under state-funded NHS contracts in North West England [12].

15 The pseudo-anonymised data set was provided by the National Health Service Business
16 Services Authority (NHSBSA).

17 The study population comprised patients ≥ 10 years old who started orthodontic treatment in
18 2008. The analysis was restricted to patients aged ≥ 10 because those aged ≤ 9 receive only
19 interceptive treatment (which amounted to 1.6% of the treatments in the data set), while those
20 aged ≥ 10 receive full courses of treatment. The NHS provides the vast majority of
21 orthodontic treatments for children in the UK, with only 2.4% (95% CI: 0.7–4.0%) of
22 children having private treatment by the age of 15 [13]. As the data set used in this study
23 represented the entire population of patients aged ≥ 10 who received orthodontic treatment

1 under state-funded NHS contracts in North West England, inferential statistics were
2 unnecessary.

3 The data set included clinician-reported information on whether each treatment was
4 completed or discontinued, along with IOTN outcome scores that were used to calculate
5 residual need (these are assessed at the final appointment before treatment completion or
6 discontinuation).

7 Discontinuation was defined as failure to complete a course of active treatment before the end
8 of the treatment plan (as recorded by clinicians in the FP17O records). Discontinuation can
9 be initiated by patients (who can request to stop treatment early or fail to return for treatment;
10 once it has been established that a patient does not wish to return, the dentist is required to
11 submit an outcome record) or by dentists (e.g., when a patient fails to comply with oral
12 hygiene advice, repeatedly misses appointments, or breaks their orthodontic appliance) [12].

13 Residual need was measured based on whether each patient's IOTN score at the end of active
14 treatment met or exceeded the NHS IOTN eligibility threshold of 3.6 (i.e., a Dental Health
15 Component [DHC] score of 3 with an Aesthetic Component [AC] score of 6) [14].

16 Discontinuation and residual need are not mutually exclusive in that, for example, a patient
17 can discontinue treatment (e.g., because the patient's parents can no longer take their child to
18 orthodontic appointments) and yet have no residual need by the time they discontinue
19 (despite not completing the full planned course of treatment).

20 As self-assessment of treatment outcomes can be subject to bias, providers are encouraged to
21 utilise the services of an independent third party calibrated in the use of the IOTN and the
22 PAR index [15]. In addition, the NHSBSA carries out independent monitoring of five
23 patients of 450 orthodontic clinicians per year, which involves requesting full patient records,
24 including photographs, radiographs, and pre- and post-treatment models of the patients'

1 occlusions [16]. While this monitoring process often involves flagging up issues for
2 discussion with the orthodontic clinicians (which are then resolved without further scrutiny),
3 it very rarely leads to further investigation being conducted [16].

4 Firstly, we calculated the proportions of patients who a) discontinued treatment, b) completed
5 treatment, and c) had a missing outcome record (i.e., no record submitted within the study
6 period indicating that treatment had been completed or discontinued). The analysis was
7 restricted to treatments that started in 2008, treatment usually takes 18–24 months to
8 complete [17], and the data set provided outcomes for the subsequent 4 years, so missing
9 outcome records were considered to be reflective of reporting issues.

10 Secondly, we calculated the proportions of patients with residual need, no residual need, and
11 incomplete IOTN outcome fields among a) patients who discontinued treatment and b) those
12 who completed treatment. Thirdly, we calculated the overall proportions of patients who had
13 residual need, no residual need, incomplete IOTN outcome fields, and missing outcome
14 records.

15 NHS expenditure was determined by calculating the numbers of Units of Orthodontic
16 Activity (UOAs) carried out in 2008 by the NHS orthodontic providers. Under NHS payment
17 arrangements, the quantity of services that an orthodontic provider is contracted to deliver is
18 expressed on the basis of an annual target number of UOAs (as agreed by the NHS and the
19 provider), and the annual payments are issued as monthly instalments, 1 month in arrears [1].
20 Courses of treatment (including an initial assessment) for patients aged 10–17 attract 21
21 UOAs and those for patients aged >17 attract 23 UOAs; one UOA (the value of which differs
22 between different contracts) has a mean value of approximately £59 [1].

23 To assess whether the proportions of treatments ending in discontinuation and residual need
24 differed by SES, ordinary least squares (OLS) linear regressions were used (whilst not used

1 to generate statistical tests, this approach provided details on the proportions of children with
2 the treatment outcomes and enabled our analyses to be adjusted for potential confounding).

3 The data set included area-level SES data in the form of Index of Multiple Deprivation (IMD)
4 scores [18] that had been matched by the NHSBSA to the patients' postcodes at the level of
5 Lower-layer Super Output Areas (LSOAs). Cut-points for IMD quintiles (with respect to the
6 population of England) were used to calculate each patient's IMD quintile. The first SES
7 analysis assessed whether discontinuation differed by SES, and the second and third analyses
8 assessed whether residual need differed by SES for patients who discontinued and completed
9 treatment, respectively.

10 Initially, unadjusted SES analyses were carried out (i.e., only the SES dummy variables were
11 included in the models). Subsequently, the analyses adjusted for potential confounding (to
12 separate the effect of confounders from the effect of SES) by adding the following potential
13 confounders to the models: IOTN AC score at the start of treatment (1–10; which was used to
14 reflect the complexity of treatment), gender, and age. This helped to ensure that any SES-
15 related differences would not reflect, for example, differences in treatment complexity or late
16 uptake of treatment.

17 In each model, the SES coefficients represent the mean percentage-point difference
18 (compared to being in the reference category, which was the least deprived group) in the
19 proportion of children with the treatment outcome variable (discontinuation or residual need)
20 when all other variables besides SES (i.e., the potential confounders) are held constant.

21 To assess potential biases to the SES analyses due to incomplete IOTN outcome fields and
22 missing outcome records, we explored whether the number of incomplete IOTN outcome
23 fields differed by SES (for patients who discontinued and completed treatment) and whether
24 the number of missing outcome records differed by SES.

1 The statistical analyses were conducted using Stata version 13 [19].

2 **Results**

3 There were 24501 treatment starts in 2008. Of these, 4746 (19.4%) were missing an outcome
4 record, while the remaining 19755 (80.6%) had an associated outcome record. Of the 19755
5 outcome records, 4636 (23.5%) had incomplete IOTN outcome fields (3456 for patients who
6 completed treatment and 1180 for those who discontinued treatment).

7 As shown in Table 1, 7.6% of treatments were discontinued and 73.1% were completed,
8 while the remaining 19.4% had missing outcome records. Among the treatments associated
9 with outcome records (n=19755), 9.4% were discontinued and 90.6% were completed. The
10 proportion of patients with residual need among those who discontinued and completed
11 treatment was 16.3% and 5.4%, respectively.

12 As shown in Table 2, overall, 5.2% of patients had residual need and 56.5% had no residual
13 need, while the remaining 38.3% had either incomplete IOTN outcome fields (18.9%) or
14 missing outcome records (19.4%). Among the treatments with IOTN outcome scores
15 (n=15119), 8.4% had residual need and 91.6% had no residual need. Compared to female
16 patients, male patients were more likely, overall, to discontinue treatment and to have
17 residual need.

18 In 2008, £2.3 m was expended by the NHS on treatments in North West England for patients
19 aged ≥ 10 that ended in discontinuations (Table 1). The corresponding value for treatments
20 that were discontinued or completed with residual need was £1.6 m (Table 2). A further £11.6
21 m was expended on treatments that had missing IOTN outcome data (Table 2). Thus, residual
22 need and missing IOTN outcome data was associated with an expenditure of £13.2 m (i.e.,
23 44% of the total NHS expenditure).

1 Table 3 shows the treatment outcomes by SES. Discontinuation was more likely for those in
2 the lower SES groups compared to those in the highest SES group, and this association
3 persisted after adjusting for potential confounders (Model 1); the distributions of the potential
4 confounders by IMD quintile are provided in Additional file 1. Furthermore, among the
5 patients who completed treatment, those in the lower SES groups were also more likely to
6 have residual need than those in the highest SES group, and this association persisted in the
7 adjusted analysis (Model 2). However, among the patients who discontinued treatment, there
8 was no association between SES and residual need (Model 3).

9 As shown in Table 4, higher SES was associated with incomplete IOTN outcome fields
10 among patients who completed treatment (Model 4), but there was no association with SES
11 among those who discontinued treatment (Model 5). In contrast, lower SES was associated
12 with missing outcome records (Model 6). The SES-related associations persisted in the
13 adjusted analyses.

14 **Discussion**

15 In North West England, 7.6% of orthodontic treatments that were started in 2008 for patients
16 aged ≥ 10 resulted in discontinuation and 5.2% resulted in residual need. The proportion of
17 patients with residual need among those who discontinued and completed treatment was
18 16.3% and 5.4%, respectively. It is likely that early discontinuation has a much larger effect
19 on residual need than discontinuation near the end of a course of treatment. However, our
20 results show that residual need is evident for some patients even when a course of treatment
21 is completed.

22 NHS expenditure on treatments that resulted in discontinuation amounted to £2.3 m, and £1.6
23 m was expended on treatments that ended with residual need (for treatments that were either

1 discontinued or completed). These figures highlight the need to increase the cost-
2 effectiveness of NHS orthodontic care.

3 Moreover, previous studies of NHS orthodontic treatment outcomes [6–10] have tended to
4 report higher rates of poor treatment outcomes compared to those identified in our study. For
5 example, a study in England of 144 patients who were treated at several hospitals and a
6 primary care practice found that 43% failed to complete their treatment (the most common
7 reasons being poor oral hygiene, multiple missed appointments, and orthodontic appliance
8 breakages) [6]. However, most of the patients were hospital patients, and treatment provision
9 may also have been affected by the three orthodontic clinicians involved being aware that the
10 discontinuation rates would be published. Another study compared the differences in residual
11 need rates (as measured using the IOTN, PAR index, and ICON) for 130 patients who were
12 treated in hospitals in the North of England [8]. The study found that different occlusal
13 indices indicated differing levels of residual need, for example, 20.1% of patients had
14 residual need according to their IOTN DHC scores and 17.2% according to their ICON
15 scores [8]. In contrast to our study, the study involved hospital patients (as in the
16 abovementioned study), so the sample may represent a more complex case mix than those
17 treated in primary care practices, and the skills and training of the clinicians involved would
18 differ from those of primary care orthodontic clinicians.

19 We also found that lower SES was associated with discontinuation and residual need after
20 completing treatment, indicating SES-related inequality in outcomes. However, there was no
21 association between SES and residual need among the patients who discontinued treatment,
22 which suggests that ceasing treatment early does not contribute to SES-related inequality in
23 residual need.

1 Previous UK studies have also indicated that there are associations between low SES and
2 poor treatment outcomes. First, a study in England and Wales of 1,431 patients (based on a
3 1990–1991 Dental Practice Board data set that covered all patients who discontinued
4 treatment and 2% of those who had completed treatment) found a larger percentage of those
5 from the more deprived groups (using multiple area-level SES measures) discontinued
6 treatment [7]. A study in England of 135 12- to 16-year-olds treated for one year with fixed
7 orthodontic appliances in the hospital dental service found that deprivation (based on
8 characteristics of parental employment) was associated with high improvement in occlusion
9 (defined as a score equal to or higher than the sample median ICON improvement score of a
10 modified version of the ICON) [9]. However, other elements of SES, namely parental
11 education and employment status, were not associated with treatment outcomes [9].
12 Moreover, a study in North West England of 144 9- to 19-year-olds reported that SES
13 (measured using Townsend scores) was not associated with discontinuation [6]. However,
14 this study largely involved patients treated in hospitals, who (like the patients in the
15 abovementioned study) may have had a different treatment experience compared to those
16 treated in primary care.

17 SES may be linked with discontinuation because patients in the more deprived groups have
18 been reported to be more likely to miss orthodontic appointments [20] and discontinuation
19 can be increased by orthodontic practices having a strict policy on discontinuing treatment for
20 patients who miss appointments [21]. It is likely that the more deprived groups are more
21 affected by prohibitive transport costs and the potential impact of lost pay for the
22 accompanying parents [22]. In addition, the SES associations with treatment outcomes may
23 be due to the effect of SES on the patient’s development of self-efficacy [23] (i.e., the
24 strength of one’s belief in one’s ability to complete tasks and reach goals [24]). Self-efficacy
25 influences health behaviours [25], and health behaviours (e.g., patient compliance with

1 treatment instructions such as to regularly replace intraoral elastics) are associated with
2 orthodontic outcomes [26–28]. Studies have shown that low SES is associated with some of
3 the elements of low patient compliance, such as poor oral health practices [29–31].

4 The data set provided comprehensive individual-level data on all NHS primary care
5 orthodontic treatments provided under NHS contracts in North West England, and the IMD
6 score for each patient. While the results reflect orthodontic outcomes in North West England,
7 they may not be generalizable to other populations if there are regional variations in
8 practitioner processes and patient preferences. However, practitioner processes should largely
9 be uniform across England given that the same standards and procedures exist across NHS
10 England. Also, patient preferences are likely to be generalizable, and approximately 13% of
11 individuals aged ≥ 10 in England resided in North West England in 2011 [32], so the analyses
12 were conducted on a significant percentage of the population of England. Additionally, North
13 West England has a diversity of individuals from different SES backgrounds, with all five
14 IMD quintiles being represented (though the lower SES groups are overrepresented, with
15 approximately a third of North West LSOAs being in the most deprived quintile in England
16 [33]).

17 We used the IMD (which is an area-level measure that takes into income, employment,
18 health, education, crime, housing and services, and living environment) because there were
19 no individual- or household-level data on income, occupation, or other indicators of SES. The
20 IMD is the most commonly used measure of SES in the UK; however, one limitation of the
21 use of the IMD is that not everyone living in a deprived area is deprived and not all deprived
22 people live in deprived areas. This implies that there can be misclassification error, which
23 could bias the SES-related associations. IMD scores are typically reported at the LSOA level,
24 which represents the smallest area for reporting UK census data, with population sizes of

1 1000–3000 individuals. As the population size of small-area deprivation measures decreases,
2 the risk of misclassification error decreases. Although individual- or household-level SES
3 indicators would help to avoid misclassification error, collecting individual-level data on, for
4 example, self-reported income, increases the likelihood of non-response. In addition, despite
5 the risk of misclassification error, small-area SES measures can help to identify areas with
6 higher proportions of deprived households, so they are useful for planning and targeting
7 healthcare services [34].

8 Another major limitation of the study is the missing outcome data, i.e., 18.9% of treatments
9 (associated with an NHS expenditure of £5.9 m) ended without an outcome record being
10 submitted and 19.4% were associated with incomplete IOTN outcome fields (£5.7 m). This
11 inevitably led to underestimation of the proportions and NHS expenditure associated with
12 discontinuations and residual need.

13 In addition, higher SES was associated with incomplete IOTN outcome fields among patients
14 who completed treatment (but not among those who discontinued treatment), for reasons that
15 are unclear. In contrast, lower SES was associated with missing outcome records. If missing
16 outcome records were partly reflective of discontinuations (e.g., if dentists did not submit
17 records because patients discontinued treatment and the dentists were initially unsure whether
18 the patients would return), the association between lower SES and discontinuations would be
19 attenuated.

20 Another limitation of the study relates to criticism regarding the ability of the IOTN to
21 measure outcomes. The developers of the ICON argue against the use of the IOTN to
22 investigate outcomes on the basis that it was ‘developed and validated to assess treatment
23 entry and exits as separate phenomena, when they are clearly part of the same clinical
24 process. This requires additional training and duplicates the effort of measuring what are

1 often similar occlusal traits' [35, p. 150]. Nonetheless, the IOTN was used on the basis that it
2 indicates the degree of residual normative need at the end of active treatment. Moreover, the
3 IOTN remains the principle index used to assess individuals' need for NHS orthodontic
4 treatment need and the prevalence of malocclusion in the population [36,37], and using the
5 same index to establish both a baseline assessment of need and the treatment outcome is
6 practical when assessing the effects of treatment. However, the IOTN outcome scores were
7 measured at the end of active treatment, but there can be relapse after active treatment has
8 finished [38], particularly if there is poor compliance with retention instructions. From this
9 perspective, both the proportion of treatments that end with residual need and the expenditure
10 on these treatments are underestimated. Lastly, the IOTN outcome scores were not
11 independently validated, which may also have led to bias in the data, and thus an
12 underestimation of residual need.

13 Regarding the implications of the findings, the quality of the NHS activity data could be
14 increased by ensuring that outcomes are reported (and validated) for all treatments (except in
15 cases where the patients fail to return, when only discontinuations, rather than IOTN scores,
16 can be reported), and monitored by the service commissioners. This is in line with 2015
17 guidance on the delivery of NHS orthodontic care in Wales, which highlighted the
18 importance of the development of local health board policies to ensure that treatment
19 outcomes in terms of completions and discontinuations are reported for each patient [39].
20 Monitoring outcomes more closely could help service commissioners to determine which
21 providers provide the best value for money.

22 In addition to recording information on discontinuations and IOTN outcome scores, there is a
23 contractual requirement for dentists to monitor the outcomes of 20 patients plus 10% of the
24 remainder of their patients using the PAR index [11], though these data are not collected

1 using the NHS activity forms [12]. Implementing a contractual requirement to monitor the
2 PAR scores of *consecutive* patients and to utilise independent third parties who are calibrated
3 in the use of the index may help to reduce bias [15]. The British Orthodontic Society have
4 noted that NHS commissioners may make participation in a peer review process a contractual
5 requirement [15], and NHS guidance on commissioning has stated that ‘PAR scoring will in
6 future be undertaken within a managed orthodontic clinical network...under a peer review
7 mechanism’ [1, p. 20].

8 Payment by Results (PbR) remuneration is used in many areas of the NHS [40], and could
9 potentially help to improve orthodontic treatment outcomes [11]. However, a difficulty with
10 implementing this policy is that there is a variation in the case mix (e.g., different percentages
11 of patients from more deprived groups) between orthodontic clinicians, which would
12 influence the percentages of patients who discontinue treatment and have residual need.
13 Further, a PbR approach may generate perverse incentives for orthodontists to reject referrals
14 of patients from disadvantaged backgrounds, widening inequalities further. In addition,
15 although contract penalties for discontinuations may help to reduce the SES-related inequity
16 in discontinuation, care would need to be taken to ensure that treatment was not continued in
17 cases where there could be risk of harm to the patient (i.e., if compliance with oral hygiene
18 advice was poor).

19 Key areas to be explored include how factors related to patient compliance underlie the
20 associations between SES and orthodontic outcomes, and why higher SES was associated
21 with incomplete IOTN outcome fields among patients who completed treatment.

22 **Conclusions**

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1 We found evidence of inefficiencies in the NHS orthodontic service, with 7.6% and 5.2% of
2 NHS primary care orthodontic treatments in North West England ending in discontinuation
3 and residual need, respectively. These outcomes were positively associated with lower SES,
4 which raises concerns about inequity in the service and indicates that policies aimed at
5 improving the levels of discontinuations and residual need may be more effective if they were
6 targeted at patients from lower SES groups. In addition, 38.3% of treatments had missing
7 outcome data, highlighting the need to improve the outcome monitoring systems.

1 **Additional file**

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3 2 Additional file 1.docx

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6 3 Title: Percentage distribution/means of variables used in the adjusted treatment outcomes
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9 4 analyses, by socioeconomic status (SES).

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11 5 Description: Additional file 1 contains information on the distribution of variables used to
12
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14 6 adjust for potential confounding: IOTN AC scores, gender, and age. This information is
15
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17 7 provided by IMD quintile.

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21 8 **List of abbreviations**

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24 9 AC: Aesthetic Component; CI: confidence interval; DHC: Dental Health Component; ICON:
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27 10 Index of Complexity, Outcome, and Need; IMD: Index of Multiple Deprivation; IOTN: Index
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29
30 11 of Orthodontic Treatment Need; LSOA: Lower-layer Super Output Area; NHS: National
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32 12 Health Service; NHSBSA: National Health Service Business Services Authority; OLS:
33
34 13 ordinary least squares; PAR: Peer Assessment Rating; SES: socioeconomic status; PbR:
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37 14 Payment by Results; UK: United Kingdom; UOA: Unit of Orthodontic Activity.

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41 15 **Declarations**

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44 16 *Ethics approval and consent to participate*

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47 17 Ethics approval was not sought for this study. The study was a retrospective analysis of
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49
50 18 pseudo-anonymised administrative data that were provided by the NHSBSA (in line with
51
52
53 19 their Information Governance procedures, i.e., the data can only be used for non-commercial
54
55 20 research, and the copyright holder remains the NHSBSA), with the request for the data
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57
58 21 approved by the Caldicott Guardian. In the process of obtaining the data, the Caldicott
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60 22 Guardian did not consider a request for ethical approval to be sought.

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1 *Consent for publication*

2
3 2 Not applicable.

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7 3 *Availability of data and materials*

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10 4 The data that support the findings of this study are available from NHSBSA
11
12 5 (nhsbsa.dentalservices@nhsbsa.nhs.uk) but restrictions apply to the availability of these
13
14
15 6 data, which were used under license for the current study, and so are not publicly available.
16
17 7 Data are however available from the authors upon reasonable request and with permission of
18
19
20 8 NHSBSA.

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22
23 9 *Competing interests*

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27 10 The authors declare that they have no competing interests.

28
29
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35
36 13 agency.

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39 14 *Authors' contributions*

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43 15 Authors JP, WW, SB, PB and MT contributed to the conception and design of the study, data
44
45
46 16 interpretation, manuscript revisions and approved the final manuscript. MT acquired the data.
47
48 17 JP and WW drew up the detailed analysis plan. JP carried out the analysis and drafted the
49
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51 18 manuscript.

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53 19 *Acknowledgements*

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57 20 Not applicable.

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Table 1. Treatment outcomes associated with discontinuation

Outcome ¹	Percentage (relative frequency)			NHS expenditure (GBP)
	All <i>n</i> = 24501	Males <i>n</i> = 10571	Females <i>n</i> = 13930	
Discontinuation	7.6 (1856/24501)	9.0 (951/10571)	6.5 (905/13930)	2300764
Residual need	16.3 (303/1856)	14.4 (137/951)	18.3 (166/905)	
No residual need	20.1 (373/1856)	20.6 (196/951)	19.6 (177/905)	
Incomplete IOTN	63.6 (1180/1856)	65.0 (618/951)	62.1 (562/905)	
Completion	73.1 (17899/24501)	71.6 (7574/10571)	74.1 (10325/13930)	22186773
Residual need	5.4 (961/17899)	5.7 (431/7574)	5.1 (530/10325)	
No residual need	75.3 (13482/17899)	74.8 (5662/7574)	75.7 (7820/10325)	
Incomplete IOTN	19.3 (3456/17899)	19.6 (1481/7574)	19.1 (1975/10325)	
Missing outcome record	19.4 (4746/24501)	19.4 (2046/10571)	19.4 (2700/13930)	5890206

GBP, Great Britain Pound; IOTN, Index of Orthodontic Treatment Need; NHS, National Health Service. ¹An outcome could be specified as either treatment discontinuation or treatment completion.

Table 2. Treatment outcomes associated with residual need

Outcome	Percentage (relative frequency)			NHS expenditure (GBP)
	All <i>n</i> = 24501	Males <i>n</i> = 10571	Females <i>n</i> = 13930	
Residual need	5.2 (1264/24501)	5.4 (568/10571)	5.0 (696/13930)	1567866
No residual need	56.5 (13855/24501)	55.4 (5858/10571)	57.4 (7997/13930)	17172127
Incomplete IOTN outcome field	18.9 (4636/24501)	19.9 (2099/10571)	18.2 (2537/13930)	5747544
Missing outcome record	19.4 (4746/24501)	19.4 (2046/10571)	19.4 (2700/13930)	5890206

GBP, Great Britain Pound; IOTN, Index of Orthodontic Treatment Need; NHS, National Health Service.

Table 3. Treatment outcomes by socioeconomic status (SES)

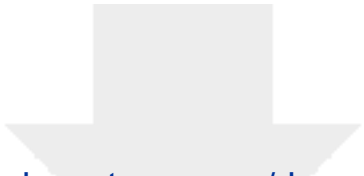
IMD quintile (reference category: 5 [least deprived])	Mean percentage change					
	Model 1: Discontinuation vs. completion <i>n</i> = 19755 ¹		Models 2 and 3: residual need vs. no residual need			
			Among patients who completed <i>n</i> = 14443 ²		Among patients who discontinued <i>n</i> = 676 ²	
	Unadjusted	Adjusted for IOTN AC, gender, age	Unadjusted	Adjusted for IOTN AC, gender, age	Unadjusted	Adjusted for IOTN AC, gender, age
1	6.4	6.1	2.8	2.6	3.5	0.6
2	5.3	5.1	3.3	3.2	-1.6	-1.0
3	3.1	3.1	1.8	1.8	0.3	-0.5
4	1.2	1.1	1.0	1.0	-0.3	-1.2
Missing	3.0	3.0	0.0	-0.3	-10.9	-12.5

AC, Aesthetic Component; IMD, Index of Multiple Deprivation; IOTN, Index of Orthodontic Treatment Need. ¹Only patients with outcome records could be included (4746 had missing outcome records). ²Only patients with completed IOTN outcome fields could be included (out of those who completed and discontinued, 3456 and 1180 had incomplete IOTN outcome fields, respectively). The same sample sizes were used for the unadjusted and adjusted analyses (as there were no missing data on gender and age, and a dummy variable was used for the missing IOTN AC data).

Table 4. Missing outcome data by SES

IMD quintile (reference category: 5 [least deprived])	Mean percentage change					
	Models 4 and 5: Incomplete IOTN outcome field					
	Among patients who completed <i>n</i> = 17899 ¹		Among patients who discontinued <i>n</i> = 1856 ¹		Model 6: Missing outcome record <i>n</i> = 24501	
	Unadjusted	Adjusted for IOTN AC, gender, age	Unadjusted	Adjusted for IOTN AC, gender, age	Unadjusted	Adjusted for IOTN AC, gender, age
1	-6.5	-6.9	0.8	0.7	3.0	3.0
2	-4.0	-4.2	-1.7	-2.3	2.4	2.3
3	-2.2	-2.4	-3.3	-3.3	1.9	1.8
4	-0.8	-0.9	-0.9	-0.5	1.9	1.9
Missing	-6.3	-6.5	2.6	1.6	0.7	1.1

AC, Aesthetic Component; IMD, Index of Multiple Deprivation; IOTN, Index of Orthodontic Treatment Need. ¹Only patients with outcome records could be included (4746 had missing outcome records).



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Supplementary Material
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