Socioeconomic position and the National Health Service 

orthodontic service 

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JULIET C PRICE 

School of Dentistry
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<th>Full Form</th>
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<tbody>
<tr>
<td>AC</td>
<td>Aesthetic Component</td>
</tr>
<tr>
<td>BASCD</td>
<td>British Association for the Study of Community Dentistry</td>
</tr>
<tr>
<td>BOS</td>
<td>British Orthodontic Society</td>
</tr>
<tr>
<td>CDHS</td>
<td>Children’s Dental Health Survey</td>
</tr>
<tr>
<td>CI</td>
<td>confidence interval</td>
</tr>
<tr>
<td>CPQ</td>
<td>Child Perceptions Questionnaire</td>
</tr>
<tr>
<td>DAI</td>
<td>Dental Aesthetic Index</td>
</tr>
<tr>
<td>DES</td>
<td>Dentist with Enhanced Skills</td>
</tr>
<tr>
<td>DHC</td>
<td>Dental Health Component</td>
</tr>
<tr>
<td>DVD</td>
<td>digital versatile disc</td>
</tr>
<tr>
<td>DwSI</td>
<td>Dentist with a Special Interest</td>
</tr>
<tr>
<td>EA</td>
<td>Education Authority</td>
</tr>
<tr>
<td>e.g.</td>
<td>exempli gratia (for example)</td>
</tr>
<tr>
<td>GBP</td>
<td>Great Britain Pound</td>
</tr>
<tr>
<td>GDP</td>
<td>General Dental Practitioner</td>
</tr>
<tr>
<td>GDS</td>
<td>General Dental Services</td>
</tr>
<tr>
<td>HLD</td>
<td>Handicapping Labiolingual Deviation</td>
</tr>
<tr>
<td>HNA</td>
<td>Healthcare needs assessment</td>
</tr>
<tr>
<td>HSCIC</td>
<td>Health and Social Care Information Centre</td>
</tr>
<tr>
<td>ICON</td>
<td>Index of Complexity, Outcome, and Need</td>
</tr>
<tr>
<td>i.e.</td>
<td>id est (that is)</td>
</tr>
<tr>
<td>IMD</td>
<td>Index of Multiple Deprivation</td>
</tr>
<tr>
<td>IOTN</td>
<td>Index of Orthodontic Treatment Need</td>
</tr>
<tr>
<td>LAD</td>
<td>Local Authority District</td>
</tr>
<tr>
<td>LPM</td>
<td>Linear probability model</td>
</tr>
<tr>
<td>LSOA</td>
<td>Lower-layer Super Output Area</td>
</tr>
<tr>
<td>Ltd</td>
<td>Limited company</td>
</tr>
<tr>
<td>Mm</td>
<td>Millimetre</td>
</tr>
<tr>
<td>n.b.</td>
<td>nota bene (note well)</td>
</tr>
<tr>
<td>NHS</td>
<td>National Health Service</td>
</tr>
<tr>
<td>NHSBSA</td>
<td>National Health Service Business Services Authority</td>
</tr>
<tr>
<td>NS-SEC</td>
<td>National Statistics Socioeconomic Classification</td>
</tr>
<tr>
<td>OA</td>
<td>Output Area</td>
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<tr>
<td>OHQoL</td>
<td>oral health-related quality of life</td>
</tr>
<tr>
<td>OHS</td>
<td>Oral Health Survey</td>
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<tr>
<td>OLS</td>
<td>ordinary least squares</td>
</tr>
<tr>
<td>Abbreviation</td>
<td>Description</td>
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<td>-----------------------------------</td>
</tr>
<tr>
<td>OR</td>
<td>odds ratio</td>
</tr>
<tr>
<td>PAR</td>
<td>Peer Assessment Rating</td>
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<tr>
<td>PbR</td>
<td>Payment by Results</td>
</tr>
<tr>
<td>PCT</td>
<td>Primary Care Trust</td>
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<tr>
<td>PDS</td>
<td>Personal Dental Services</td>
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<tr>
<td>RPTN</td>
<td>residual post-treatment need</td>
</tr>
<tr>
<td>SC</td>
<td>Social Class</td>
</tr>
<tr>
<td>SEG</td>
<td>Socioeconomic Groups</td>
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<tr>
<td>SEP</td>
<td>socioeconomic position</td>
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<tr>
<td>TDS</td>
<td>Trust-led Dental Services</td>
</tr>
<tr>
<td>UA</td>
<td>Unitary Authority</td>
</tr>
<tr>
<td>UK</td>
<td>United Kingdom</td>
</tr>
<tr>
<td>UOA</td>
<td>Unit of Orthodontic Activity</td>
</tr>
<tr>
<td>US</td>
<td>United States</td>
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ABSTRACT

The University of Manchester, Juliet Clare Price, Doctor of Philosophy (PhD), Socioeconomic position and the National Health Service orthodontic service, 27 February 2016

Background: The National Health Service (NHS) aims to achieve maximum health gains with its limited resources, while also ensuring that it provides services according to need, irrespective of factors such as socioeconomic position (SEP).

Aim: The aim of this thesis is to explore the relationships between SEP and various aspects of the NHS orthodontic service, including need, demand, supply, and outcomes.

Methods: Three main data sources were used: two population-based surveys (the 2003 United Kingdom (UK) Children’s Dental Health Survey (CDHS) and the 2008-2009 NHS Dental Epidemiology Programme for England Oral Health Survey (OHS) in the North West) and an administrative data set (containing 2008-2012 North West NHS orthodontic activity data). The data were used to investigate levels of need and willingness to have orthodontic treatment, treatment utilisation, assessment procedures, and treatment outcomes, and the costs associated with the service. Subsequently, regression analyses were carried out to explore the associations between SEP and the various orthodontic variables.

Results: Over a third of 12-year-olds had normative need for orthodontic treatment and over half had patient-defined need. Those in the most deprived groups in the North West tended to have lower levels of treatment compared to those in the least deprived group (despite the fact that normative need was not shown to vary by SEP), and they were more likely to discontinue treatment and have residual post-treatment need (RPTN). There was a great deal of variation among practices/orthodontic clinicians in terms of the percentages of patients with repeated assessments, treatment discontinuations, and RPTN. The major sources of potential inefficiency costs in the NHS orthodontic service in the North West are treatments that result in discontinuations (which cost £2.4 million per year), RPTN (which cost £1.8 million per year), and unreported treatment outcomes (which cost £13.0 million per year).

Discussion: The NHS is not delivering orthodontic care equitably between SEP groups in the North West, as those from more deprived groups are more likely to fail to receive treatment, and to have poor outcomes if they do receive treatment. In addition, the wide range of process and outcome indicators between practices/orthodontic clinicians raises issues about quality of the overall service. In particular, treatment outcomes are frequently unreported, which highlights the need to improve the outcome monitoring systems in the NHS orthodontic service.
DECLARATION

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This thesis is dedicated to my parents.
1 INTRODUCTION

1.1 Background

The National Health Service (NHS) is currently under a great deal of pressure to reduce costs due to the widespread growth of NHS hospital trust deficits (Johnstone, 2015). The NHS dental service is under particular strain due to the high levels of demand for complex procedures by older generations in the population who have a legacy of heavily filled teeth and who therefore require maintenance treatment in order to avoid having tooth extractions (Steele, 2009). Against the backdrop of this increasing strain on NHS resources, there has been an increased demand for orthodontic treatment in recent years (de Oliveira, 2003; Health, Wellbeing and Local Government Committee, 2011), which treats patients with malocclusion (i.e., abnormal positioning of the teeth).

In addition to maximising the health of the population using its limited resources, the NHS also aims to ensure that it fulfils its core principal of providing services according to need, irrespective of factors such as socioeconomic position (SEP), as set out in both the recently published constitution (NHS England, 2009) and the original 1944 governmental white paper on the creation of the NHS (Ministry of Health, 2014). This white paper outlined the founding values of the NHS by stipulating that the service would ensure that ‘every man, woman and child can rely on getting all the advice and treatment and care they may need [and] that their getting these shall not depend on whether they can pay for them or any other factor irrelevant to real need’ (Ministry of Health, 2014, p. 2).

Initiatives to decrease the influence on the service of non-need factors such as SEP form a major part of NHS policy (Department of Health, 2010; Ministry of Health, 2014; NHS England, 2009), so it is important to monitor whether or not both the care provided by the NHS orthodontic service, and the outcomes achieved, vary by SEP.

1.2 Aim and research questions

In order to investigate whether NHS orthodontic resources are being used in accordance with the NHS principle of providing services according to need, the aim of this thesis is to explore the relationships between SEP and various aspects of the NHS orthodontic service, including need, demand, supply, and outcomes.

The research questions are as follows:

- Need and willingness to have treatment: What is the prevalence of a) normative need for orthodontic treatment, b) patient-defined need for orthodontic treatment, and c) willingness to have orthodontic treatment, and are they associated with SEP?
• **Treatment utilisation:** What is the prevalence of utilisation of orthodontic treatment, and is it associated with SEP?

• **Assessment procedures:** What is the prevalence in the NHS orthodontic service of a) the use of one or more ‘assessment & review’ appointments\(^1\) per patient, b) the use of two or more ‘assessment & review’ appointments per patient, c) early access to orthodontic assessments at ages 9-10, and d) the use of an ‘assessment & refuse’ appointment\(^2\) for those with Index of Orthodontic Treatment Need (IOTN) scores of \(\geq 3.6\)\(^3\). Are these assessment procedures associated with SEP?

• **Treatment outcomes:** What is the prevalence in the NHS orthodontic service of a) treatment discontinuations and b) residual post-treatment need (RPTN)? Are these treatment outcomes associated with SEP?

• **Differences between practices/orthodontic clinicians:** Do assessment procedures (i.e., the use of two or more ‘assessment & review’ appointments per patient) and treatment outcomes (i.e., treatment discontinuations and RPTN) vary between practices/orthodontic clinicians? Are the differences associated with the types of NHS contracts that the orthodontic clinicians work under (i.e., General Dental Services (GDS), Personal Dental Services (PDS), or Trust-led Dental Services (TDS) contracts)?

• **Costs:** What are the costs of the NHS orthodontic service, including the costs associated with the various assessment procedures and treatment outcomes?

### 1.3 Rationale

#### 1.3.1 Overview

The research presented in this thesis expands the current body of knowledge regarding the relationships between SEP and need, demand, supply, and outcomes in the NHS orthodontic service. The orthodontic service is used as an exemplar service to examine SEP-related associations in the NHS because there is a measure of normative need for orthodontics that is universally used across the NHS to measure both need and outcomes (i.e., the IOTN). In addition, the NHS orthodontic service is a significant part of the overall primary care dental service: the budget for

---

1 ‘Assessment & review’ appointments are clinical examinations that result in the orthodontic clinician deciding that NHS orthodontic treatment is indicated, but the patient is not ready to start treatment.

2 ‘Assessment & refuse’ appointments are clinical examinations that result in the orthodontic clinician deciding that NHS orthodontic treatment is unnecessary or inappropriate.

3 An IOTN score of 3.6 is the threshold that indicates eligibility for NHS orthodontic treatment.
orthodontics forms approximately a tenth of the budget for the whole of the primary care dental service (Chestnutt et al., 2004). Moreover, there are multiple data sources available that have collected data on orthodontics, including a previously unused data set on NHS primary care orthodontic activity.

Sections 1.3.2 to 1.3.7 provide further detail on the analysis-specific rationales for each of the analysis topics. In addition, the following chapter expands on the contribution of the research to the current body of knowledge by presenting a critical review of literature on each of the research questions, which includes information on the limitations of the previous studies and where gaps in the literature exist.

1.3.2 Need and willingness to have treatment

Normative need, patient-defined need, and the patients’ willingness to have treatment can all affect the demand for, and provision of, NHS orthodontic treatment. Therefore, investigating the levels of these factors among the at-risk population is important in order to plan for the future of the service, including the management of demand for the service among those with no normative need. In addition, it is important to discern whether SEP is associated with these factors, as they can legitimately affect treatment utilisation, and may therefore need to be adjusted for when investigating the association between SEP and utilisation.

1.3.3 Treatment utilisation

Information on differences between normative need and treatment utilisation in the at-risk population, and on the variations in utilisation by SEP, could help those managing NHS orthodontic contracts to ensure that the contracts are adequate to meet need across all SEP groups. This is in line with a recommendation of a recent inquiry into NHS orthodontic services in Wales, which stated that further research should be commissioned to assess orthodontic unmet need (Health, Wellbeing and Local Government Committee, 2011).

1.3.4 Assessment procedures

Orthodontic assessments are clinical examinations by orthodontic clinicians that aim to establish whether or not orthodontic treatment should be provided (and, if treatment is indicated, what the treatment plan should be). NHS England has recommended that an adequate ratio of orthodontic assessments to treatments is 1.5-2.0: 1, with a 1:1 ratio being the ideal (NHS England Primary Care Commissioning, 2013). Large numbers of assessments indicate inefficiencies in the referral and assessment systems. For example, the frequent use of one or more ‘assessment &
review’ appointments per patient can occur if the referring General Dental Practitioner (GDP) refers patients to the NHS orthodontic service too early for treatment, while the frequent use of two or more ‘assessment & review’ appointments per patient would suggest that the orthodontic clinician may be overusing orthodontic assessments. If SEP were associated with the various assessment procedures, this would indicate that they are influenced by factors that do not reflect need. Understanding these associations could help to develop and target policies to reduce the overuse of ‘assessment & review’ and ‘assessment & refuse’ appointments. This could involve reducing the number of inappropriate referrals to the NHS orthodontic service, which would decrease the waiting times for new patients and increase the capacity of the service to meet the rising demand for orthodontic treatment (Health, Wellbeing and Local Government Committee, 2011).

1.3.5 Treatment outcomes

Understanding the associations between SEP and treatment outcomes (i.e., treatment discontinuations and RPTN) could help to identify groups that are more likely to have poor treatment outcomes and to develop policies to reduce these issues. This would increase the quality and value for money of the service, particularly as there have been reports of issues with performance management and cost-effectiveness in the service in parts of the United Kingdom (UK) (Richmond and Karki, 2012).

1.3.6 Differences between practices/orthodontic clinicians

Differences between practices in the percentages of their patients with two or more ‘assessment & review’ appointments per treated patient, and between clinicians in the percentages of their patients with treatment discontinuations and RPTN, would indicate that the effectiveness and efficiency of the service could be improved by changing performance management and contracting policies. In addition, evidence of better performance by those working under different types of NHS contracts could affect policies on the training of specialist orthodontists and non-specialist orthodontic clinicians.

1.3.7 Costs

Describing the costs of the NHS primary care orthodontic service, including the costs related to assessment procedures and the various treatment outcomes, would help to identify the largest areas of potential inefficiency where cost savings could be made, and would therefore help to indicate where to prioritise improvements in the service.
1.4 Outline of thesis

Chapter 2 (Background) provides the context for the research by introducing the background topics of a) SEP, and equality and equity in healthcare, b) need, demand, supply, and access, and c) the NHS orthodontic service. Chapter 2 also provides definitions of key terms referred to in the thesis. In addition, Chapter 2 presents a critical review of the literature related to each of the research questions, and the conceptual frameworks associated with each of the research questions.

Chapter 3 (Methodology) begins with a description of the research philosophy underpinning the research presented in this thesis and it provides details on the sources of the data used in the research. Chapter 3 goes on to provide descriptions of how the variables were created, and broad overviews of the descriptive and inferential statistical techniques that were employed. Subsequently, each of the analysis-specific methods is presented in turn.

Chapter 4 (Results) presents brief descriptions of the three main data sets used followed by sections covering the findings for each of the research questions in turn, including summaries highlighting the most significant findings.

Chapter 5 (Discussion) includes a summary of the main findings of the research and a discussion of the interpretation of the findings in light of the current body of knowledge and the conceptual frameworks introduced in Chapter 2. Chapter 5 goes on to discuss the strengths and weaknesses of the research before outlining the implications of the research for the NHS and for future research.

Chapter 6 (Conclusions) sets out each of the research questions in turn, and summarises the contribution made by the research to the current literature.

Chapter 7 (References) sets out a list of the reference materials cited in the thesis.
2 BACKGROUND

2.1 Overview

This chapter provides the background information for the research presented in this thesis. It focuses primarily on information from English populations and more recent information is prioritised, with much of the most relevant evidence coming from key grey literature sources from governmental and arm’s length bodies.

Firstly, Sections 2.2 to 2.4 provide the broad context for the research by introducing the following key background topics:

- SEP, and equality and equity in healthcare
- Need, demand, supply, and access
- NHS orthodontic service

Secondly, Section 2.5 presents a critical review of the literature related to each of the research questions. This review includes a critique of the current evidence base, information on limitations of the previous studies, and information on the gaps in the evidence (thereby providing further justification for the research questions). It also includes conceptual frameworks associated with each of the research questions (informed by the current body of knowledge).

2.2 Socioeconomic position, and equality and equity in healthcare

2.2.1 Socioeconomic position

2.2.1.1 Introduction

SEP refers to the social and economic factors that influence what positions individuals or groups hold within the structure of a society (Krieger et al., 1997). SEP is an aggregate concept that includes both resource-based measures (i.e., measures of material and social resources, including income and subsidies, and wealth and debt) and prestige/status-based measures (i.e., measures of rank in a social hierarchy) (Krieger et al., 1997).
SEP can be assessed at multiple levels, including the individual level, the household level, and area levels (e.g., neighbourhood, regional, and national levels) (Krieger et al., 1997). Multiple measures can be used to represent SEP. The two used in this thesis are the National Statistics Socioeconomic Classification (NS-SEC, which can be used as an individual- or household-level measure of SEP) (Office for National Statistics, 2010) and the Index of Multiple Deprivation (IMD, which can be used as a neighbourhood-level measure of SEP) (Department for Communities and Local Government, 2011, 2007).

2.2.1.2 National Statistics Socioeconomic Classification

Individual- and household-level measures of SEP have several limitations, the main one being that they often use single indicators of SEP such as income or occupation. Single indicators such as income or occupation do not fully reflect the varied determinants of life chances, as other factors can play a role, such as health status and experience of crime. In addition, using indicators such as income or occupation can lead to two individuals with the same level of income or the same occupation being labelled as being from the same SEP group, even if they live in areas that have vastly different costs of living.

The NS-SEC was developed with the intention of replacing two SEP classifications that were widely used in the UK in both official statistics and academic research, i.e., Social Class based on Occupation (SC, formerly the Registrar General’s Social Class) and Socioeconomic Groups (SEG) (Office for National Statistics, 2010; Rose, 1995). The NS-SEC was created to measure employment relations and conditions (encompassing factors such as economic security, prospects of enhancement, and level of authority and control at work) in the UK (Sheaff, 2005). These factors are key to explaining the structure of SEP in modern societies and in helping to explain variations in social behaviour (Office for National Statistics, 2010).

Unlike the IMD, the NS-SEC can be used to directly represent a household’s SEP. One member of the household is used as the reference person, whose position is used to represent that of the whole household (Office for National Statistics, 2010). Traditionally, the reference person is defined as the person responsible for the household’s accommodation (Office for National Statistics, 2010). However, if this information is unavailable, the ‘dominance’ approach can be used, where the person who had the highest NS-SEC position is treated as the reference person (Krieger et al., 1997).

The data required to assess a reference person’s NS-SEC includes details such as whether he/she is an employer, self-employed, or an employee, whether he/she is a supervisor, and the number of employees at his/her workplace (Office for National Statistics, 2010). The most commonly used version of the NS-SEC has eight classes, as follows (Office for National Statistics, 2010):
• 1 – Higher managerial, administrative and professional occupations
• 2 – Lower managerial, administrative and professional occupations
• 3 – Intermediate occupations
• 4 – Small employers and own account workers
• 5 – Lower supervisory and technical occupations
• 6 – Semi–routine occupations
• 7 – Routine occupations
• 8 – Never worked and long-term unemployed
• Not classified (students, occupations not stated or inadequately described, and not classifiable for other reasons)

2.2.1.3 Index of Multiple Deprivation

The main advantage of neighbourhood-level measures of SEP over individual- and household-level measures of SEP is that they include numerous domains, thereby taking into account a broad range of indicators. However, they have several disadvantages in that there can be a lack of up-to-date data for some of the indicators and there can be issues with assigning the weights given to the different domains. There can also be issues with whether the areas in question are urban or rural, as these types of areas can have vastly different access issues when considering specialist services (such as NHS orthodontic services) that are not taken into account by some neighbourhood-level measures.

The IMD represents the ‘official’ measure of relative deprivation in areas across England, and it is used to help target resources for social programmes appropriately (McLennan et al., 2011). Deprivation can be defined as a situation in which an individual does not have the living standards (e.g., the diet and services) that allow him/her to participate in the customary behaviour of the society to which he/she belongs (and poverty can be defined as a situation in which a person has insufficient resources to obtain access to these living standards) (Townsend, 1993). The IMD includes several distinct domains of deprivation that are weighted and combined into a single measure: income, employment, health, education, crime, housing and services, and living environment, as it is based on the concept that deprivation refers to a broad lack of resources and opportunities, rather than simply a lack of money (McLennan et al., 2011).

IMD scores across England are associated with areas that match census geography. The UK census collects population statistics for planning and allocating resources. It is undertaken every 10 years, and the last survey took place in 2011. The lowest geographical level at which census estimates are provided is known as an Output Area
(OA). OAs have a minimum population of 100 and there are 171,372 OAs in England (Office for National Statistics, 2015a). OAs are designed to be as socially homogenous as possible (based on tenure of household and dwelling type) (Office for National Statistics, 2015a). Lower-layer Super Output Areas (LSOAs) are built up from groups of OAs (Office for National Statistics, 2015b). LSOAs are designed to have a minimum population of 1,000, and there are 32,844 LSOAs in England (Office for National Statistics, 2015b). An individual’s SEP can be determined by matching his/her postcode to his/her LSOA-level IMD score. In order to aid the interpretation of IMD scores, the standard method for presenting the data is to use quintiles or deciles, with respect to the population of England.

One of the limitations of the IMD is that not everyone living in a deprived area is deprived and not all deprived people live in deprived areas. However, neighbourhood-level SEP measures may be better predictors of the health status of population subgroups compared to individual- or household-level measures because they capture diverse domains of SEP across the life course, during which the SEP of an individual or household can change (Krieger et al., 1997). In addition, given that neighbourhood-level SEP measures identify where the most deprived groups live, they are useful for planning and targeting healthcare services (Locker, 1993).

The two most recent sets of IMD scores are the IMD 2007 and the IMD 2010. The IMD 2007 uses data from 2001 to 2005, whereas the IMD 2010 uses data from 2001 to 2008. The sources for these data primarily consist of the UK census, the Office for National Statistics, the Home Office, Revenue and Customs, the Department for Communities and Local Government, the Department for Work and Pensions, the Department for Transport, the Department for Education, the NHS Information Centre, NHS Connecting for Health, NHS Prescription Services, the Higher Education Statistics Agency, the Post Office Ltd, the English House Condition Survey, the Family Resources Survey, and the Regulated Mortgage Survey.

### 2.2.2 Equality and equity in healthcare

Equality refers to equal distribution of benefits, e.g., access to services (see Section 2.3.3), utilisation of services, expenditure, and outcomes, across society. Inequalities in health can include disparities in health between groups in the population that differ in terms of factors such as SEP, gender, age, ethnicity, sexuality, disability, and geography.

Equity refers to the fair, or just, distribution of benefits, e.g., access, utilisation, expenditure, and outcomes, across society. Inequities in access, utilisation, expenditure, and outcomes can be one of the factors behind inequalities in health. Unlike equality, the choice of what constitutes equity is not an objective one, and different (but sometimes
overlapping) approaches to social justice can be taken by healthcare systems that aim to ensure an equitable (though not necessarily equal) distribution of benefits. The following approaches to social justice provide examples of various ways in which equity in society can be viewed:

- **Egalitarianism** (Arneson, 2013; Tsuchiya and Dolan, 2009), which is based on the principle that all individuals are equal. There are several different types of egalitarianism, including material, outcome, and gain egalitarianism, which, in a healthcare setting, emphasise that individuals should have equal access to healthcare services, equal health outcomes, and equal health gain, respectively.

- **Utilitarianism** (Mill, 1871), which aims to achieve the greatest utility (which can have numerous definitions, including preference satisfaction) for the greatest number of people.

- **Rawlsianism** (Rawls, 1993), which is based on the idea that if a hypothetical group of people did not know what group (in terms of e.g., SEP, gender, age, ethnicity, sexuality, disability, and geography) they would eventually belong to (i.e., they were under a ‘veil of ignorance’), they would choose to maximise the benefits of the most disadvantaged people.

- **Libertarianism** (Nozick, 1974), which stresses that individuals are entitled to what they can acquire justly in a free market (i.e., they have a right to liberty that should not be interfered with by the state).

- **Desert-based principles** (Lamont and Favor, 2014), which are based on the idea that distributive systems are just insofar as they distribute incomes according to the levels deserved by the individuals for a) their efforts, b) the value of their contributions, or c) the costs they incur while working.

In healthcare systems, it is common to consider equity (e.g., of access, utilisation, expenditure, and outcomes) in terms of two broad principles (Steinbach, 2010):

- **Horizontal equity**, where individuals or groups that share similar needs are treated equally. For example, horizontal inequity in access to healthcare services refers to unequal access to services for those with the same need for healthcare (i.e., the same health condition, the same severity, and the same capacity to benefit from treatment) (van Doorslaer et al., 2000; Wagstaff et al., 1991).

- **Vertical equity**, where individuals or groups that have different needs are treated differently, in proportion to the differences in their levels of need. For example, the risk of poor health increases with age, so the utilisation of public healthcare services tends to increase as people grow older (Nie et al., 2008).

The focus of this thesis is horizontal inequities, in both utilisation and outcomes (after taking need into account), that occur between groups that differ in terms of SEP. For many health conditions, SEP-related disparities in health tend to exist in terms of a gradient in health from the top to the bottom of the socioeconomic spectrum, as
deprivation is relative, i.e., there is often no threshold – between those in deprivation and the rest of society – above which there are no health disparities (Macintyre, 2007). This socioeconomic gradient is a global phenomenon, seen in low, middle, and high income countries (Macintyre, 2007).

In addition to being a matter of fairness, reducing disparities in health across society can bring about social and economic benefits, such as improved productivity and lower welfare payments. In order to reduce these disparities, interventions that address all the determinants of health are required, not just interventions within the healthcare system. Dahlgren and Whitehead’s model of the wider social determinants of health provides an overview of the causes of health inequalities (Dahlgren and Whitehead, 1991). These causes of health inequalities include the factors that influence an individual’s risk of illness and the factors that influence the actions he/she takes to deal with illness when it occurs (Dahlgren and Whitehead, 1991). The framework was published in 1991 and it continues to inform the work of those concerned with reducing health inequalities as it highlights the fact that many factors that affect health can be influenced by governmental policies (Dahlgren and Whitehead, 1991):

- Personal characteristics (including gender, age, ethnicity, and genetic factors), which can be highly significant factors for health but cannot be influenced by policy changes
- Individual lifestyle factors (such as smoking, alcohol misuse, poor diet, and lack of physical activity)
- Social and community networks (including family, friends, and wider social circles), which are protective factors in terms of health
- Living and working conditions (including access to education, training, employment, healthcare services, welfare services, public transport, housing, running water, sanitation, and essential goods such as food, clothing, and fuel)
- General socioeconomic, cultural and environmental conditions (including issues related to the availability of work, wages, taxation, fuel, transport, and food), which can directly influence government spending capacity, and therefore they can have a direct effect on health and social policy priorities

### 2.2.3 Summary

SEP refers to the social and economic factors that influence what positions individuals or groups hold within the structure of a society, and it can be measured at the individual, household, neighbourhood, regional, national levels (Krieger et al., 1997). When individuals in different SEP groups share similar needs for healthcare but experience different levels of access, utilisation, expenditure, and outcomes, this is referred to as SEP-related horizontal inequity. The monitoring of SEP-related health inequities in utilisation and outcomes is important for
public healthcare systems, as disparities can indicate that public resources are being distributed unfairly, according to the principles of material and outcome egalitarianism.

The following section provides information on the definitions of and relationships between need, demand, supply, and access.

2.3 Need, demand, supply, and access

2.3.1 Need

A technical definition of need for healthcare is the capacity to benefit, which takes into account the fact that need is subject to the current evidence base because there must be effective healthcare available to treat the condition (Culyer and Wagstaff, 1993; Stevens and Gabbay, 1991). In addition, this definition reflects the fact that individuals’ abilities to benefit from treatment can vary, and need can be influenced by cultural factors (Stevens and Gabbay, 1991).

Different stakeholders can have different perspectives on who has the capacity to benefit from which healthcare services, which is reflected in the following categories of need identified in Bradshaw’s taxonomy of need (Bradshaw, 1972):

- Normative need: need that is defined by experts, i.e., what healthcare specialists view as the desirable standard that people ought to have in any given situation (Popay and Williams, 1994). Normative needs are not absolute and there can be more than one judgement regarding this desirable standard (Clayton, 1983).
- Felt/patient-defined need: need perceived by an individual. Felt/patient-defined needs are limited by individual perceptions and knowledge of services (Bradshaw, 1972).
- Comparative need: need determined by whether an individual has similar characteristics to those who have utilised services in the past (Bradshaw, 1972).

In order to assess the levels of need in the population, healthcare needs assessments (HNAs) can be carried out. A HNA is a systematic method for reviewing the health issues facing a population, which can be used to inform how resources are allocated to improve health and reduce inequalities (Stevens and Gillam, 1998). HNAs often incorporate elements of the following approaches to the assessment of need (Stevens and Gillam, 1998):
• Epidemiological approach, which considers the distribution of the health condition and its determinants, current levels of service provision, and the effectiveness and cost-effectiveness of interventions
• Comparative approach, which compares service provision between different populations
• Corporate approach, which is based on eliciting the views of stakeholders (e.g., healthcare specialists, patients, the public, and politicians) on what services are needed

2.3.2 Supply and demand

Utilisation of healthcare services is influenced by both supply and demand, though neither necessarily reflect need. Supply originates from the amount of goods or service that suppliers are willing to offer at a given price and demand originates from the amount that individuals desire at a given price.

However, supply and demand in healthcare markets can be affected by many additional factors that are not generally present in other markets, which means that market forces in healthcare markets are often not in operation to the same extent as they would otherwise be. This situation is accentuated in third-party payer healthcare systems (i.e., when public or private organisations reimburse healthcare providers for patients’ healthcare expenses) such as the NHS:

• When patients do not directly pay for the services they consume (as is the case in the NHS orthodontic service, which is free at the point of use for children), demand can be highly price-inelastic (i.e., changes in the price have a relatively small effect on the quantity of the service demanded). In these cases, patients can demand more services than the quantity that the third-party payer is willing to provide. Alternatively, if individuals lack knowledge of the available services or do not wish to use healthcare services (e.g., because of time constraints and loss of earning during healthcare appointments or the side effects associated with treatment), even free services will not lead to increased demand.

• In addition, some methods used to reimburse healthcare providers (such as fee-per-item payments, where providers are paid according to the number of treatments they carry out) can lead to supplier-induced demand, which is the amount of demand that exists beyond what would have occurred in a market in which patients are fully informed (Donaldson et al., 2004). This can occur in a healthcare setting because healthcare providers often act as agents on behalf of patients, in part due to the large knowledge differential between the two (Folland et al., 2006). A ‘perfect agent’ is one who would make recommendations that the patient would choose for themselves if they had the same information (Folland et al., 2006). Supplier-induced demand can occur when this agency relationship fails and healthcare providers encourage patients to demand more services than they would if they were fully informed, e.g.,
when orthodontic patients attend repeated assessments (in cases where this could be avoided) before they starts treatment.

Managing supply and demand is very important in third-party payer healthcare systems. Like all third-party payers, the NHS has budget constraints and therefore cost-containment methods are required. This is particularly important in the context of an aging population with large numbers of individuals who require expensive new medical technology, or, in the case of the NHS orthodontic services, in the context of increased demand for treatment (de Oliveira, 2003; Health, Wellbeing and Local Government Committee, 2011). Both supply-side interventions (targeting healthcare providers) and demand-side interventions (targeting potential patients) can be used to reduce utilisation (Park et al., 2007):

- The most important supply-side non-monetary interventions focus the healthcare service on addressing need rather than demand. These interventions include a) planning the workforce based on the epidemiology of the health condition in question (as opposed to historical patterns of utilisation), b) the use of evidence-based clinical guidelines that are part of standardised patient care pathways, and c) continuous medical education regarding both diagnosis and treatment.
- Supply-side monetary incentives include capitation (where providers are paid a fixed amount based the number of patients they provide a range of services for) and setting a fixed budget for remunerating a set of services in a lump-sum fashion. These remuneration strategies can both promote cost-containment but can also lead to undersupply of services.
- A key demand-side monetary intervention is the use of co-payments, which require patients to pay out-of-pocket for part of the cost of services while the third-party payer covers the remainder of the cost.

In an ideal situation, the need for healthcare would lead to a proportionate demand for services, which can then be supplied in a systematic way (Black, 1983). However, this ideal balance between need, demand, and supply can be distorted by multiple factors including the failure of demand to be generated by patient-defined need, demand where normative need does not exist, and inappropriate supply that matches neither normative need nor demand (Black, 1983). Julian Tudor Hart described a pervasive relationship between need and supply of healthcare services in the ‘inverse care law’, which states that ‘the availability of good medical care tends to vary inversely with the need for it in the population served. This operates more completely where medical care is most exposed to market forces, and less so where such exposure is reduced.’ (Tudor Hart, 1971).
2.3.3 Access

Some have argued that access to healthcare services is wholly a question of supply (Mooney, 1983), but there are many critics of this point of view. For example, Donabedian stressed that ‘the proof of access is use of service, not simply the presence of a facility’ (Donabedian, 1972, p. 111). In light of this, access to healthcare services has been defined as the empowerment of an individual to use healthcare services, based on the ‘degree of fit’ between healthcare systems and individuals, households, and communities (McIntyre et al., 2009). This implies that a ‘one size fits all’ approach will not lead to high levels of access, and access issues can arise where healthcare services are organised from the perspective of the providers (i.e., a normative perspective under which individuals ‘should’ use services) as opposed to from the perspective of potential patients (i.e., a positive perspective concerned with the conditions required to empower individuals to use services) (McIntyre et al., 2009).

In 2000, NHS made equity of access an explicit policy, stating that ‘patients will get fair access to consistently high quality, prompt and accessible services right across the country’ (NHS Executive, 2000), rather than allowing utilisation of healthcare services be influenced by factors such as SEP (Mackenbach et al., 2008; Sienkiewicz, 2010). Conceptual frameworks of access to healthcare services can aid in the assessment of access and can help to highlight the potential policy levers for improving access (McIntyre et al., 2009). For example, McIntyre et al. summarised the three major dimensions of access as availability (which concerns whether the appropriate healthcare providers and services are supplied in the right place and at the right time to meet the needs of the population), affordability (which encompasses both the individual’s ability to pay the costs of using healthcare services and the resulting impact of those expenditures on household wellbeing), and acceptability (which describes the fit between healthcare providers’ and patients’ attitudes and expectations of each other) (McIntyre et al., 2009). This framework, with examples of how access to healthcare services can be influenced by non-need factors (Gulliford et al., 2002; McIntyre et al., 2009; Sienkiewicz, 2010), is provided below:

- Barriers due to lack of availability
  - Large distances to healthcare facilities (which is especially common in rural areas), and services provided at multiple facilities rather than comprehensive care provided at a single facility
  - Inconvenient opening hours (which is especially problematic for working adults who have little flexibility in their work hours)
  - Lack of home visits for those with mobility issues
  - Lack of interpreters for those who do not speak English
- Barriers due to lack of affordability
• Lack of public funding or private insurance coverage for certain healthcare services, especially dental, reproductive, mental, ophthalmic, and rehabilitation healthcare services
• Patient’s lack of money (e.g., savings, assets that can be translated into cash, or the ability to access loans) to pay for the out-of-pocket healthcare costs that are not reimbursed, such as prescription charges
• Lack of affordable transport to attend healthcare facilities
• Patient’s lack of time to attend healthcare facilities, and the indirect costs incurred such as loss of income
• Lack of affordable care services for dependents to be cared for while the patients is attending a healthcare facility
• Barriers due to lack of acceptability
  • Patient’s lack of access to information about how to identify healthcare needs and about the existence of the healthcare service
  • Patient’s health beliefs\(^4\), including those related to risk behaviours and cultural practices
  • Healthcare providers that fail to minimise the burden of accessing healthcare on patients, respect patient privacy, avoid stigmatisation, and show their concern about the patient’s wellbeing (e.g., by listening to the patient and discussing his/her condition and the treatment alternatives)
  • Healthcare providers’ prejudice against certain patients (e.g., due to the patient’s SEP, age, ethnicity, or health condition) or lack of cultural sensitivity about the types of healthcare appropriate for certain groups
  • Patient’s prejudice against certain healthcare providers (e.g., due to the provider’s ethnicity or gender)

2.3.4 Summary

Need for healthcare services is defined as the capacity to benefit (Culyer and Wagstaff, 1993; Stevens and Gabbay, 1991), though different stakeholders can have different perspectives on who has a capacity to benefit from which healthcare services, e.g., normative need is defined by experts (Clayton, 1983; Popay and Williams, 1994) and felt need is defined by patients (Bradshaw, 1972). Utilisation of healthcare services is influenced by

\(^4\) Patients’ fundamental health beliefs can lead them to make different choices regarding healthcare utilisation, which are considered to reflect personal autonomy rather than differences in ‘empowerment’ to access to healthcare (e.g., Jehovah’s Witnesses may refuse blood transfusions). However, access is heavily influenced by communication of information between healthcare providers and patients, in order to empower individuals with the knowledge to make fully informed decisions (McIntyre et al., 2009).
both supply from healthcare providers and demand from potential patients, though neither supply nor demand necessarily reflect need. A key intervention to prevent unnecessary utilisation of healthcare is to focus the healthcare service on addressing need by basing supply on evidence-based clinical guidelines (Park et al., 2007).

The following section introduces the NHS orthodontic service, and discusses need, demand, supply, and utilisation in the context of orthodontics.

2.4 NHS orthodontic service

2.4.1 Orthodontics and malocclusion

Orthodontics is an area of specialism within dentistry that is concerned with treating malocclusion (i.e., abnormal positioning of the teeth).

Malocclusion is commonly classified using Angle’s classification system, which is based upon the relationship between the permanent upper molars and the permanent lower first molars (Angle, 1907). There are three classes of malocclusion according to Angle’s classification system (Angle, 1907):

- Class I malocclusion, which occurs when the upper and lower first molars are properly positioned but there are other issues, such as:
  - Spacing, where there is too much space between the teeth
  - Crowding, where there is a discrepancy between tooth size and jaw size that results in a misalignment of the tooth row, which can cause impaction (i.e., the permanent teeth are prevented from coming in)
  - Crossbites, where any or all of the upper teeth fit on the inside of the lower teeth
  - Openbite, where the upper and lower front teeth do not overlap, which creates an opening straight into the mouth
  - Rotations, where a tooth turns or tips out of its normal position
- Class II malocclusion, which occurs when the lower first molars are positioned more towards the throat than the upper first molars, so the upper teeth and jaw project further forward than the lower teeth and jaw. Class II malocclusions can occur when either an excessive overbite is present (i.e., when the upper front teeth reach too far down over the lower front teeth, which, in severe cases, can cause the lower teeth to bite into the roof of the mouth) or an overjet is present (i.e., when the upper front teeth are pushed outward)
Class III malocclusion, which occurs when the lower first molars are positioned more away from the throat than the upper first molars, so the lower teeth and jaw project further forward than the upper teeth and jaw, which is the case when a reverse overjet is present.

2.4.2 Purpose of orthodontic treatment, and its effectiveness and cost-effectiveness

2.4.2.1 Purpose of orthodontic treatment

By treating malocclusion, orthodontic treatment can be used to improve oral health and/or function, but this is only true for patients with specific types of malocclusion:

- Oral health:
  - Except for in severe cases (e.g., cleft lip and palate), orthodontic treatment is not able to prevent caries (i.e., tooth decay), periodontal disease (i.e., gum disease), gingival recession (i.e., receding gums), or temporomandibular dysfunction (which is a problem affecting the muscles that move the jaw and the joints between the lower jaw and the skull) (Burden, 2007; Luther et al., 2010; Seehra et al., 2009).
  - However, orthodontic treatment can help to reduce the risk of root resorption (i.e., dissolving) of teeth adjacent to impacted teeth, and to reduce the risk of cyst formation around impacted teeth (which is rare) (Clinical Standards Committee of the British Orthodontic Society, 2008).
  - In addition, the risk of trauma to the upper incisors (which can lead to tooth fracture and nerve damage) increases for children with a significant overjet, which orthodontics can treat (Todd and Dodd, 1985).

- Oral function:
  - Certain types of malocclusion increase the likelihood of speech disorder (e.g., an anterior openbite is associated with a lisp (Laine, 1987)). However, there is a large potential for compensation that reduces the likelihood of speech disorders developing (Johnson and Sandy, 1999) and there is little evidence that orthodontic treatment (even if it involves orthognathic surgery for severe skeletal discrepancies) will resolve problems without adjunctive speech therapy (Hassan et al., 2007).
  - Certain types of malocclusion can make eating difficult or socially embarrassing (e.g., an anterior openbite) (Benson et al., 2015) and malocclusion can sometimes reduce the efficiency of chewing (Magalhães et al., 2010), though this does not necessarily result in a detrimental effect on everyday life (Benson et al., 2015).
The evidence regarding the effect of orthodontic treatment on the improvement of dental aesthetics and resultant improvements in psychological wellbeing, social wellbeing, and oral health-related quality of life (OHQoL) have also been considered as justifications for orthodontic treatment:

- People who have psychological wellbeing have high self-esteem (i.e., they value themselves as individuals), find life productive and satisfying, and tend to cope effectively with challenges (though they may still feel negative emotions at times) (Benson et al., 2015; Orth et al., 2012). Psychological wellbeing is thought to be influenced by numerous factors in an individual’s life (including genetic factors, SEP, general health, and, in particular, education) (Benson et al., 2015). Therefore, for most individuals, embarrassment about dental appearance would only be a small part of complex interactions between multiple factors (Benson et al., 2015). Consequently, it is unrealistic to expect that orthodontic treatment will lead to major long-term changes in psychological wellbeing, and multiple studies have found this to be the case (Arrow et al., 2011; Kenealy et al., 2007; Shaw et al., 2007). Notably, it has been reported that psychological factors explain more about the impact of malocclusion upon individuals than normative measures of malocclusion (Agou et al., 2011, 2008; Baker et al., 2010; Nammontri et al., 2013), i.e., poor dental aesthetics is likely to concern someone with low self-esteem much more than someone with high self-esteem (Benson et al., 2015). This helps to explain why some individuals are upset about relatively minor malocclusion, while others, with much more severe malocclusion, do not have patient-defined need (Benson et al., 2015).

- While psychological wellbeing reflects how content an individual is with his/herself, social wellbeing reflects how that individual interacts with others. Several studies have confirmed that people who seek orthodontic treatment feel under pressure due to exposure to unrealistic beauty norms in the media (Josefsson et al., 2010; Taghavi Bayat et al., 2013). This leads to people with malocclusion using various coping strategies to try to reduce the impact of their malocclusion in social situations, such as not showing their teeth when they smile (Josefsson et al., 2010; Taghavi Bayat et al., 2013). In addition, bullying due to dental appearance has been widely reported in many different cultures (Al-Bitar et al., 2013; Helm et al., 1985; Onyeaso and Sanu, 2005; Rwakatema et al., 2006; Seehra et al., 2011; Shaw et al., 1980; Zammit et al., 1995) and orthodontic treatment can help to alleviate this (Seehra et al., 2013).

- The World Health Organisation defines quality of life as ‘an individual’s perception of their position in life in the context of the culture and value systems in which they live and in relation to their goals, expectations, standards and concerns’ (World Health Organisation, 1997, p. 1), and the influence of oral health conditions on an individual’s overall quality of life is defined by the concept of OHQoL. A systematic review of malocclusion and OHQoL concluded that the relationship between the severity of
malocclusion and OHQoL was moderate (Liu et al., 2009). There is also evidence that orthodontic treatment can lead to a modest improvement in OHQoL, as reported by Zhou et al. in a recent systematic review (Zhou et al., 2014).

Many consider the improvement of dental aesthetics to be the primary justification for orthodontic treatment (Benson et al., 2015). Some see this focus on aesthetics as evidence that much of the orthodontic treatment carried out in the NHS is ‘cosmetic treatment’. In contrast, as orthodontic treatment can improve a patient’s social wellbeing and OHQoL, others see orthodontic treatment as a legitimate treatment for a public healthcare system to fund, which is in line with the World Health Organization’s definition of health as ‘a state of complete physical, mental and social wellbeing and not merely the absence of disease or infirmity’ (World Health Organization, 2009, p. 1).

2.4.2.2 Effectiveness and cost-effectiveness of orthodontic treatment

The recent systematic review by Zhou et al. of the effect of orthodontic treatment on OHQoL included 11 studies published between 1960 and 2013 and found that there was generally an association between orthodontic treatment and improved OHQoL, but the strength of the association was modest (Zhou et al., 2014). As noted above, psychological factors play a bigger role than normative measures of malocclusion in determining whether or not an individual is concerned by his/her malocclusion (Agou et al., 2011, 2008; Baker et al., 2010; Nammontri et al., 2013), and, moreover, a recent study showed that OHQoL outcomes are modified by pre-treatment physiological wellbeing (Agou et al., 2008). Furthermore, the same study showed that, when comparing individuals who received treatment to those on waiting lists, the amount of variance in OHQoL scores explained by having orthodontic treatment was relatively small (9%) compared to the amount of variance explained by physiological wellbeing (26%) (Agou et al., 2008). The authors concluded that children with better physiological wellbeing are, in general, more likely to report better OHQoL regardless of their orthodontic treatment status while children with low physiological wellbeing who did not receive orthodontic treatment experienced worse OHQoL compared to those who received treatment (Agou et al., 2008).

A course of orthodontic treatment for 10- to 17-year-olds costs the NHS approximately £1,300 (Wise, 2015). A recent systematic review of the cost-effectiveness of orthodontic treatment included 8 studies published between 1966 and 2014 but due to the studies’ lack of quality, the authors concluded that the evidence base was inadequate to evaluate the cost-effectiveness of orthodontic treatment (Sollenius et al., 2015).
2.4.3  Normative need, patient-defined need, and eligibility for NHS orthodontic treatment

2.4.3.1 Normative need for orthodontic treatment

Malocclusion represents a continuum of biological diversity, so defining a threshold at which patients are eligible for NHS treatment is complex. There are several occlusal indices available to prioritise patients with malocclusion according to their severity of malocclusion (Cardoso et al., 2011). These indices promote uniformity in who is provided with treatment, help with patient counselling, and can be used for monitoring outcomes (Shaw et al., 1991).

One of the most widely used of these occlusal indices is the IOTN, which was developed by Brook and Shaw at the University of Manchester (Brook and Shaw, 1989). The IOTN was developed after the Minister of Health commissioned an enquiry into the provision of poor or unnecessary dental treatment (Schanschieff and Toulmin, 1986), which reinforced concerns about the existence of high volume caseloads associated with unnecessary and poor quality treatment (Schanschieff and Toulmin, 1986).

The IOTN has two components: the Dental Health Component (DHC) score and the Aesthetic Component (AC) score:

- The IOTN DHC score is an objective measure that takes into account five occlusal traits: missing teeth, size of overbite, size of overjet, crossbite, and displacement of contact points (where there is spacing between the teeth). The IOTN DHC score ranges from 1 (representing no need) to 5 (representing very great need), as shown in Table 2.1.

- The IOTN AC score is a subjective measure that allows orthodontic clinicians to compare the anterior teeth with a set of 10 photographs representing different levels of dental attractiveness, from 1 (representing very straight teeth) to 10 (representing severe malocclusion), which were originally arranged in order by members of the general public, as shown in Figure 2.1.
Table 2.1: IOTN DHC scoring

<table>
<thead>
<tr>
<th>IOTN DHC score</th>
<th>Details</th>
</tr>
</thead>
<tbody>
<tr>
<td>5: very great need</td>
<td>5i Impeded eruption of teeth (with the exception of third molars) due to crowding, displacement, the presence of supernumerary teeth, retained primary teeth, and any pathological cause</td>
</tr>
<tr>
<td></td>
<td>5h Extensive hypodontia (i.e., more than one tooth missing in any quadrant)</td>
</tr>
<tr>
<td></td>
<td>5a Increased overjet &gt; 9 mm</td>
</tr>
<tr>
<td></td>
<td>5m Reverse overjet &gt; 3.5 mm with masticatory and speech difficulties</td>
</tr>
<tr>
<td></td>
<td>5p Cleft lip and palate or craniofacial anomalies</td>
</tr>
<tr>
<td></td>
<td>5s Submerged primary teeth</td>
</tr>
<tr>
<td>4: great need</td>
<td>4h Less extensive hypodontia</td>
</tr>
<tr>
<td></td>
<td>4a Increased overjet &gt; 6 mm but ≤ 9 mm</td>
</tr>
<tr>
<td></td>
<td>4b Reverse overjet &gt; 3.5 mm with no masticatory or speech difficulties</td>
</tr>
<tr>
<td></td>
<td>4m Reverse overjet &gt; 1 mm but ≤ 3.5 mm with masticatory and speech difficulties</td>
</tr>
<tr>
<td></td>
<td>4c Anterior/posterior crossbites with &gt; 2 mm discrepancy between retruded contact position and intercuspal position</td>
</tr>
<tr>
<td></td>
<td>4l Posterior lingual crossbite with no functional occlusal contact in one or both buccal segments</td>
</tr>
<tr>
<td></td>
<td>4d Contact point displacements of teeth &gt; 4 mm</td>
</tr>
<tr>
<td></td>
<td>4e Extreme lateral or anterior openbites &gt; 4 mm</td>
</tr>
<tr>
<td></td>
<td>4f Increased and complete overbite with gingival or palatal trauma</td>
</tr>
<tr>
<td></td>
<td>4t Partially erupted teeth, tipped and impacted against adjacent teeth</td>
</tr>
<tr>
<td></td>
<td>4x Presence of supernumerary teeth</td>
</tr>
<tr>
<td>3: borderline need</td>
<td>3a Increased overjet &gt; 3.5 mm but ≤ 6 mm with incomplete lip seal</td>
</tr>
<tr>
<td></td>
<td>3b Reverse overjet &gt; 1 mm but ≤ 3.5 mm</td>
</tr>
<tr>
<td></td>
<td>3c Anterior/posterior crossbites with &gt;1 mm but ≤ 2 mm discrepancy between retruded contact position and intercuspal position</td>
</tr>
<tr>
<td></td>
<td>3d Contact point displacements of teeth &gt; 2 mm but ≤ 4 mm</td>
</tr>
<tr>
<td></td>
<td>3e Lateral or anterior openbite &gt; 2 mm but ≤ 4 mm</td>
</tr>
<tr>
<td></td>
<td>3f Increased and complete overbite without gingival or palatal trauma</td>
</tr>
<tr>
<td>2: little need</td>
<td>2a Increased overjet &gt; 3.5 mm ≤ 6 mm with complete lip seal</td>
</tr>
<tr>
<td></td>
<td>2b Reverse overjet &gt; 0 mm but ≤ 1 mm</td>
</tr>
<tr>
<td></td>
<td>2c Anterior/posterior crossbites with ≤ 1 mm discrepancy between retruded contact position and intercuspal position</td>
</tr>
<tr>
<td></td>
<td>2d Contact point displacements of teeth &gt;1 mm but ≤ 2 mm</td>
</tr>
<tr>
<td></td>
<td>2e Anterior or posterior openbite &gt; 1 mm but ≤ 2 mm</td>
</tr>
<tr>
<td></td>
<td>2f Increased overbite ≥ 3.5 mm without gingival contact</td>
</tr>
<tr>
<td></td>
<td>2g Class II or class III occlusions with no other anomalies</td>
</tr>
<tr>
<td>1: no need</td>
<td>1 Extremely minor malocclusions including contact point displacements of teeth ≤ 1 mm</td>
</tr>
</tbody>
</table>

DHC: Dental Health Component; IOTN: Index of Orthodontic Treatment Need; mm: millimetre

Source: Brook and Shaw, 1989
Other than the IOTN, the three most commonly used American and European occlusal indices are:

- The Handicapping Labiolingual Deviation (HLD) index
- The Dental Aesthetic Index (DAI)
- The Index of Complexity, Outcome, and Need (ICON)

The HLD index was developed in 1960 to identify handicapping malocclusion, and degree of the handicap (Draker, 1960), and it is used to determine eligibility for publically-funded orthodontic treatment in parts of the United States (US) (Theis et al., 2005). It takes into account multiple occlusal traits to determine whether potential patients are eligible for treatment, though different states use different eligibility thresholds (Theis et al., 2005). However, some critics felt that the original form of the HLD index was not a reliable index to assess orthodontic
treatment need so it was modified in California to create the HLD (CalMod) index in order to take into account additional factors, including occlusal traits that can cause tissue damage (Theis et al., 2005).

The DAI was developed in 1986 as an epidemiological instrument to classify malocclusions (Cons et al., 1987), though it is also used as a screening device to determine priority for publically-funded orthodontic treatment in parts of the US (Jenny and Cons, 1996). Unlike the HLD index and the ICON, the DAI is based on societal norms for dental appearance, which were linked with objective measurements of ten occlusal traits. The ten components include the number of missing teeth and the size of overjet (in mm), which are weighted and summed, along with a constant of 13, to provide a final score between 13 and 80. A score of 36 represents handicapping malocclusions, but other thresholds have been defined to categorise less severe malocclusion (Jenny and Cons, 1996).

The ICON was developed in 2000 in order to assess the outcomes and complexity of orthodontic treatment as well as need, and it is commonly used in research settings (Daniels and Richmond, 2000). It assesses five occlusal traits: the IOTN AC score, crossbite, upper arch crowding or spacing, antero-posterior relationships in the buccal segments, and anterior vertical relationships (Daniels and Richmond, 2000). These are scored, weighted, and summed to provide a final score (Daniels and Richmond, 2000). Although the index does not include any OHQoL measures, the IOTN AC score is given the largest weighting of all the five occlusal traits (Daniels and Richmond, 2000), which aids in identifying patients with OHQoL concerns.

2.4.3.2 Patient-defined need for orthodontic treatment

There is substantial evidence that there are differences in the value systems of patients and orthodontic clinicians regarding orthodontic need (de Oliveira et al., 2008; Hamdan, 2004; McKeta et al., 2012), indicating that patient-defined need will tend to differ from normative need. Given that orthodontic treatment is often justified by the affects that treatment could have on the social wellbeing and OHQoL of an individual with malocclusion, patient-defined need is a particularly important aspect of determining who has need for treatment. Despite this, the IOTN does not directly take into account patients’ perceptions of their malocclusions and the impact on their lives, even though a recent UK study found that combining IOTN scores with a measure of OHQoL predicted patients-defined need much better than the IOTN scores alone (de Oliveira et al., 2008).

However, there is an increasing focus on dental aesthetics in society, and so what may previously have been regarded as a minor case of malocclusion may now be considered by potential patients to constitute a need for treatment (Birkeland et al., 2000). A recent Welsh inquiry into the NHS orthodontic service found that while the maximum number of patients that can be treated under the current contractual arrangements in Wales has remained fixed since 2006, demand has grown among the public, partly due to demand from children not meeting
the IOTN eligibility threshold (Health, Wellbeing and Local Government Committee, 2011). This shift presents a challenge to the NHS regarding where the threshold should lie between need for publically-funded treatment and ‘cosmetic treatment’ (Welsh Assembly Government, 2011).

2.4.3.3 Eligibility for NHS orthodontic treatment

Many public healthcare systems, including those in England, Wales, Scotland, Northern Ireland, and the Republic of Ireland, use the IOTN to determine which children are eligible for orthodontic treatment. In addition, there is also a requirement for the patient to have patient-defined need, and the resultant motivation to undergo a full course of treatment, along with no untreated caries and good oral hygiene (because orthodontic treatment puts patients at an increased risk of caries).

England and Wales introduced the IOTN as a mandatory needs assessment tool in 2006 (after previously leaving the assessment of need to the discretion of the orthodontic clinicians). Both healthcare systems cover orthodontic treatment for patients with an IOTN score of 3.6 or above, i.e., an IOTN DHC score of 4-5 or an IOTN DHC score of 3 with an IOTN AC score of 6 or above (Department of Health, 2006). Subsequently, Scotland and Northern Ireland started using the IOTN, with similar regulations to those in England and Wales (Northern Ireland British Dental Association, 2012; Taylor, 2011).

Northern Ireland has considered restricting orthodontic treatment to individuals with IOTN DHC scores of 4-5, as the Northern Ireland Department of Health, Social Services and Public Safety stated that there is a strong clinical and public health argument for moving to a threshold of an IOTN DHC score of 4 (Northern Ireland British Dental Association, 2012). However, after consultation with the British Dental Association in Northern Ireland, it was decided that the threshold for orthodontic treatment would remain similar to that used in England, Wales, and Scotland (Northern Ireland Assembly, 2012). In contrast, in the Republic of Ireland, only children with IOTN DHC scores of 4-5 (and a number of additional minor restrictions) are eligible for publically-funded orthodontic treatment (Republic of Ireland Health Service Executive, 2006).

As a result of the IOTN threshold of 3.6 being implemented in the UK, NHS treatment for those with IOTN scores of under 3.6 is now very rare. However, there are some exceptional cases where patients receive treatment after an appeal procedure despite not qualifying under the IOTN criteria (Welsh Assembly Government Dental Division, 2013).

In light of these decisions to make the use of the IOTN mandatory when assessing eligibility for treatment, the IOTN can be considered in one of two ways (or both):
Firstly, the IOTN can be regarded as a consistent, standardised metric to assess normative need, and prioritise patients into categories reflecting the severity of their malocclusion (de Oliveira, 2003). If framed in this light, the use of the IOTN helps to increase efficiency (by maximising the health gain brought about by a given level of orthodontic resources) and horizontal equity of access (by promoting equal access for equal need) for a necessary healthcare service, whilst simultaneously serving to protect children from the risks of unnecessary treatment (de Oliveira, 2003).

On the other hand, the IOTN can be thought of as a cost-containment tool to manage demand for a service with questionable health gains, by allocating finite orthodontic resources only to those whose malocclusion meets a certain threshold, which has been described as ‘arbitrary’ (McIntyre, 2012).

Population-based surveys of orthodontic treatment need commonly use a modified version of the IOTN that is quicker and simpler to use than the unmodified version, thereby saving resources during the data collection stage. The modified IOTN can be used to classify individuals as having either IOTN DHC scores of 1-3 or IOTN DHC scores of 4-5 (and the IOTN AC scores are assessed as normal). Therefore, these surveys cannot collect data on which individuals have IOTN scores of 3.6-3.10. Although reports on these surveys can provide information on the numbers of individuals with IOTN AC scores of 6-10, they tend to report on those with IOTN AC scores of 8-10 instead (those with an IOTN DHC score of 4-5 and/or an IOTN AC score of 8-10 are defined as having ‘definite’ normative need), which is at odds with the eligibility threshold used in the NHS.

2.4.4 NHS orthodontic patients

The vast majority of patients who utilise NHS orthodontic treatment are aged 17 or under. In principle, adults can be provided with NHS orthodontic treatment, but most NHS orthodontic contracts do not allow for the treatment of adults (Health, Wellbeing and Local Government Committee, 2011). However, some adults with severe malocclusion (e.g., orthodontic treatment involving orthognathic surgery) receive NHS orthodontic treatment on a case-by-case basis (Health, Wellbeing and Local Government Committee, 2011).

Orthodontic treatment can be divided into interceptive and comprehensive treatment. Interceptive treatment is rare in the NHS. It is provided to those aged under 10 and it aims to minimise the need for treatment later on by modifying the growth pattern of the jaw, thereby correcting any skeletal imbalances (Tzemach et al., 2014). Comprehensive treatment is provided to those aged 10 and over, and is generally started after the development of the early permanent dentition (Clinical Standards Committee of the British Orthodontic Society, 2010).
2.4.5 NHS orthodontic workforce

As shown in Figure 2.2, both specialist orthodontists and non-specialist orthodontic clinicians provide NHS orthodontic services.

Specialist orthodontists are dentists who have undertaken a 3-year training course and have completed the Membership in Orthodontics examination of the Royal College of Surgeons in order to be registered as specialists with the General Dental Council. In contrast, non-specialist orthodontic clinicians are dentists who treat orthodontic patients but are not registered as specialists, i.e., they are GDPs (Hodge and Parkin, 2015). Most of these non-specialists were classified as Dentists with a Special Interest (DwSI) in orthodontics but they are now known as Dentists with Enhanced Skills (DES) (Hodge and Parkin, 2015). DES are trained in training schemes for foundation dentists, with placements in specialist practices or hospital departments (Hodge and Parkin, 2015).

Figure 2.2: NHS orthodontic workforce

NHS: National Health Service

Non-specialists have tended to be commissioned to provide NHS orthodontic services in areas where there are few NHS specialist orthodontists practicing (Department of Health and the Faculty of General Dental Practice, 2006). In the past, much of orthodontic treatment was carried out by non-specialists, with 2003-2004 data showing that the majority of orthodontic provision in Shropshire, Staffordshire, Trent, North and East Yorkshire, and Lincolnshire was carried out by non-specialists, and, across the UK in 2003-2004, over 17% of orthodontic
clinicians were non-specialists (Robinson et al., 2005). However, more recently, the majority of new orthodontic contracts have been made with specialist orthodontists (Hodge and Parkin, 2015). Although some non-specialists have had their contracts renewed, they are expected to refer patients with more complex malocclusions to specialist orthodontists (Hodge and Parkin, 2015). In addition, in recent times, there have been more Dental Care Professionals in orthodontics (i.e., support staff providing orthodontic services) working with clinicians in primary care settings.

There are several different NHS contracts that primary care dentists can work under (Hodge and Parkin, 2015):

- **PDS contracts.** Under these contracts, there is no requirement to provide the full range of mandatory NHS dental services, so they can involve solely specialist orthodontic treatment. If a person or organisation enters into a contract with the NHS to provide orthodontic treatment and then subcontracts all the activity, this has to be provided under a PDS contract.

- **GDS contracts.** The full range of mandatory dental services must be provided under these contracts, so they cannot provide solely orthodontic treatment, i.e., the focus is on providing comprehensive primary care dentistry rather than solely specialist orthodontic treatment.

- **TDS contracts.** Only a small percentage of primary care orthodontic clinicians work under TDS contracts, and these clinicians are paid a fixed salary. They are known as community specialist orthodontists, and they undertake treatment for vulnerable patients (i.e., patients for whom there is evidence that they would not otherwise obtain treatment from other orthodontic clinicians). This includes people with disabilities and special needs, those who are medically compromised, children with behavioural problems, and anxious and phobic patients who require sedation (Elliott, 2012). These patients often require close liaison with other healthcare professionals.

The distribution of NHS orthodontic clinicians (working under PDS or mixed PDS-GDS contracts, and working under GDS contracts) varies across England, as shown in Figure 2.3.
In addition to the NHS primary care orthodontic service, the NHS hospital dental service treats patients with complex malocclusions that can require surgery, such as patients with developmental anomalies affecting tooth structure and those with a cleft lip and palate (Hodge and Parkin, 2015). These cases are treated by consultant specialist orthodontists (who have undergone additional 2-year training courses to become consultants, after completing the 3-year specialist orthodontist course), often in combination with interdisciplinary teams including consultant oral and maxillofacial surgeons, plastic surgeons, or paediatric surgeons (Hodge and Parkin, 2015).

In addition to the NHS orthodontic service, treatment for malocclusion is also available in the private sector for those who can afford it. NHS dentists are predominantly self-employed professionals who have varying time commitments to the NHS, and so they are largely free to offer private services (Hodge and Parkin, 2015). The private sector mainly caters for adults, but it can also provide an alternative to NHS treatment for children who do not meet the eligibility criteria for NHS treatment, those who want shorter waiting times for treatment (as waiting time for NHS treatment can be greater than two years in some parts of the country) or treatment options that are only available privately (e.g., lingual appliances that are fitted behind the teeth).
2.4.6 NHS orthodontic treatment pathways

NHS GDPs are the first point of contact for orthodontic patients with the NHS dental service. Patients who are judged to be eligible for treatment can either be referred to the NHS primary care orthodontic service by their GDP, or they can be treated by the GDP, if the GDP is an orthodontic clinician. When complex cases of malocclusion are present, the patient can be referred on to the hospital dental service.

All orthodontic treatments require an initial assessment by an orthodontic clinician. An assessment can involve assessing a patient’s oral hygiene, and taking photographs, radiographs, and models of the patient’s occlusion. It is intended to establish whether orthodontic treatment is necessary and, if so, when treatment should be undertaken.

As shown in Figure 2.4, an assessment can lead to the patient being refused treatment, or patients can have repeated assessments before starting treatment (especially if they are referred too early (NHS England Primary Care Commissioning, 2013), despite the fact that guidelines recommend that if patients are referred too early, orthodontic clinicians should send the patients back to the referring GDPs (Welsh Assembly Government Dental Division, 2013)).

Figure 2.4: NHS orthodontic treatment pathways

GDP: General Dental Practitioner; NHS: National Health Service

In the NHS, treatment generally commences after a patient’s permanent teeth have started to erupt (Clinical Standards Committee of the British Orthodontic Society, 2010). Although the timing of orthodontic treatment
remains a matter of conjecture (DiBiase, 2002; Kiyak et al., 2004), the British Orthodontic Society (BOS) states that the ‘early permanent dentition is the best time to carry out treatment for the majority of patients…This is the ideal time for a full orthodontic assessment to be carried out in order to determine whether active orthodontic treatment is indicated’ (Clinical Standards Committee of the British Orthodontic Society, 2010, p. 12). It is during this stage that the alveolar bone (i.e., the bone that contains the tooth sockets) is readily remodelled during periods of active skeletal growth, which facilitates the tooth movements produced by orthodontic appliances (Clinical Standards Committee of the British Orthodontic Society, 2010). Therefore, the perspective in the NHS is that treatment from approximately age 12 is optimal for most patients. However, referral guidelines from both the BOS (Clinical Standards Committee of the British Orthodontic Society, 2010) and the NHS (NHS Milton Keynes & Northamptonshire Dental Team, 2013) recommend that, in specific cases, certain children need early referral and treatment due to physiological anomalies such as class III malocclusions and missing teeth, to allow for the earliest possible treatment planning. The expected impact of early treatment on the social wellbeing and OHQoL of patients is also considered (Clinical Standards Committee of the British Orthodontic Society, 2010).

Recent guidance from NHS England suggests that a reasonable benchmark ratio of assessments to treatments is 1.5-2.0: 1, with a 1:1 ratio being the ideal (NHS England Primary Care Commissioning, 2013). Overuse of assessments can result in unnecessary costs to the NHS, and to patients and their parents, so they have led to measures to improve the referral process, such as the implementation of centralised referral management and triage systems. Many examples of these centralised referral validation and triage systems started to be developed in 2012 by Primary Care Trust (PCTs) in Greater Manchester (McGrady and Bridgman, 2013). These systems were detailed in a recent HNA report from Greater Manchester, but they were not evaluated at the time, so a comparison of their cost-effectiveness is not possible (McGrady and Bridgman, 2013). Descriptions of the 10 different systems being set up across Greater Manchester showed that while some involved extensive validation, others were more rudimentary (McGrady and Bridgman, 2013):

- Manchester used a system with face-to-face visits, which involved establishing that the patient had good oral hygiene, awareness of orthodontic treatment requirements and a willingness to comply, and an optimum time to begin treatment of 0-6 months, 6-12 months, or 12-18 months (if the optimum time was more than 18 months, the patient was judged to have been referred too early). Over the course of a year (2012-2013), 17.4% of referrals to this system were rejected, most of which were avoidable. For example, 22.0% of rejections were due to patients being referred too early, 12.0% were due to patients having IOTN scores of < 3.6 (5.6% had IOTN scores of score significantly less than 3.6), 10.9% were due to patients having poor oral hygiene, 3.6% were due to patients being unwilling to have treatment, and 1.3% were due to the patients being aged over 18 (while the remainder when due to factors such administrative errors or
the patients failing to attend their referral appointments). This suggests there could have been significant inefficient use of NHS orthodontic assessments if the referrals had been made directly to orthodontic clinicians for assessment.

- Tameside and Glossop used a centralised triage system, which used dental impressions (i.e., negative imprints of teeth and soft tissues in the mouth) to facilitate the triage of orthodontic referrals. However, this system did not check for factors such as oral hygiene status or willingness to comply with treatment requirements.
- Six localities used only administrative systems and two had systems that were at the planning stages.

A course of orthodontic treatment can involve the following types of orthodontic appliance:

- Fixed appliances, which are made up of brackets bonded to each tooth and connected with wires. They can tip teeth, rotate teeth, and cause translation of teeth (where all points on the body of the tooth move in the same direction and with the same magnitude). They are the most common type of orthodontic appliance and, if provided by the NHS, they are usually made out of stainless steel.
- Removable appliances, which are usually plastic plates with metal wires attached. They clip on to the teeth and can be removed for cleaning. This type of appliance can only be used for limited tooth movements (e.g., to tip teeth) so they are only used to correct minor problems.
- Functional appliances, which are pairs of braces that fit on to the upper and lower teeth, and are designed to interact together and utilise the muscle action of the patient’s jaws to generate forces. They can be used to treat problems with the position of the upper jaw and teeth relative to the lower jaw and teeth.
- Headgear and reverse-pull headgear (i.e., orthodontic facemasks), which can be attached to an orthodontic appliance in a patient’s mouth for a few hours per day. They are used for correcting severe malocclusions. Headgear can be used by growing patients to correct overbites by holding back the growth of the upper jaw, allowing the lower jaw to catch up. In contrast, reverse-pull headgear is can be used by growing patients to correct a reverse overjet by assisting the growth of the upper jaw, allowing it to catch up with the lower jaw.

A course of treatment usually takes 18-24 months to complete, and involves regular appointments in order to have the appliance adjusted and to check that oral hygiene is being maintained. A US survey in 2005 of 59 orthodontic clinicians found that the most common appointment interval was five to six weeks, followed closely by seven to eight weeks (Sheridan, 2005).
A course of treatment ends with either treatment completion or early treatment discontinuation (at the request of the orthodontic clinician or the patient, or if the patient fails to return to the practice). NHS funding is rarely available for retreatment of orthodontic patients if the first course of treatment is unsatisfactory (NHS Suffolk, 2010). However, a second course of NHS treatment can be authorised in exceptional circumstances (NHS Suffolk, 2010).

After active treatment has finished, retainers are used in order to hold the adjusted teeth in place while the surrounding gum and bone adjusts. If a patient stops wearing his/her retainers it is likely that there will be some tooth movement because there is an almost universal tendency for the teeth to relapse once active treatment has finished (Clinical Standards Committee of the British Orthodontic Society, 2010). This happens because fibres of the periodontal ligament (which attach the teeth to the alveolar bone within which they sit) and gingivae (which attach the teeth to the gum tissue) are put under tension or pressure during the active stages of treatment and it takes time for these fibres to re-attach so that the tension no longer exists (Clinical Standards Committee of the British Orthodontic Society, 2010). The minimum period of full-time retention is usually three to six months followed by six months part-time retention (e.g., at night) (Clinical Standards Committee of the British Orthodontic Society, 2010). However, some argue that the only way to ensure that there is no relapse is to use more long-term or even permanent retention (Linklater and Fox, 2002), because even after 12 months of retention, there is likely to be some deterioration in the position of the teeth (Clinical Standards Committee of the British Orthodontic Society, 2010).

A study on relapse rates post-retention (i.e., after the patient finishes wearing retainers) was carried out on patients treated in the NHS hospital dental service (Linklater and Fox, 2002). The study minimised the bias in the selection of cases for inclusion by selecting consecutive patients (including patients who discontinued treatment and those treated with removable appliances, who tend to have poorer outcomes than those treated with fixed appliances (O’Brien et al., 1993; Richmond et al., 1993)). The study confirmed that some degree of post-retention occlusal deterioration is almost universal (Linklater and Fox, 2002). However, at a mean post-retention time of 6.5 years, only 24% had an IOTN DHC score of 4-5, though a further 33% had an IOTN DHC score of 3 (Linklater and Fox, 2002). In terms of IOTN AC scores, 8% had an IOTN AC score of 8-10 and a further 30% had an IOTN AC score of 5-7 (Linklater and Fox, 2002). As noted in a systematic review of studies on relapse rates post-retention, there are several additional studies on relapse rates, but the authors concluded that few evidence-based conclusions could be made from them because of issues with small sample sizes, high dropout rates, short follow-up periods, and lack of untreated control groups (Bondemark et al., 2007).
2.4.7 **NHS orthodontic commissioning**

2.4.7.1 *Impact of the 2006 NHS dental reforms*

The introduction of a new dental contracting framework in 2006 in England (UK Parliament, 2005) and Wales (National Assembly for Wales, 2006) brought the largest change in dental provision since the inception of the NHS in 1948 (NHS England Primary Care Commissioning, 2013). Under the pre-2006 system of NHS dentistry, dentists were remunerated on a fee-per-item basis that created incentives for more invasive and complex treatment (Department of Health, 2007). The NHS also had little control over the location of dental practices and the volume of services provided locally (Department of Health, 2007). Dentists were moving away from the NHS into the private sector but there was no local funding to replace them, which led to access issues in some areas (Department of Health, 2007). Another key problem for patients was that there were more than 400 patient charges for different dental treatments, which caused confusion for patients and made it unclear what was NHS and what was private treatment (Department of Health, 2007).

As a result of the 2006 reforms there was a transition to a system of locally commissioned services (Department of Health, 2007). Under this new local system, dentists are paid an agreed annual income in return for an agreed level of patient care, measured in terms of courses of treatment (rather than individual items of treatment) (Department of Health, 2007). In addition, the patient charge system has been simplified and linked to courses of treatment (Department of Health, 2007).

There has been much criticism of the 2006 reforms, especially regarding how dentistry is remunerated, as they have led a focus on treatment and repair services rather than preventative care (Department of Health, 2015). In light of this, the Department of Health has stated that a new system of remuneration is needed to meet the needs of the increasingly segmented population, as younger people tend to have little or no dental decay while older people tend to have little new disease but they often have heavily filled teeth that can require increasingly intensive levels of repair (if they are not extracted) (Department of Health, 2015). As a consequence, a new system is being piloted (Department of Health, 2015). This system provides guidance on treatment care pathways, measures the quality of the care delivered, and remunerates providers in a way that supports continuing care and prevention (by blending together capitation and payments for activity and quality) (Department of Health, 2015).
2.4.7.2 Impact of the 2006 NHS dental reforms on the orthodontic service

After the 2006 reforms, as for other dental contracts, the annual values of the NHS orthodontic contracts were based on NHS earnings during a 12-month reference period prior to the reforms (October 2004 to September 2005) (Department of Health, 2007). However, a significant transitional issue arose because of the time lag between starting and completing a course of orthodontic treatment, which meant that the reference period could not take into account the more recent caseloads of new or growing NHS practices (Department of Health, 2007). As a result, commissioners gradually developed a more strategic approach to commissioning orthodontic services and commissioned additional services to reflect the outcomes of local HNAs (Department of Health, 2007).

Before the 2006 reforms, orthodontic providers were paid the majority of their contract payments only after they completed courses of treatment (NHS England Primary Care Commissioning, 2013), though they were able to claim an interim payment of approximately 20% of the total payment at the start of each patient’s treatment (NHS England Primary Care Commissioning, 2013). Under the new contracts, the annual payment due to providers is paid in monthly instalments, one month in arrears (NHS England Primary Care Commissioning, 2013). It is expected that, as courses of treatment are completed, providers will take on new patients in accordance with his/her annual contract value (NHS England Primary Care Commissioning, 2013).

As mentioned above, providers must provide a certain quantity of courses of treatment, as agreed on by the NHS and the provider (Department of Health, 2007). In the orthodontic service, the quantity of services that a provider is contracted to deliver is expressed on the basis of a target number of Units of Orthodontic Activity (UOAs). As shown in Table 2.2, orthodontic assessments are awarded one UOA and courses of orthodontic treatment (each with one inclusive assessment) are weighted according to the age of the patient at the date treatment starts. Interceptive treatment for those aged under 10 is awarded 4 UOAs, a comprehensive course of treatment for a 10- to 17-year-old is awarded 21 UOAs, and a comprehensive course of treatment for an adult is awarded 23 UOAs.

Those aged 17 or under are not required to pay a co-payment for courses of NHS dental treatment. As most orthodontic patients are aged 17 or under, most patients are not required to pay a patient charge for orthodontic treatment (except in cases where they require a replacement orthodontic appliance when their original appliance is lost or broken (Department of Health, 2005)). In contrast, some of the small number of adults who have NHS orthodontic treatment are required to pay a patient charge towards the cost of their treatment, though many are wholly or partially exempt from paying patient charges (e.g., if they are nursing mothers or they are aged 18 and in full-time education) (Drakeford, 2015). The patient charges for adults are linked to the number of UOAs awarded for each type of clinical orthodontic work, as shown in Table 2.2.
Table 2.2: UOAs awarded for clinical orthodontic work, and corresponding patient charges

<table>
<thead>
<tr>
<th>Clinical orthodontic work</th>
<th>UOAs awarded</th>
<th>Patient charge in England as of 2013 (GBP)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Assessment only</td>
<td>1 UOA</td>
<td>18</td>
</tr>
<tr>
<td>‘Assessment &amp; review’ appointment (if NHS orthodontic treatment is indicated, but the patient is not ready to start)</td>
<td>1 UOA</td>
<td></td>
</tr>
<tr>
<td>‘Assessment &amp; refuse’ appointment (if NHS orthodontic treatment is deemed unnecessary or inappropriate)</td>
<td>1 UOA</td>
<td></td>
</tr>
<tr>
<td>Course of treatment (UOAs are awarded even if cases are not completed)</td>
<td>4 UOA</td>
<td>214</td>
</tr>
<tr>
<td>Assessment &amp; treatment for a patient under 10</td>
<td>21 UOA</td>
<td></td>
</tr>
<tr>
<td>Assessment &amp; treatment for a patient aged 10 to 17</td>
<td>23 UOA</td>
<td></td>
</tr>
<tr>
<td>Assessment &amp; treatment for a patient aged over 17</td>
<td>0 UOA</td>
<td>49</td>
</tr>
<tr>
<td>Repairs and replacements of orthodontic appliances</td>
<td>0.8 UOA</td>
<td></td>
</tr>
<tr>
<td>Repairs to an orthodontic appliance fitted by another dentist</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Replacement orthodontic appliances under regulation 11 of the Dental Charges Regulations (this applies when the replacement of an appliance is necessitated by an act or omission of the patient (or parent/guardian if the patient is under 16) which cause loss of the appliance or damage beyond repair)</td>
<td></td>
<td>64.20, for each appliance (upper and lower)</td>
</tr>
</tbody>
</table>

GBP: Great Britain Pound; NHS: National Health Service; UOA: Unit of Orthodontic Activity

Source: Bennett and Health, Wellbeing and Local Government Committee, 2010

Although the value of a UOA varies between contracts, the mean value of a UOA in England from 2008-2012 was approximately £61, as shown in Table 2.3, based on contracts that only included the provision of orthodontic services (Wise, 2015).

Table 2.3: Mean value of a UOA in England

<table>
<thead>
<tr>
<th>Year of contract</th>
<th>Mean UOA value (GBP)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2008-2009</td>
<td>60.23</td>
</tr>
<tr>
<td>2009-2010</td>
<td>61.11</td>
</tr>
<tr>
<td>2010-2011</td>
<td>61.79</td>
</tr>
<tr>
<td>2011-2012</td>
<td>60.94</td>
</tr>
<tr>
<td>2008-2012</td>
<td>61.00</td>
</tr>
</tbody>
</table>

GBP: Great Britain Pound; UOA: Unit of Orthodontic Activity

Data source: Wise, 2015
2.4.8 *Measures of treatment outcomes used in the NHS orthodontic service*

The National Health Service Business Services Authority (NHSBSA) collects data submitted by NHS primary care orthodontic providers via NHS orthodontic activity forms (NHSBSA, 2013a), of which there are two main types:

- **Claims forms**, which are used to make claims for UOAs when clinical work (such as an assessment or a course of treatment) is started, in order for the NHSBSA to produce the providers’ monthly and annual financial statements
- **Notification forms**, which are used to notify the NHSBSA when a course of treatment has finished

The NHSBSA collects data on two aspects of orthodontic treatment outcomes:

- **Treatment discontinuation**, which can be instigated by either the orthodontic clinician (e.g., because of the risk to the patient’s oral health when compliance with oral hygiene instructions is low) or the patient (e.g., if a patient requests that treatment be abandoned or fails to return). Not all treatment discontinuations represent treatment failures, as there can be improvements in IOTN scores even if treatments are discontinued. Treatment discontinuation can be due to poor case selection for treatment (related to lack of motivation to complete a full course of treatment or to comply with oral hygiene instructions) or a strict policy on discontinuing treatment for patients who miss appointments (Welsh Assembly Government Dental Division, 2013).
- **IOTN outcome scores**, which can be used to determine whether or not a patient has RPTN, using the IOTN eligibility threshold of 3.6 as the threshold to assess whether normative need for treatment remains at the end of active treatment.

The NHS orthodontic contracts require providers to submit NHS activity notification forms within two months of the removal of fixed appliances or, for cases where fixed appliances are not used, after the patient has been discharged. For cases where treatment is discontinued due to a patient failing to return, the contracts stipulate that the NHS activity notification forms should be submitted as soon as it has been established that the patient does not wish to return to complete his/her treatment. Forms submitted after 62 days are considered to be late submissions.

In addition to recording information on treatment discontinuations and IOTN outcome scores, there is a contractual requirement for orthodontic clinicians to monitor treatment outcomes for 20 patients plus 10% of the remainder of their patients using the Peer Assessment Rating (PAR) index (Richmond et al., 1992). However, data on these PAR improvement scores are not collected on the NHS activity notification forms (NHSBSA, 2013a).
The PAR index requires the differences between pre-treatment and post-treatment models of a patient’s occlusion to be calculated after taking several measurements with a PAR ruler (Richmond et al., 1992). It was designed as an objective, fast, and simple method of assessing treatment outcomes for a large group of patients, rather than an individual patient, as it does not adequately represent the results obtained by some patients (British Orthodontic Society, 2015). A mean PAR improvement score of > 70% represents a very high standard of treatment, < 50% represents a poor standard, and < 30% represents lack of improvement of the group’s malocclusions (Public Health England, 2015a).

Finally, the NHSBSA also carry out independent monitoring of five patients of 450 of orthodontic clinicians per year. This involves requesting full patient records including photographs, radiographs, and pre- and post-treatment models of the patients’ occlusions (NHSBSA, 2013b). This monitoring process often leads to the flagging up of issues for discussion with the orthodontic clinician (which are then resolved without further scrutiny) but very rarely leads to further investigation being conducted (NHSBSA, 2013b).

### 2.4.9 Cost of the NHS orthodontic service

The total budget for NHS England for 2015-2016 is approximately £115 billion (NHS Choices, 2015a). However, the NHS is currently under a great deal of pressure to contain costs due to the large growth of budget deficits among NHS hospital trusts (Johnstone, 2015). Of the NHS England budget, approximately £3.4 billion is spent on dentistry (NHS England, 2014). However, the budget for NHS dentistry is under strain due to the high levels of demand for complex procedures (such as root canals and crowns) by those over 40 who have had high levels of dental disease and treatment, and who now require high cost maintenance treatment in order to avoid having to have their teeth extracted (Steele, 2009). These costs pressures increase the risk of dentists moving out of the NHS to the private sector and they have caused the NHS principles of universality and comprehensiveness to be put under strain (Steele, 2009).

NHS primary care orthodontic services make up around a tenth of the budget for NHS primary care dentistry in England (Chestnutt et al., 2006). The cost of NHS primary care orthodontic services was reported to have almost doubled in the decade after 1992, which was linked to a general rise in the expectations of people regarding their dental appearance (de Oliveira, 2003). This trend in demand for orthodontic treatment is predicted to continue due to the increasing public awareness of the benefits of orthodontic treatment and the increased social acceptance of fixed orthodontic appliances (Jawad et al., 2015).
2.4.10 Summary

The previous section provided the broad context for the research presented in this thesis by describing various aspects of the NHS orthodontic service. The following section provides an overview of the evidence base related to each of the research questions, along with an outline of where the evidence gaps are and the conceptual frameworks associated with each research question.

2.5 Analysis-specific literature review

2.5.1 Need and willingness to have treatment

2.5.1.1 Normative need

Evidence from previous literature and evidence gaps

Many studies on normative need for orthodontic treatment have limitations because, in order to be accurate, they have to be conducted using a cohort of children who are at the appropriate age for their permanent teeth to have come through but have (largely) not yet received orthodontic treatment.

However, the 2003 Children’s Dental Health Survey (CDHS) (Chestnutt et al., 2004) and 2013 CDHS (Tsakos et al., 2015) both conducted surveys of 12-year-olds in the UK, who are at an optimum age to be surveyed for normative need for orthodontic treatment. The 2003 report stated that 35% of 12-year-olds in the UK had ‘definite’ normative need (where ‘definite’ normative need is defined as an IOTN DHC score of 4-5 and/or an IOTN AC score of 8-10) (Chestnutt et al., 2004). The 2013 report stated that 37% of 12-year-olds in the UK had ‘definite’ normative need (Tsakos et al., 2015). However, it should be noted that some of the 12-year-olds with ‘definite’ normative need may have received treatment in the past, as RPTN can remain at the end of treatment, and malocclusion can subsequently worsen in the years after treatment has finished (Clinical Standards Committee of the British Orthodontic Society, 2010).

Normative need is generally believed not to vary by SEP (Chestnutt et al., 2004; Tsakos et al., 2015). The 2003 CDHS found no statistically significant difference in ‘definite’ normative need between 12-year-olds from deprived schools (defined as such if more than 30% of the pupils were eligible for free school meals) and the remainder of schools (Chestnutt et al., 2004). The 2013 CDHS found no statistically significant difference in
'definite’ normative need between 12-year-olds who were eligible for free school meals and those who were ineligible (Tsakos et al., 2015). However, there is a gap in the literature concerning whether IOTN categories (i.e., IOTN DHC score of 5, representing very great need; IOTN DHC score of 4, representing great need; and IOTN DHC score of 3 with an IOTN AC score of 6-10, representing moderate need) vary by SEP.

Besides the 2008-2009 NHS Dental Epidemiology Programme for England Oral Health Survey (OHS) data set of 12-year-olds (Dental Observatory and North West Public Health Observatory, 2009) used in this thesis, multiple other surveys of the NHS Dental Epidemiology Programme for England has collected data on dental health, but they did not include data on orthodontic treatment need because, for example, some focussed on children attending special support schools (Public Health England, 2013) while others focused on 3-year-olds (Dental Observatory and North West Public Health Observatory, 2012) and 5-year-olds (Dental Observatory and North West Public Health Observatory, 2011, 2007; Public Health England, 2014a), who would not have reached the appropriate dental stage to assess normative need.

Conceptual framework

The risk factors for malocclusion are poorly understood, with conflicting theories about the causes of malocclusion, and further uncertainty about whether the potential risk factors vary by SEP.

Thumb sucking, use of dummies after the age of 3 years old, prolonged use of a bottle, and severe injury have been put forward as causes (Medline Plus, 2013). In addition, it has been proposed that lack of masticatory stress affects jaw development (Ingervall and Bitsanis, 1987; Lieberman et al., 2004). This theory posits that the decreased bite forces required to chew the foods in our modern post-industrial diet (i.e., processed foods rather than diets associated with pre-agricultural evolution) may cause the jaw to develop differently in modern post-industrial populations compared to those living in the pre-agricultural era (von Cramon-Taubadel, 2011). According to this model, although malocclusion has a hereditary contribution (Mossey, 1999), genetic factors are probabilistic rather than deterministic. This implies that an individual’s genetics do not work in a vacuum, and that environment and lifestyle pose a large role in the development of the condition (as Dr Francis Collins of the US National Institutes of Health has said, ‘All illnesses have some hereditary contribution. Genetics loads the gun and environment pulls the trigger’).

The prevalence of each of the underlying risk factors (including genetic risk factors (Mossey, 1999)) for the different types and severities of malocclusions does not necessarily follow a simple trend across SEP groups. Given this, the trends in the differences in severity of malocclusion (i.e., IOTN DHC score of 5, IOTN DHC score
of 4, and IOTN DHC score of 3 with an IOTN AC score of 6-10) between SEP groups are expected to be complex.

2.5.1.2 Patient-defined need and willingness to have treatment

Evidence from previous literature and evidence gaps

Patient-defined need is often measured using self-assessed IOTN AC scores. For example, a recent study of 389 10- to 11-year-olds in England found that 14% had self-perceived aesthetic need, defined as self-assessed IOTN AC scores of 5-10 (Hamdan et al., 2012). In addition, the 2003 CDHS asked the parents of children who were not in treatment, ‘At the moment, do you think your child’s teeth are alright as they are or would you prefer him/her to have them straightened?’, with the options ‘Alright’ or ‘Prefer them straightened’ (Chestnutt et al., 2004). (90.0% of the replies were given by parents alone, 8.4% were given by both parents and children, and 0.7% were given by children alone, i.e., the parents passed the questionnaire that was sent to them on to their children (Chestnutt et al., 2004)). 12% and 10% of respondents preferred the children’s teeth to be straightened, for 12-year-olds and 15-year-olds who had no ‘definite’ normative need, respectively (Chestnutt et al., 2004). 58% and 80% of respondents thought the children’s teeth were ‘alright’, for 12-year-olds and 15-year-olds who had ‘definite’ normative need, respectively (Chestnutt et al., 2004).

Different SEP associations may exist for the percentages of those with a) overall patient-defined need, b) patient-defined need among those with no normative need, and c) no patient-defined need among those with normative need. In terms of overall patient-defined need, there have been conflicting reports on children in different countries:

- A UK study of 5,918 14-year-olds indicated that patient-defined need (based on answers to the question ‘Do you think your teeth need straightening?’) varies by SEP (measured using the Super Profiles geodemographic classification system, an area-level measure of SEP that uses small area typology), with those in the more deprived groups being more likely to think that their teeth need straightening (Tickle et al., 1999). Many of these children did not have normative need, and those who had patient-defined need among those without normative need were more likely to be from more deprived groups, suggesting that their perceptions of need were based on something other than their own level of malocclusion (Tickle et al., 1999).

- A US study of 1,566 8- to 11-year-olds recently reported that patient-defined need (based on answers to multiple questions about each child’s occlusion) does not vary by SEP (Christopherson et al., 2009).
However, the study estimated SEP in each of the 29 schools included in the study using the percentages of pupils who received free school meals, which is more likely than area-level measures (that use small area typology) to misclassify children, and may lead to an underestimation of any effect (Christopherson et al., 2009).

- An Italian study of 2,284 6- to 16-year-olds and an Italian study of 101 8- to 9-year-olds both found that patient-defined need (as assessed using the Child Orthodontic Attitude Survey questionnaire) did not vary by SEP (based on characteristics of parental employment) (Deli et al., 2012, 2009).

There is little published on the association between SEP and the levels of willingness to have treatment in the at-risk population.

**Conceptual framework**

The association between SEP and both patient-defined need and willingness to have treatment may be influenced by numerous factors, for example:

- Occlusal traits that are classified as evidence of normative need (by the IOTN DHC) due to dental health risk (e.g., deep traumatic overbite, severe posterior crossbite, or impacted teeth) do not necessarily have aesthetic implications (Chestnutt et al., 2004), so some children may not be aware of the full benefits of treatment, and this may vary between SEP groups.
- Poor self-esteem is more likely in those from more deprived groups compared to those from less deprived groups (Twenge and Campbell, 2002), which may lead to differences in the acceptance of malocclusion between SEP groups because poor dental aesthetics are likely to be more detrimental to someone with low self-esteem than someone with high self-esteem (Benson et al., 2015).
- Willingness to have treatment can be influenced by the familiarity with orthodontic appliances among a child’s peer group (Burden, 1995).

**2.5.2 Treatment utilisation**

**Evidence from previous literature and evidence gaps**

The 2003 CDHS report stated that 13% of 12-year-olds and 32% of 15-year-olds reported having current or past use of orthodontic appliances (Chestnutt et al., 2004). The report concluded that, given that ‘21% of 15-year-olds are still regarded as in need of treatment, [this] suggests that overall about 50% of the treatment need …is being
met’ by age 15 (Chestnutt et al., 2004). The 2013 CDHS report did not give details about the percentages of children with either current or past use of orthodontic appliances; however, 20% of 15-year-olds were reported to have unmet need (Tsakos et al., 2015), a similar percentage to that in the 2003 report (Chestnutt et al., 2004).

Before the 2006 dental reforms, levels of orthodontic provision have varied significantly across the UK based on practitioners’ past decisions as to where to set up practice (NHS England Primary Care Commissioning, 2013). Several UK studies that took place before the 2006 dental reforms reported conflicting results regarding the association between SEP and utilisation of orthodontic treatment:

- A study in Manchester reported a lack of an association between SEP and utilisation (Mandall et al., 2005). This study involved surveying 525 school children at age 11 to 12 years old, and again three years later (Mandall et al., 2005). SEP was measured using area-level Townsend scores and utilisation was determined by answers to a question on whether each child had utilised orthodontic treatment or were on a waiting list for orthodontic treatment (Mandall et al., 2005). Although the study showed no association between SEP and utilisation, the analysis involved a regression model that included additional explanatory variables (such as the dentist to population ratio in the local area, whether or not each child was teased about their teeth, and the IOTN AC score as perceived by each child) which may have been associated with the SEP variable, and may have masked the associations between SEP and utilisation.

- In contrast, multiple studies in England have reported an association between deprivation and lower utilisation of orthodontic treatment (Drugan et al., 2007; Mandall et al., 2000; Morris and Landes, 2006):
  - The first study involved 334 14- to 15-year-olds from schools in Manchester (Mandall et al., 2000). SEP was measured using area-level Townsend scores and utilisation was determined from answers to a question about whether or not each child had received orthodontic treatment (Mandall et al., 2000). The study found that those from more deprived groups were less likely to have utilised orthodontic treatment (Mandall et al., 2000). However, given that those from more deprived groups tend to utilise orthodontic treatments later in adolescence compared to those from less deprived groups (according to the NHS activity data used in this thesis), this does not clarify whether utilisation differs by SEP by the time the children reach adulthood.
  - The second study used 2002-2004 Dental Practice Board data from Durham and Tees Valley (Morris and Landes, 2006). SEP was measured in terms of the area-level IMD scores (associated with the wards of each orthodontic practice), and utilisation was determined by the NHS orthodontic treatment claim rates per 1,000 of the at-risk population for each ward (Morris and Landes, 2006). More deprived wards were associated with lower utilisation rates (Morris and
Landes, 2006), though many of the children would not necessarily live in the same ward as the practice they visited.

- The third study used 2001-2002 Dental Practice Board data from Avon (Drugan et al., 2007). SEP was measured in terms of quintiles of the area-level Income Deprivation Affecting Children Index (associated with the LSOA of each child) and utilisation was determined by the NHS orthodontic treatment claims per 1,000 of the at-risk population for each LSOA (Drugan et al., 2007). More deprived LSOAs were associated with lower utilisation rates (Drugan et al., 2007).

- In addition, the 2003 CDHS report stated that both 12-year-olds from ‘deprived’ schools (i.e., schools where over 30% of pupils were eligible for free school meals) and those from ‘non-deprived’ schools had the same level of current use of orthodontic treatment at the time of the dental examinations, but among 15-year-olds, children from ‘deprived’ schools had lower levels of current use (however, these analyses did not take into account past use along with current use) (Chestnutt et al., 2006). A limitation of the analyses is that many of the students in ‘deprived’ schools may not have been in deprived groups according to area-level or household measures of SEP, and many of those that attended the ‘non-deprived’ schools may have been in deprived groups.

- In contrast, the 2013 CDHS found that the current use of orthodontic treatment at the time of the dental examinations was higher for 12-year-olds who were eligible for schools meals than those who were ineligible, but not for 15-year-olds, which suggests that those from less deprived groups may start treatment earlier than those from less deprived groups (Tsakos et al., 2015).

Due to the introduction of the new NHS dental contracts in 2006, along with the introduction of the IOTN eligibility threshold (which has enabled the NHS orthodontic service to be targeted at those with normative need for treatment), any pre-2006 association between SEP and utilisation may have been reduced.

*Conceptual framework*

Despite the even distribution of normative need for orthodontic treatment between SEP groups in the UK (Chestnutt et al., 2004; Tsakos et al., 2015) and the implementation of the IOTN in 2006, SEP may influence access to the NHS orthodontic service in numerous ways:

- Barriers due to lack of availability
  - Lack of NHS orthodontic clinicians in some areas of the country has led to long waiting lists (Health, Wellbeing and Local Government Committee, 2011). A 2003-2004 workforce survey reported that the Gini coefficient for full-time equivalent orthodontic clinicians was 0.098,
indicating that 9.8% of orthodontic clinicians would need to be relocated for an equitable distribution (Robinson et al., 2005). For specialist orthodontists, the Gini coefficient was higher, at 0.166 (Robinson et al., 2005), and a 2006-2007 survey of these specialist orthodontists found that approximately a third were working in the same region as their undergraduate or postgraduate university (Collins et al., 2008). In addition, in areas where there were fewer specialist orthodontists present, less time was spent treating patients with IOTN DHC scores of 4 and 5 rather than cases with lower scores (i.e., the limited number of specialist orthodontists did not focus their time on patients with the greatest need) (Robinson et al., 2005).

- Barriers due to lack of affordability
  - Lack of public transport or lack of affordability can prevent some people from deprived groups from accessing long-term treatment such as orthodontic treatment (Gosney, 1985).
  - Time constraints can prevent some parents (particularly those in single-parent families) from accompanying their children to orthodontic appointments, as they may lose pay while taking time off work (Gosney, 1985). Parents from less deprived groups are more likely to have flexible working hours, or to be able to afford losing pay.

- Barriers due to lack of acceptability
  - Children from more deprived groups may have a lack of access to information about what orthodontic treatment is for and how treatment works, which can lead to differences in patient-defined need and willingness to have treatment.
  - Differences in health beliefs such as considering the short-term disadvantages of wearing appliances to be greater than the long-term benefits of treatment may reduce willingness to have treatment for those from more deprived groups. Studies on health behaviours have frequently reported that deprivation is associated with lower health consciousness, stronger beliefs in the influence of chance on health, and less thinking about the future, which can lead to more risky behavioural choices (Wardle and Steptoe, 2003).
  - On the other hand, differences in health beliefs such as the importance placed dental aesthetics could also play a role in patient-defined need and willingness to have treatment. This is especially important when considering patient-defined need among those who have no normative need. A Swedish study on the importance of dental appearance to adults reported that low education was associated with high importance place on dental appearance (Söderfeldt et al., 1993). In addition, poor self-esteem (which is associated with deprivation (Twenge and Campbell, 2002)) has been reported to lead to a greater importance placed on dental aesthetics (Benson et al., 2015).
Those in more deprived groups have lower attendance of general dental check-ups, which could reduce the likelihood of them being referred for orthodontic treatment (Breistein and Burden, 1998). The report from the 2003 CDHS stated that, among 12-year-olds, a larger percentage of children from families with managerial and professional backgrounds visited GDPs regularly (70%) compared to children from families with routine and manual backgrounds (64%) (Morris et al., 2004). In addition, deprivation is associated with higher rates of untreated caries and poor oral hygiene (Holmes et al., 2015; Locker, 2000), and this can preclude children from being referred for orthodontic treatment.

Lastly, parents in more deprived groups may be less able to advocate for their children to be referred to specialist services, or may be less likely to request early referrals. (Studies on various other health conditions have previously shown that deprivation is associated with later diagnoses (Barnabe et al., 2014; Fountain et al., 2011; Lyratzopoulos et al., 2013)).

### 2.5.3 Assessment procedures

*Evidence from previous literature and evidence gaps*

There are evidence gaps regarding the frequency of use of various assessment procedures (i.e., the use of one or more ‘assessment & review’ appointments per patient, the use of two or more ‘assessment & review’ appointments per patient, early access at ages 9-10, and the use of an ‘assessment & refuse’ appointment for those with IOTN scores of ≥ 3.6) and their associations with SEP.

However, in Wales, there are a large number of assessments being undertaken in comparison to treatments (Health, Wellbeing and Local Government Committee, 2010) and it is likely that a significant percentage of patients who are being assessed do not need to be (Health, Wellbeing and Local Government Committee, 2011). More recently, a report on Manchester’s centralised referral validation and triage system showed that there was a large percentage of rejected referrals in 2012-2013, i.e., 17.4% (McGrady and Bridgman, 2013). This report was comprehensive in that it looked at all the referrals to the centralised referral validation and triage system, but the report did not look at what happened to the patients who were referred on for treatment, i.e., whether the centralised referral validation and triage system was able to reduce the overall numbers of orthodontic assessments, and whether the cost of these reductions outweighed the cost of the centralised system.

Early referral by GDPs can lead to the use of ‘assessment & review’ appointments by orthodontic clinicians because the patients are initially not at the optimum stage of dental development to begin treatment (Welsh
Assembly Government Dental Division, 2013). A 2006 survey examining the orthodontic referral behaviour of GDPs in West Sussex reported that only 20% of the GDPs surveyed made appropriate decisions on the timing of referral (according to a review of the literature and the findings of focus groups with consultant specialist orthodontists), for three cases involving different types of malocclusion (Jackson et al., 2009). In addition, there has been an increase in the number of early referrals in the NHS in order to circumvent the long waiting times caused by the high levels of demand for treatment, and patients have been referred multiple times to different orthodontic practices (NHS Milton Keynes & Northamptonshire Dental Team, 2013), which further compounds the issue of long waiting lists (Health, Wellbeing and Local Government Committee, 2011).

Conceptual framework

SEP may be associated with assessment procedures as follows:

- The use of one or more ‘assessment & review’ appointments per treated patient is more likely if the referring GDP refers a patient prematurely, before his/her dentition has developed to the optimum stage to begin treatment. Those from less deprived groups may be more likely to enter the referral system prematurely as a result of higher levels of attendance for dental check-ups at earlier ages, and requests from the parents of patients for early referral (Welsh Assembly Government Dental Division, 2013). This is likely, as higher SEP is associated with earlier diagnoses of many other health conditions (Barnabe et al., 2014; Fountain et al., 2011; Lyratzopoulos et al., 2013).

- The use of two or more ‘assessment & review’ appointments per treated patient is more likely if the orthodontic clinician arranges a re-assessment too early. This would not necessarily be related to SEP unless patients from less deprived groups were more likely to enter the referral system prematurely, which would then create the conditions to make additional assessments more likely.

- Early access (i.e., early first assessment) at ages 9-10 among those who were assessed can lead to the use of ‘assessment & review’ appointments as many appointments attended at ages 9-10 are premature.

- The use of an ‘assessment & refuse’ appointment among those who have IOTN scores of ≥ 3.6 and who were refused or received treatment can be caused by lack of willingness to have treatment and/or poor oral hygiene, which are more likely for those from more deprived groups (Holmes et al., 2015; Locker, 2000),
2.5.4 Treatment outcomes

Evidence from previous literature and evidence gaps

A number of recent studies have highlighted the potential for treatment failure in the NHS orthodontic service (Fox et al., 2002; Joury et al., 2011; Radnzic, 2002). One study compared the differences in the treatment failure rates as measured by the IOTN, the PAR index, and the ICON for the patients who were treated in hospitals in the North of England (Fox et al., 2002). The study involved 130 patients and found that different occlusal indices indicated differing levels of treatment failure (e.g., 20.1% of patients had RPTN according to their IOTN DHC scores and 17.2% had RPTN according to their ICON scores) (Fox et al., 2002). This study has limitations in that it involved hospital patients, so the sample may represent a more complex case mix than those treated in primary care practices, and the skills and training of the orthodontic clinicians involved would differ from those of primary care orthodontic clinicians.

Studies have also been undertaken to investigate the levels of treatment discontinuations in the NHS orthodontic service (Fox et al., 2002; Mandall et al., 2008; Turbill et al., 2003). One of these studies was a study in England of 144 patients who were at several hospitals and a primary care practice (Mandall et al., 2008). This study reported that 43% of patients failed to complete their treatment (the most common reasons being poor oral hygiene, multiple failed appointments, and orthodontic appliance breakages) (Mandall et al., 2008). This study has limitations in that most of the patients were hospital patients, and the three orthodontic clinicians involved were aware that the discontinuation rates would be published after the study had finished, which may have affected how they provided treatment (i.e., the discontinuation rate may have been higher if the orthodontic clinicians were not observed under study conditions; this is known as the Hawthorne effect or the observer effect, which is a type of reactivity in which individuals modify an aspect of their behaviour in response to their awareness of being observed.)

There are many studies that report that there is an association between deprivation and poor treatment outcomes for adolescents, for a range of conditions including cancer, asthma and cystic fibrosis (Halfon and Newacheck, 1993; McWhirter et al., 1983; Schechter et al., 2001). In addition, several UK studies have reported on the association between SEP and orthodontic treatment outcomes:

- A study in England and Wales used data on 1,431 patients from a 1990-1991 Dental Practice Board data set that covered all patients who discontinued treatment and 2% of those who had completed treatment (Turbill et al., 2003). The study used several area-level measures of SEP: Townsend, Carstairs, and Jarman index scores, and the percentages of ‘heads of household’ who worked in manual jobs in the area (based on
both the patients’ and the practices’ addresses) (Turbill et al., 2003). The study found a greater percentage of those from more deprived groups discontinued their treatments (Turbill et al., 2003).

- A study in England used data on 135 12- to 16-year-olds treated for one year with fixed orthodontic appliances in the hospital dental service (Joury et al., 2011). The study reported that those from more deprived groups (determined by a household-level measure based on characteristics of parental employment) were less likely to have high improvement in occlusion (defined as a score equal to or higher than the sample median ICON improvement score of a modified version of the ICON) compared to those from less deprived groups (Joury et al., 2011). Other elements of SEP, namely, parental education and employment status were not shown to be associated with treatment outcomes, which the authors hypothesised may be related to the lack of conceptual clarity concerning which aspects of SEP these elements measure (Joury et al., 2011).

- In contrast, a study in the North West of England of 144 9- to 19-year-olds reported that SEP (measured using Townsend scores) was not associated with treatment discontinuations (Mandall et al., 2008). However, in comparison to the study on Dental Practice Board data (Turbill et al., 2003), this study largely involved patients treated by consultant specialist orthodontists, who may have had a different treatment experience compared to those treated in primary care. For example, all the patients who received treatment with removable orthodontic appliances also had a subsequent phase of treatment with a fixed appliance, which would not automatically happen in primary care settings, and the percentage of patients who discontinued treatment was very high (Mandall et al., 2008).

**Conceptual framework**

SEP may be associated with treatment outcomes for several reasons. Firstly, treatment discontinuation may be more likely for those from more deprived groups because of prohibitive transport costs and the impact of lost pay for the accompanying parents (Gosney, 1985).

In addition, aspects of a child’s SEP can have an effect on the child’s development of self-efficacy (Boardman and Robert, 2000). Self-efficacy is the strength of one’s belief in one’s own ability to complete tasks and reach goals (Ormrod, 2006). Self-efficacy is known to influence health behaviours (Luszczynska and Schwarzer, 2005) such as patient compliance with treatment instructions, which has been shown to predict orthodontic treatment outcomes (Fox et al., 1997; Joury et al., 2013; Sergl et al., 1998; Taylor et al., 1996).

Patient compliance with treatment instructions encompasses elements such as wearing orthodontic appliances during the active treatment phase and then wearing retainers once active treatment has finished, and regularly
replacing intraoral elastic bands that move the teeth. Indicators of poor compliance (which are sometimes considered to be elements of lack of patient compliance) include appliance breakages (e.g., due to eating hard or sticky foods), lack of appliance maintenance (e.g., failing to clean headgear tubes), poor oral hygiene, periodontal disease, missing appointments, and lack of punctuality for appointments. Known predictors of patient compliance include the patient’s expectations regarding orthodontic treatment (Bos et al., 2005) and the patient’s response to any initial pain experienced (Sergl et al., 1998). Deprivation is known to be associated with some of these elements of patient compliance, such as poor oral health practices (Maes et al., 2006) and poor attendance of orthodontic appointments (Can et al., 2003).

### 2.5.5 Differences between practices/orthodontic clinicians

**Evidence from previous literature and evidence gaps**

There are no data from the literature on the differences in assessment procedures between practices/orthodontic clinicians. However, several studies have investigated differences between orthodontic clinicians regarding treatment outcomes. Firstly, a study in England and Wales was conducted on orthodontic treatment outcomes for 1210 patients, and it found that patients treated by specialist orthodontists had greater improvements in occlusion compared to non-specialists, but when the treatment outcomes were analysed according to the type of appliance used, there were no differences in outcomes of treatment undertaken by specialist orthodontists and non-specialists (Richmond et al., 1993). However, this study was undertaken in the 1990s, when different techniques and technologies were used, and a very high percentage of patients finished treatment with no improvement in their malocclusion (Richmond et al., 1993). A US study of 196 patients that also found that, on average, specialist orthodontists had better treatment outcomes than non-specialists, though this study was also conducted using records from treatment that occurred in the 1990s (Abei et al., 2004). A more recent study in Brazil of 60 patients also found that specialist orthodontists had considerably better outcomes than non-specialists (Marques et al., 2011).

**Conceptual framework**

There are likely to be differences between orthodontic clinicians in the use of two or more ‘assessment and review’ appointments per patient and treatment outcomes (i.e., treatment discontinuations and RPTN). This may be due to numerous factors, including differences between orthodontic clinicians in their length of training and amount of experience, e.g., specialist orthodontists have more training, which enables them to treat a wider range of malocclusions compared to non-specialists (Hodge and Parkin, 2015). The more extensive training and
experience of specialist orthodontists may decrease the use of two or more ‘assessment and review’ appointments per patient because the optimum time to begin treatment may be gauged more accurately. In addition, the more extensive training and experience may decrease treatment discontinuations and RPTN because specialist orthodontists may be more knowledgeable about engaging the patient in their treatment in order to increase patient compliance (Sinha et al., 1996). Several authors have highlighted that the relationship between the clinician and the patient is the most important factor in patient compliance (Nanda and Kierl, 1992; Nurminen et al., 1999; Sinha et al., 1996), and several authors cite the benefits of clear communication of instructions and provision of positive feedback to patients (Bartsch et al., 1993; Bos et al., 2005; Mehra et al., 1998; Nanda and Kierl, 1992; Nurminen et al., 1999; Sinha et al., 1996). Clinician skill may be able to moderate any association between SEP and treatment outcomes, as clinicians with good communication skills may have more influence on patients with potentially poor compliance.

Creation of non-need demand for services by orthodontic clinicians may also be an issue, as one UOA is still awarded for an assessment even if only oral hygiene advice is given (i.e., even if no photographs, radiographs, or models of the patient’s occlusion are taken) or if the time interval between ‘assessment & review’ appointments is short (Bennett and Health, Wellbeing and Local Government Committee, 2010). During the recent inquiry into the use of NHS orthodontic services in Wales, Public Health Wales raised concerns about the number of patients being ‘recycled’ by specialist orthodontists until they were at the optimum stage of dental development to begin treatment (Health, Wellbeing and Local Government Committee, 2011). This had occurred despite the existence of guidelines that recommend that patients should be referred back to their GDPs if they are considered to have been referred too early (Welsh Assembly Government Dental Division, 2013). In addition, the inquiry into orthodontics in Wales recommended that consideration should be given to whether orthodontic clinicians should be allowed to claim for a second assessment appointment within a short period of time unless it is clinically justified (Health, Wellbeing and Local Government Committee, 2011).

Moreover, there are no disincentives in the system of allocation of UOAs for having large assessment to treatment ratios, nor for treatments that end with discontinuation or RPTN.

### 2.5.6 Summary

It is widely accepted that normative need does not vary by SEP (Chestnutt et al., 2004; Tsakos et al., 2015). However, the evidence concerning the relationships between SEP and other orthodontic variables is conflicting. For example, there is some evidence suggesting that SEP is associated with patient-defined need, utilisation, and treatment outcomes (Chestnutt et al., 2006; Drugan et al., 2007; Joury et al., 2011; Mandall et al., 2000; Morris...
and Landes, 2006; Tickle et al., 1999; Turbill et al., 2003) while other studies suggest that there are no associations (Christopherson et al., 2009; Mandall et al., 2008, 2005; Tsakos et al., 2015). There is little evidence on the associations between SEP and factors such as need, utilisation, and treatment outcomes that is both current and relevant to orthodontic services in England (given that both dental contract reforms and the use of the IOTN were introduced in 2006), and no evidence concerning either the association between SEP and assessment procedures, or the associations between the types of NHS contracts and both assessment procedures and treatment outcomes.
3 METHODOLOGY

3.1 Overview

This chapter describes the data and methods used for the research presented in this thesis:

- Section 3.2 covers the research philosophy underpinning the thesis
- Section 3.3 provides details of the data sets
- Section 3.4 covers the methods, including descriptions of how the variables were created for the analyses, justifications for the descriptive and inferential statistical methods used, and details of the methods used for each of the analysis topics in turn
- Lastly, Section 3.5 includes a summary of the chapter

3.2 Research philosophy

The philosophy underpinning this research is positivism, which is based on the idea that scientific methods are the only way to obtain knowledge and involves viewing the world as objective and independent of subjective experiences (Research Observatory at the University of the West of England, 2015). It uses deductive reasoning (so that conclusions drawn from the research setting may be used to provide evidence to support or dispel hypotheses generated at the start of the research process) and empirical evidence (i.e., evidence acquired by means of observation or experimentation as opposed to evidence acquired by reason and reflection alone) (Research Observatory at the University of the West of England, 2015).

3.3 Data

3.3.1 Overview

The research questions were answered using quantitative research methods, i.e., statistical analysis of the data collected in cross-sectional population-based surveys and of routine, longitudinal NHS activity data. The following data sets were used:

- 2003 UK CDHS
• 2008-2009 North West data set of the NHS Dental Epidemiology Programme for England OHS
• 2008-2012 North West data set from NHS orthodontic activity forms
• 2009-2011 Health and Social Care Information Centre (HSCIC) data on a) the percentage of children attending dental check-ups, by PCT and b) the supply of orthodontic clinicians, by PCT

3.3.2 Descriptions of data sets

3.3.2.1 Children’s Dental Health Survey data set

The CDHS has been conducted by the Office for National Statistics every 10 years since 1973 (Bulman, 1975; Downer, 1995; Jackson, 1984; Pendry et al., 2004), and the data from the 2003 survey (Pendry et al., 2004) was the latest version available for this research.

The purpose of the CDHS is to establish the current state of oral health among children, and to make comparisons with previous surveys in order to monitor the change in oral health status between successive cohorts of children. The 1973 survey (Bulman, 1975) was conducted only in England and Wales, whereas the 1983, 1993 and 2003 surveys (Downer, 1995; Jackson, 1984; Pendry et al., 2004) were conducted in England, Wales, Scotland, and Northern Ireland.

The 2003 CDHS data were collected by random sampling, to ensure that the data were representative. Multistage clustered sampling was carried out to reduce the fieldwork associated with the dental examinations of the children: firstly, Local Authority Districts (LADs) were sampled in England, Unitary Authorities (UAs) were sampled in Wales, and Education Authorities (EAs) were sampled in Scotland. Secondly, schools were sampled within these areas and, lastly, children were sampled within the schools. Further details regarding the sampling techniques, including clustered sampling and stratified sampling, are shown in Section 3.4.7.4, as are details regarding weighting.

The survey collected data from dental examinations of 12-year-olds (2,595 examined) and 15-year-olds (2,142 examined). The data set includes data on a modified version of the IOTN DHC, which only records individuals as having either IOTN DHC scores of 1-3 or IOTN DHC scores of 4-5 (the IOTN AC scores were assessed as normal).

65% of schools consented and, within these, 83% and 68% of 12-year-olds and 15-year-olds, respectively, were examined (lack of examination was due to reasons such as the child being absent during the data collection, the child refusing to be examined, the parents of the child refusing for their child to be examined, and the child leaving the school).
Further data were obtained via postal questionnaires, including information on orthodontic treatment utilisation and household-level SEP data. NS-SEC data (Office for National Statistics, 2010) were used to represent SEP, using the 8-category classification system. The questionnaires were sent to the parents of half the examined children. 785 (60%) of the questionnaires of examined 12-year-olds were returned with NS-SEC data and 612 (57%) of the questionnaires of examined 15-year-olds were returned with NS-SEC data. (Although the 2003 CDHS data used in this analysis has been used in a previous publication (Chestnutt et al., 2004), the research presented in this thesis re-analyses the data using NS-SEC data to represent SEP, rather than the (binary) deprivation status of the children’s schools used in the previous publication.)

A summary of the data collected is shown in Table 3.1, and further details about the creation of new variables are shown in Table 3.4 and Table 3.5 in Section 3.4.

**Table 3.1: Information from the CDHS data set**

<table>
<thead>
<tr>
<th>Information</th>
<th>Type of variable(s) created</th>
</tr>
</thead>
<tbody>
<tr>
<td>Patient information</td>
<td>Anonymised data indexing the patients</td>
</tr>
<tr>
<td></td>
<td>Age (12 or 15 years old)</td>
</tr>
<tr>
<td></td>
<td>Gender</td>
</tr>
<tr>
<td></td>
<td>SEP</td>
</tr>
<tr>
<td>Information on need</td>
<td>Normative need:</td>
</tr>
<tr>
<td></td>
<td>IOTN DHC scores (either 1-3 or 4-5)</td>
</tr>
<tr>
<td></td>
<td>IOTN AC scores (1, 2, 3, 4, 5, 6, 7, 8, 9, or 10)</td>
</tr>
<tr>
<td></td>
<td>Wearing an appliance at the time of the dental examinations</td>
</tr>
<tr>
<td>Information on treatment utilisation</td>
<td>Current or previous utilisation:</td>
</tr>
<tr>
<td></td>
<td>Patient-reported NHS/private orthodontic treatment</td>
</tr>
<tr>
<td></td>
<td>Parent-reported NHS/private orthodontic treatment</td>
</tr>
<tr>
<td></td>
<td>Parent-reported private orthodontic treatment</td>
</tr>
</tbody>
</table>

AC: Aesthetic Component; CDHS: Children’s Dental Health Survey; DHC: Dental Health Component; IOTN: Index of Orthodontic Treatment Need; NHS: National Health Service; SEP: socioeconomic status

1 The data on orthodontic treatment used in this analysis did not differentiate between NHS and private orthodontic treatment. (The data were based on answers of ‘Yes’ to the question ‘Have you got an orthodontic brace or appliance?’, which encompasses both NHS and/or private orthodontic treatment).

2 The data on orthodontic treatment used in this analysis did not differentiate between NHS and private orthodontic treatment. (The data were based on the answer ‘A brace fitted or adjusted’ to the survey question ‘Has your child ever had any of the following treatments?’, which encompasses both NHS and/or private orthodontic treatment. The same answer – ‘A brace fitted or adjusted’ – to a secondary survey question asking ‘What treatment did your child have that you paid for?’ does not clarify whether the answer to the first question implies NHS treatment).

3.3.2.2 **NHS Dental Epidemiology Programme for England Oral Health Survey data set**

The OHS was conducted by the Dental Observatory and the North West Public Health Observatory, as part of the NHS Dental Epidemiology Programme for England (which is now known as the Dental Public Health Intelligence...
Programme). A key stakeholder in the programme is the British Association for the Study of Community Dentistry (BASCD), which is the UK’s professional association for preventing oral diseases and promoting oral health. BASCD’s work includes supporting members by providing training and developing an evidence base to facilitate their work, including monitoring oral health and oral healthcare utilisation.

The purpose of the NHS Dental Epidemiology Programme for England was to conduct nationally coordinated surveys of dental health to be used by PCTs (which were in place at the time the 2008-2009 survey was carried out, but have now been disbanded) when conducting local HNAs.

The 2008-2009 OHS was a one-off survey of 12-year-olds (Dental Observatory and North West Public Health Observatory, 2009). However, the NHS Dental Epidemiology Programme for England has carried out multiple surveys of 5-year-olds (in 2007-2008 (Dental Observatory and North West Public Health Observatory, 2007), 2011-2012 (Dental Observatory and North West Public Health Observatory, 2011) and 2014-2015 (Public Health England, 2014a)) in addition to surveys in 2013-2014 of 3-year-olds (Dental Observatory and North West Public Health Observatory, 2012), children attending special support schools (Public Health England, 2013), and elderly, dependent people (Public Health England, 2014b).

The OHS data were collected by random sampling, to ensure that the data were representative. Multistage clustered sampling was carried out: first schools were sampled and then children were then sampled within the schools. Further details regarding the sampling techniques, including clustered sampling and stratified sampling, are shown in Table 3.12 in Section 3.4.7.4, as are details regarding weighting.

The OHS data set is a much larger data set than the CDHS data set, with data from the dental examinations of 12-year-olds (19,908 examined) attending schools in the North West (no questionnaires were sent to the parents of the children)\(^6\). The OHS data set included data on the modified version of the IOTN DHC, as used in the CDHS.

Area-level SEP data, in the form of IMD quintiles (Department for Communities and Local Government, 2007), were matched in before the data were supplied. This involved matching LSOA-level IMD quintiles (with respect to the population of England) to each survey participants’ postcode.

A summary of the data collected is shown in Table 3.2, and further details about the creation of new variables are shown in Table 3.4 and Table 3.5 in Section 3.4.

\(^6\) 88% of schools consented and, within these, 74% of 12-year-olds were examined (lack of examination was due to the following reasons: 7.3% of 12-year-olds were activity withdrawn by their parents, 6.7% 12-year-olds declined to take part, and 11.8% of 12-year-olds were absent during the data collection period).
### Table 3.2: Information from the OHS data set

<table>
<thead>
<tr>
<th>Information</th>
<th>Type of variable(s) created</th>
</tr>
</thead>
<tbody>
<tr>
<td>Patient information</td>
<td>Anonymised data indexing the patients</td>
</tr>
<tr>
<td>Age (12 years old)</td>
<td>Categorical</td>
</tr>
<tr>
<td>SEP</td>
<td>Categorical</td>
</tr>
<tr>
<td>Information on need and willingness to have treatment</td>
<td>Normative need:           Categorical</td>
</tr>
<tr>
<td></td>
<td>- IOTN DHC scores (either 1-3 or 4-5)</td>
</tr>
<tr>
<td></td>
<td>- IOTN AC scores (1, 2, 3, 4, 5, 6, 7, 8, 9, or 10)</td>
</tr>
<tr>
<td></td>
<td>- Wearing an appliance at the time of the dental examinations</td>
</tr>
<tr>
<td>Patient-define need (based on answers of ‘Yes’, ‘No’, or ‘Don’t know’ in response to the question ‘Do you think your teeth need straightening?’, which was asked of those who were not in treatment at the time of the dental examinations)</td>
<td>Categorical</td>
</tr>
<tr>
<td>Willingness to have treatment (based on answers of ‘Yes’, ‘No’, or ‘Don’t know’ in response to the question ‘Would you be prepared to have treatment and wear a brace if it were necessary?’, which was asked of those not in treatment at the time of the dental examinations who also had patient-defined need)</td>
<td>Categorical</td>
</tr>
<tr>
<td>Information on treatment utilisation</td>
<td>Current patient-reported NHS/private orthodontic treatment utilisation</td>
</tr>
</tbody>
</table>

AC: Aesthetic Component; DHC: Dental Health Component; IOTN: Index of Orthodontic Treatment Need; NHS: National Health Service; OHS: Oral Health Survey; SEP: socioeconomic position

1The data on orthodontic treatment used in this analysis did not differentiate between NHS and private orthodontic treatment. (The data were based on children who were wearing an appliance at the time of the dental examinations, which encompasses both NHS and/or private orthodontic treatment).

### 3.3.2.3 NHS orthodontic activity data set

The 2008-2012 NHS activity data set was provided by the NHSBSA, which originally obtained the data from NHS orthodontic activity forms submitted by primary care orthodontic clinicians who were working under NHS contracts in the North West (NHSBSA, 2013a).

Area-level SEP data, in the form of LSOA-level IMD scores (Department for Communities and Local Government, 2011), were matched to the patients’ postcodes before the data were supplied. Subsequently, using IMD score cutpoints for IMD quintiles and deciles (with respect to the population of England), each patient was associated with an IMD quintile and decile. 6.4% of the patients in the data set had no IMD score and so did not have an IMD quintile or decile. The vast majority of these patients also had missing PCT data (because the patients’ postcodes were incorrectly recorded on the NHS activity forms and so could not be matched to PCT data by the NHSBSA), and the remainder had either Welsh or Scottish PCTs (and so could not be assigned an English IMD score).
This data set is comprehensive as it includes all NHS orthodontic activity that took place in the North West between 2008 and 2012. The data set includes data on the information shown in Table 3.3.

### Table 3.3: Information from the NHS orthodontic activity data set

<table>
<thead>
<tr>
<th>Information</th>
<th>Type of variable(s) created</th>
</tr>
</thead>
<tbody>
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<td></td>
</tr>
<tr>
<td>Age</td>
<td>Categorical</td>
</tr>
<tr>
<td>Gender</td>
<td>Categorical</td>
</tr>
<tr>
<td>PCT</td>
<td>Categorical</td>
</tr>
<tr>
<td>SEP</td>
<td>Categorical</td>
</tr>
<tr>
<td><strong>Information on assessments and treatment utilisation</strong></td>
<td></td>
</tr>
<tr>
<td>Type of activity, including whether the activity was:</td>
<td>Categorical</td>
</tr>
<tr>
<td>- An assessment only (and the result of the assessment: treatment refusal or re-assessment at a later date)</td>
<td></td>
</tr>
<tr>
<td>- A course of treatment (interceptive or comprehensive treatment)</td>
<td></td>
</tr>
<tr>
<td>Type (s) of orthodontic appliance used</td>
<td>Categorical</td>
</tr>
<tr>
<td>Dates of treatment acceptance, treatment finish, and receipt of each form</td>
<td>-</td>
</tr>
<tr>
<td><strong>Information on treatment outcomes</strong></td>
<td></td>
</tr>
<tr>
<td>IOTN score at each assessment and at the end of treatment</td>
<td>Categorical</td>
</tr>
<tr>
<td>Whether the treatment finish represented a completion or a discontinuation</td>
<td>Categorical</td>
</tr>
<tr>
<td>Whether the treatment discontinuation was initiated by the orthodontic clinician or the patient (at the patient’s request or because the patient failed to return)</td>
<td>Categorical</td>
</tr>
<tr>
<td><strong>Information on orthodontic contracts</strong></td>
<td></td>
</tr>
<tr>
<td>Type of NHS contract:</td>
<td>Categorical</td>
</tr>
<tr>
<td>- General Dental Services (GDS)</td>
<td></td>
</tr>
<tr>
<td>- Personal Dental Services (PDS)</td>
<td></td>
</tr>
<tr>
<td>- Trust-led Dental Services (TDS)</td>
<td></td>
</tr>
<tr>
<td><strong>Anonymised data</strong></td>
<td></td>
</tr>
<tr>
<td>Data indexing the contracts</td>
<td>-</td>
</tr>
<tr>
<td>Data indexing the orthodontic clinicians</td>
<td>-</td>
</tr>
<tr>
<td>Data indexing the patients</td>
<td>-</td>
</tr>
</tbody>
</table>

IOTN: Index of Orthodontic Treatment Need; NHS: National Health Service; PCT: Primary Care Trust; SEP: socioeconomic position

#### 3.3.2.4 Health and Social Care Information Centre data sets

Two PCT-level variables were used in the utilisation analyses involving the OHS and NHS activity data sets (with the PCT reflecting the location of the dental practices):

- The percentage of children attending dental check-ups, by PCT
  - Defined as the percentage of those aged 17 and under, by PCT, who were seen by an NHS GDP during a two-year period (1 April 2009 to 31 March 2011)
• This represents the percentage of the at-risk population who were in contact with an NHS GDP, who would either be able to provide orthodontic treatment or refer patients to the NHS orthodontic service, as necessary

• The supply of orthodontic clinicians, by PCT
  • Defined as the number of dentists, by PCT, who provided UOAs per 1,000 10- to 17-year-old (as at 31 March 2009)
  • The number of dentists was available by the type of NHS contract they were working under (i.e., GDS contracts, PDS contracts, or mixed PDS-GDS contracts)
  • The number of dentists working under NHS contracts was not restricted to dentists with a minimum level of orthodontic activity, as there were no data available at this level of detail

3.3.3 Permissions to use data sets

3.3.3.1 Children’s Dental Health Survey data set

The 2003 CDHS data set was publically available from the UK Data Service, which acts as a distributor of the data.

The data were provided in pseudoanonymised form (i.e., survey participant identifiers were replaced with other values, which do not allow the identities of survey participants to be inferred).

3.3.3.2 NHS Dental Epidemiology Programme for England Oral Health Survey data set

A data sharing agreement regarding the 2008-2009 OHS data set was made with the Dental Observatory (which is now known as the Dental Public Health Epidemiology Team (Public Health England, 2015b)) and the North West Public Health Observatory (which is now known as the North West Knowledge and Intelligence Team (Public Health England, 2015b)). The Dental Public Health Epidemiology Team supports NHS dental public health activity in the North West by creating a network of expertise for a range of activities including service evaluations and HNAs. The data supplied were restricted to the North West.

The data were provided in pseudoanonymised form. IMD data (Department for Communities and Local Government, 2007) were matched in before the data were supplied so that the data set included SEP data while guaranteeing that it did not include the survey participants’ postcodes. The data were encrypted before being sent electronically in order to ensure the data set was secure.
3.3.3.3 NHS orthodontic activity data set

The 2008-2012 NHS activity data set was provided by the NHSBSA, in line with Information Governance procedures (i.e., the data can only be used for non-commercial research and the copyright holder remains the NHSBSA). The data supplied were restricted to the North West.

The data were provided in pseudoanonymised form. IMD data (Department for Communities and Local Government, 2011) were matched in by the NHSBSA before the data were supplied so that the data set included SEP data while guaranteeing that it did not include the patients’ postcodes. Other information that could lead to the identification of the patients (including the patients’ names, NHS identification numbers, addresses, and dates of births (which were replaced with ages)) was removed. The data were delivered on a digital versatile disc (DVD) in order to ensure the data set was secure.

3.3.3.4 Health and Social Care Information Centre data sets

The two PCT-level variables used in the utilisation analyses were obtained from the HSCIC, which is a public body sponsored by the Department of Health that provides data and information technology systems for commissioners, analysts, and orthodontic clinicians. The first variable (the percentage of children attending dental check-ups) was publically available and the second variable (the supply of orthodontic clinicians) was available on request.

As the variables were calculated at the PCT level, there were no anonymity issues.

3.3.4 Overview of the use of data sets

Figure 3.1 gives an indication of how each of the analysis topics (need and willingness to have treatment, treatment utilisation, assessment procedures, treatment outcomes, and differences between practices/orthodontic clinicians) fit with the NHS orthodontic treatment pathways, and which data sets were used in each of the analyses. As the diagram shows, the use of the three main data sets enabled all of the research questions to be answered, as two of the data sets were population-based survey data sets that provided information on need and willingness to have treatment in the at-risk population, while the activity data set provided data on assessment procedures and treatment outcomes in the NHS orthodontic service, and all three data sets provided data on utilisation of orthodontic treatment (though they covered different areas and time periods). The data sets were all analysed using Stata 13 software (StataCorp, 2013).
Figure 3.1: NHS orthodontic treatment pathways, analysis topics, and data sets

1 – Need and willingness to have treatment – CDHS, OHS, and NHS activity data sets
2 – Treatment utilisation – CDHS, OHS, NHS activity, and HSCIC data sets
3 – Assessment procedures – NHS activity data set
4 – Treatment outcomes – NHS activity data set
5 – Differences between practices/orthodontic clinicians (in process and outcome indicators) – NHS activity data set

CDHS: Children’s Dental Health Survey; GDP: General Dental Practitioner; HSCIC: Health and Social Care Information Centre; NHS: National Health Service; OHS: Oral Health Survey

3.4 Methods

3.4.1 Overview

The following sections provide details of the methods of analysis:

- Sections 3.4.2 to 3.4.4 provide descriptions of the dependent variables, explanatory variables of interest (e.g., SEP), and the potential confounding and mediator variables
- Sections 3.4.5 to 3.4.7 provide broad explanations of the descriptive and inferential statistical analyses used in this thesis
Section 3.4.8 provides specific descriptions of the analyses of need and willingness to have treatment, treatment utilisation, assessment procedures, treatment outcomes, differences between practices/orthodontic clinicians, and costs.

### 3.4.2 Dependent variables

#### 3.4.2.1 Need and willingness to have treatment

Data on normative need for orthodontic treatment among the at-risk population were obtained from the OHS and CDHS data sets, while data on the IOTN categories among those undergoing NHS orthodontic treatment were obtained from the 2008-2012 NHS activity data set. Data on patient-defined need and willingness to have treatment among the at-risk population were obtained from the OHS data set. Details of the definitions and denominator populations involved in the analyses are shown in Table 3.4.

**Table 3.4: Definitions of need and willingness to have treatment**

<table>
<thead>
<tr>
<th>Data set</th>
<th>Variable</th>
<th>Definition and denominator population&lt;sup&gt;1&lt;/sup&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>CDHS and OHS data sets</td>
<td>Normative need among 12-year-olds</td>
<td>Children with an IOTN DHC score of 4-5 and/or an IOTN AC score of 6 or above (IOTN DHC scores of 3 were not recorded) Denominator populations: random samples of 12-year-olds in the in the UK (for the CDHS) and the North West (for the OHS)</td>
</tr>
<tr>
<td>OHS data set</td>
<td>Wearing an appliance at the time of the dental examinations</td>
<td>Children who were wearing an appliance at the time of the dental examinations (i.e., at 12 years old) Denominator populations: random samples of 12-year-olds in the UK (for the CDHS) and the North West (for the OHS)</td>
</tr>
<tr>
<td>NHS activity data set</td>
<td>IOTN categories</td>
<td>Children with an IOTN DHC score of 5 (representing very great need), an IOTN DHC score of 4 (representing great need), an IOTN DHC score of 3 with an IOTN AC score of 6 or above (representing moderate need), and an IOTN score of less than this (determined to have need for NHS treatment on a case-by-case basis) Denominator population: 10- to 17-year-olds who had NHS orthodontic treatment in the North West</td>
</tr>
<tr>
<td>OHS data set</td>
<td>Patient-defined need overall</td>
<td>Children who answered ‘Yes’ to the question ‘Do you think your teeth need straightening?’ were defined as having patient-defined need and children who answered ‘No’ were defined as not having patient-defined need (those who answered ‘Don’t know’ or who did not answer were excluded from the analyses) Denominator population: random sample of 12-year-olds in the North West who were not in treatment at the time of the dental examinations (these were the only children who were asked the question on patient-defined need)</td>
</tr>
<tr>
<td></td>
<td>Patient-defined need among those with no normative need</td>
<td></td>
</tr>
<tr>
<td></td>
<td>No patient-defined need among those with normative need</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Willingness to have treatment among 12-year-olds with normative need and patient-defined need</td>
<td>Children who answered ‘Yes’ to the question ‘Would you be prepared to have treatment and wear a brace if it were necessary?’ were defined as having willingness to have treatments and children who answered ‘No’ were defined</td>
</tr>
</tbody>
</table>
3.4.2.2 Treatment utilisation

Data on treatment utilisation among the at-risk population were obtained from the OHS and CDHS data sets. Data on those undergoing NHS orthodontic treatment were obtained from the NHS activity data set (which was used in combination with 2011 census data from the North West on the number of 10- to 17-year-olds in the at-risk population). Details of the definitions and denominator populations involved in the analyses are shown in Table 3.5.

Table 3.5: Definitions of treatment utilisation

<table>
<thead>
<tr>
<th>Data set</th>
<th>Variable</th>
<th>Definition and denominator population¹</th>
</tr>
</thead>
<tbody>
<tr>
<td>NHS activity data set and 2011 census data set</td>
<td>Utilisation among 10- to 17-year-olds in the North West</td>
<td>Documented NHS orthodontic treatment claims awarded 21 UOAs (i.e., the number of UOAs awarded for orthodontic treatment of 10- to 17-year-olds) The mean (from 2008-2012) annual utilisation percentage of NHS orthodontic treatment for each age group (10, 11, 12, 13, 14, 15, 16, and 17) was determined and then the cumulative utilisation percentage for 10- to 17-year-olds was calculated by summing the mean annual utilisation percentages (see Section 3.4.9.2). Denominator population: the population for each age group in the North West (according to data from the 2011 census).</td>
</tr>
<tr>
<td>OHS data set</td>
<td>Utilisation among 12-year-olds in the North West</td>
<td>Patient-reported NHS/private orthodontic treatment Children who answered ‘Yes’ to the question ‘Have you got an orthodontic brace or appliance?’ during the dental examinations (i.e., at 12 years old). (The children who answered ‘No’ would include those who had received orthodontic treatment in the past, before the age of 12 (though levels of treatment in young children are generally low (Bennett and Health, Wellbeing and Local Government Committee, 2010))). Denominator population: random sample of 12-year-olds in the North West.</td>
</tr>
<tr>
<td>CDHS</td>
<td>Utilisation among those</td>
<td>Patient-reported NHS/private orthodontic treatment Children who were wearing an appliance at the time of the dental examinations (i.e., at 12 and 15 years old) and</td>
</tr>
</tbody>
</table>

¹ The denominator populations were influenced by the levels of consent for both of the population-based surveys:

OHS: 88% of schools consented and, within these, 74% of 12-year-olds were examined (lack of examination was due to the following reasons: 7.3% of the 12-year-olds were activity withdrawn by their parents, 6.7% declined to take part, and 11.8% were absent during the data collection period).

CDHS: 65% of schools consented and, within these, 83% and 68% of 12-year-olds and 15-year-olds, respectively, were examined (lack of examination was due to reasons such as the child being absent during the data collection, the child refusing to be examined, the parents of the child refusing for their child to be examined, and the child leaving the school).
CDHS: Children’s Dental Health Survey; NHS: National Health Service; OHS: Oral Health Survey; UOA: Unit of Orthodontic Activity; UK: United Kingdom

1 The denominator populations were influenced by the levels of consent for both of the population-based surveys:

OHS: 88% of schools consented and, within these, 74% of 12-year-olds were examined (lack of examination was due to the following reasons: 7.3% of the 12-year-olds were activity withdrawn by their parents, 6.7% declined to take part, and 11.8% were absent during the data collection period).

CDHS: 65% of schools consented and, within these, 83% and 68% of 12-year-olds and 15-year-olds, respectively, were examined (lack of examination was due to reasons such as the child being absent during the data collection, the child refusing to be examined, the parents of the child refusing for their child to be examined, and the child leaving the school).

2 90.0% of all the returned CDHS questionnaires had replies given by parents alone, 8.4% had replies given by both parents and children, and 0.7% had replies given by children alone.

3.4.2.3 Assessment procedures

Data on assessment procedures were obtained from the NHS activity data set. The variables created were:

- Use of one or more ‘assessment & review’ appointments per treated patient
- Use of two or more ‘assessment & review’ appointments per treated patient
- Early access (i.e., early first assessment) at ages 9-10 among those who were assessed
- Use of an ‘assessment & refuse’ appointment for those who had IOTN scores of ≥ 3.6 among those who were refused or received treatment

Details of the definitions and denominator populations involved in the analyses are shown in Table 3.6.

**Table 3.6: Definitions of assessment procedures**

<table>
<thead>
<tr>
<th>Data set</th>
<th>Variable</th>
<th>Definition and denominator population</th>
</tr>
</thead>
<tbody>
<tr>
<td>NHS activity</td>
<td>Use of one or more ‘assessment &amp; review’ appointments per treated</td>
<td>Patients who had at least one/two ‘assessment &amp; review’ appointments from 2008-</td>
</tr>
</tbody>
</table>

1 The denominator populations were influenced by the levels of consent for both of the population-based surveys:

OHS: 88% of schools consented and, within these, 74% of 12-year-olds were examined (lack of examination was due to the following reasons: 7.3% of the 12-year-olds were activity withdrawn by their parents, 6.7% declined to take part, and 11.8% were absent during the data collection period).

CDHS: 65% of schools consented and, within these, 83% and 68% of 12-year-olds and 15-year-olds, respectively, were examined (lack of examination was due to reasons such as the child being absent during the data collection, the child refusing to be examined, the parents of the child refusing for their child to be examined, and the child leaving the school).

2 90.0% of all the returned CDHS questionnaires had replies given by parents alone, 8.4% had replies given by both parents and children, and 0.7% had replies given by children alone.
<table>
<thead>
<tr>
<th>Data set</th>
<th>Variable</th>
<th>Definition and denominator population</th>
</tr>
</thead>
<tbody>
<tr>
<td>data set</td>
<td>patient and Use of two or more ‘assessment &amp; review’ appointments per treated patient</td>
<td>2012 (and an additional assessment associated with a treatment start). Denominator population: patients who started NHS treatment in the North West from 2010-2012. (The data were restricted to mitigate the risk of censored assessment data¹, as patients who started treatment from 2008-2009 who had pre-2008 ‘assessment &amp; review’ appointments would not have these appointments recorded in the data set.)</td>
</tr>
<tr>
<td></td>
<td>Early access (i.e., early first assessment) at ages 9-10 among those who were assessed</td>
<td>Patients who had their first assessment at age 9 or 10 from 2008-2012. Denominator population: patients who were aged 9 and over and had NHS assessments in the North West from 2008-2012. (Stage of dental development rather than chronological age is used to guide treatment timings, and dental stage does not correlate perfectly with chronological age. However, the definition of early access at ages 9 to 10 was informed by the finding from the NHS activity data that assessments at these ages were more likely to be ‘premature’, i.e., there were large ratios of assessments to treatments for those aged 9 and 10: 7.9:1 and 5.3:1, respectively, compared to 3.0:1, 1:1, 0.6:1, 0.7:1 at ages 11, 12, 13, and 14, respectively. Children aged 7 and 8 are significantly less likely to have repeated assessments than those aged 9, as they are generally referred for interceptive treatment.)</td>
</tr>
<tr>
<td></td>
<td>Use of an ‘assessment &amp; refuse’ appointment for patients with IOTN scores of ≥ 3.6 among those who were refused or received treatment</td>
<td>Patients who were refused treatment from 2008-2012 who also had an IOTN score of ≥ 3.6. Denominator population: patients who were refused or received NHS treatment in the North West from 2008-2012. (Patients who did not receive NHS treatment but were also not refused treatment (e.g., patients with only ‘assessment &amp; review’ appointments) were excluded so that the IOTN scores used in the analysis would represent either the IOTN scores at refusal or at the beginning of treatment. This mitigates the issues of a) IOTN scores improving or worsening after the initial ‘assessment &amp; review’ appointment and b) censored data¹.)</td>
</tr>
</tbody>
</table>

IOTN: Index of Orthodontic Treatment Need; NHS: National Health Service

¹ Censoring refers to the situation where the values of a variable may only be partially known. A common example occurs when participants in a drug trial withdraw at a certain age so it is known that they lived until at least that age, but it is unknown whether they lived past that age.

### 3.4.2.4 Treatment outcomes

Data on treatment outcomes were obtained from NHS activity data set. Details of the definitions and denominator populations involved in the analyses are shown in Table 3.7.

#### Table 3.7: Definitions of treatment outcomes

<table>
<thead>
<tr>
<th>Data set</th>
<th>Variable</th>
<th>Definition and denominator population</th>
</tr>
</thead>
<tbody>
<tr>
<td>NHS activity data set</td>
<td>Treatment discontinuation</td>
<td>Patients who did not complete their treatment, either due to the orthodontic clinician discontinuing the treatment (e.g., because of the risk to the patient when compliance with oral hygiene instructions was poor) or due to the patient (e.g., because of requests that treatment be abandoned or failure to return for treatment). Denominator population: 10- to 17-year-olds who started NHS treatment in the North West in 2008 and had NHS activity notification forms returned (within the subsequent four years covered by the data set after 2008) to indicate that treatment had finished. (Treatment discontinuation can occur irrespective of the type(s) of orthodontic appliance chosen by...</td>
</tr>
</tbody>
</table>
Data on differences between practices/orthodontic clinicians were obtained from the NHS activity data set. The differences analysed where a) the percentage of treated patients with two or more ‘assessment & review’ appointments per practice, b) the percentage of treatment discontinuations per orthodontic clinician (initiated by orthodontic clinicians or patients, by orthodontic clinicians, and by patients) and c) the percentage of patients with RPTN per orthodontic clinician (in addition to the percentages with no RPTN, incomplete IOTN outcome score fields, and unreported treatment finishes).

### 3.4.3 Explanatory variables under study

#### 3.4.3.1 Socioeconomic position

The association between SEP and the dependent variables was analysed using the CDHS, OHS, and NHS activity data sets. The OHS and NHS activity data sets used IMD quintiles and deciles to represent SEP, while the CDHS data set used NS-SEC categories.
In the analyses, dummy variables (i.e., numeric stand-ins for qualitative facts in a regression model, which take a value of 0 or 1) were used for the SEP groups. This is because the SEP variables are measured on ordinal scales rather than interval scales (i.e., although the categories can be ordered, the intervals between the groups are not necessarily equally spaced). In addition, using dummy variables allows freedom of functional form in the regression models used to analyse the associations with SEP.

3.4.3.2 Type of NHS contract and size of NHS caseload

In the analyses using the NHS activity data set, in addition to SEP, the explanatory variables under study included the type of NHS contract and size of NHS caseload. Details of the definitions involved in these analyses are shown in Table 3.8.

Table 3.8: Definitions of type of NHS contract and size of NHS caseload

<table>
<thead>
<tr>
<th>Data set</th>
<th>Variable</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>NHS activity data set</td>
<td>Type of NHS contract</td>
<td>NHS orthodontic services can be provided under the following types of contracts:</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- General Dental Services (GDS)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- Personal Dental Services (PDS)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- Trust-led Dental Services (TDS)</td>
</tr>
<tr>
<td>Size of NHS caseload</td>
<td>Maximum annual number of NHS patients who received treatment, per practice/orthodontic clinician in the North West, during the five years (2008-2012) covered by the data set. Non-specialists tend to have small caseloads, as do some specialist orthodontists who treat a small number of NHS patients (and have larger private practices).</td>
<td></td>
</tr>
</tbody>
</table>

GDP: General Dental Practitioner; NHS: National Health Service

3.4.4 Potential confounding and mediator variables

3.4.4.1 Potential confounding variables

As shown in Figure 3.2, a confounding variable (or confounder) is an extraneous variable in a statistical model that is correlated with both the dependent variable and the explanatory variable under study, but is not in the causal pathway between the explanatory variable under study and the dependent variable (Meinert and Tonascia, 1986). Therefore, the confounding variable falsely obscures the relationship between the explanatory variable and the dependent variable. Adjusting for confounding variables allows the effect of these variables to be separated from the effect of the explanatory variable, so the spurious component of the association between the explanatory variable and the dependent variable will be decreased or eliminated (MacKinnon et al., 2000). The explanation for the restriction that the potential confounding variable must not be in the causal pathway between the explanatory
variable and the dependent variable is that the overall association between the explanatory variable and the dependent variable is of interest; if part of this association is mediated through another variable, and this other variable is adjusted for, the adjusted association will be an underestimate of the overall association.

**Figure 3.2: Diagram illustrating a simple case of confounding**

![Diagram illustrating a simple case of confounding](image)

The confounding variable is associated (directly or indirectly) with the dependent variable, independently of the explanatory variable under study, and it is also associated (directly or indirectly) with the explanatory variable under study. The confounding variable is not in the causal pathway between the explanatory variable under study and the dependent variable.

Knowledge of the causal structure of the issue in question is a prerequisite to accurately label a variable as a confounding variable, and it is important to balance the risk of bias due to the omission of important confounding variables and inappropriate adjustment for non-confounders (Hernán et al., 2002). Determining whether or not a variable is a confounding variable using causally blind statistical approaches cannot substitute for a priori knowledge about the nature of the effects of the variable (Hernán et al., 2002). Causally blind statistical approaches include automatic variable selection procedures such as stepwise selection (which assumes that although not all variables selected will be confounding variables, all the important confounding variables will be selected) and comparing the relative difference between adjusted and unadjusted effect estimates (which assumes that any variable substantially associated with an estimate change should be adjusted for) (Hernán et al., 2002). The more a priori knowledge that is identified about the causal structure of the issue in question and the more causal restrictions placed on the criteria for confounding, the more accurate the decision to label a variable as a confounding variable will be (Hernán et al., 2002).

**IOTN categories**

The IOTN categories (5, 4, 3.6-3.10, and < 3.6) are used to reflect the severity of malocclusion, and they are shown (in this thesis) to vary slightly by SEP. Therefore, regarding the analyses of the associations of SEP and assessment procedures, a patient’s IOTN category is a potential confounding variable, based on the following hypotheses:
• Use of one or more ‘assessment & review’ appointments and two or more ‘assessment & review’ appointments per treated patient: a patient’s IOTN score at his/her first orthodontic assessment may have an influence on whether the outcome of the assessment is to begin treatment or to be reviewed at a later date. This is because more severe cases of malocclusion are prioritised over less severe cases for reasons related to the patient’s social wellbeing and OHQoL.

• Early access (i.e., early first assessment) at ages 9-10 among those who were assessed: IOTN scores may be related to whether an early assessment is legitimate, because it is legitimate to prioritise patients with the most severe malocclusions over other patients for reasons related to the patient’s social wellbeing and OHQoL (although specific occlusal traits such as missing teeth also affect whether an early assessment is legitimate on the grounds that early treatment may avert more difficult treatment later on).

• Use of an ‘assessment & refuse’ appointment for those who have IOTN scores of ≥ 3.6 among those who were refused or received treatment: IOTN scores may have an effect on ‘assessment & refuse’ appointments because those with IOTN DHC scores of 3 may be more likely to be refused on the grounds of lack of motivation, as a patient may be more likely to have low motivation if he/she has less severe malocclusion.

The IOTN variable is an ordinal variable and it is represented in the regression analyses as a categorical variable (using dummy variables) in order to allow freedom of functional form.

\textit{IOTN AC scores}

The IOTN AC scores (1-10) are shown (in this thesis) to vary slightly by SEP. Therefore, regarding the analyses of the associations between SEP and treatment outcomes, the IOTN AC score is a potential confounding variable, as it is thought to influence treatment outcomes:

• The IOTN AC score reflects treatment complexity, and it has been noted that treatment complexity is associated with treatment failure (Daniels and Richmond, 2000; Richmond et al., 1997; Richmond and Daniels, 1998). (In addition, high IOTN AC scores are associated with RPTN in an unadjusted analysis of the NHS activity data.)

• IOTN AC scores are a much better proxy for treatment complexity than IOTN DHC scores (which are used to reflect the severity of malocclusion). The IOTN AC score is the most heavily weighted component of the five components of the ICON, which was developed, in part, to measure treatment complexity (Daniels and Richmond, 2000), and there is a strong correlation between IOTN AC scores and the ICON scores (Arora, 2008; Borzabadi-Farahani and Eslamipour, 2010; Fox et al., 2002).
The IOTN AC score variable is an ordinal variable and it is represented in the regression analyses as a categorical variable (using dummy variables) in order to allow freedom of functional form.

**Gender and age**

Gender cannot confound the associations between SEP and need, willingness to have treatment, and utilisation, as, in the UK, males and females are distributed similarly between SEP groups. As shown in Table 3.9, there is generally at ratio of approximately 1.05-1.06 10 to 17 year old males to every 10 to 17 year old female in each SEP group, as, for mammalian species, slightly more males are born compared to females (Grech et al., 2002). This means that analyses of the associations between SEP and need, willingness to have treatment, and utilisation are not invalidated by not adjusting for gender. In addition, these analyses also take age into account (without directly adjusting for age), where appropriate, e.g., the association between SEP and normative need is explored in analyses of 12-year-olds.

**Table 3.9: Distribution of gender in the North West in 2011, by SEP**

<table>
<thead>
<tr>
<th>IMD decile</th>
<th>Ratio of 10 to 17 year old males to 10 to 17 year old females</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1.05</td>
</tr>
<tr>
<td>2</td>
<td>1.05</td>
</tr>
<tr>
<td>3</td>
<td>1.05</td>
</tr>
<tr>
<td>4</td>
<td>1.06</td>
</tr>
<tr>
<td>5</td>
<td>1.05</td>
</tr>
<tr>
<td>6</td>
<td>1.05</td>
</tr>
<tr>
<td>7</td>
<td>1.06</td>
</tr>
<tr>
<td>8</td>
<td>1.05</td>
</tr>
<tr>
<td>9</td>
<td>1.06</td>
</tr>
<tr>
<td>10</td>
<td>1.06</td>
</tr>
<tr>
<td>All</td>
<td>1.05</td>
</tr>
</tbody>
</table>

IMD: Index of Multiple Deprivation; SEP: socioeconomic position; UK: United Kingdom

Data source: 2011 census data set

However, the analyses of assessment procedures and treatment outcomes were adjusted for gender and age as they can confound the associations between SEP and these outcome variables. This is because gender and age are not inevitably distributed similarly in each of the SEP groups presenting for assessments and being granted treatment
(e.g., as shown by the NHS activity data, those in the least deprived group who present for assessments are more likely to be younger compared to those in the most deprived group).

### 3.4.4.2 Potential mediator variables

A mediator variable, or mediator, is a variable that explains the mechanism that underlies the association between the explanatory variable under study and the dependent variable, i.e., the explanatory variable influences the mediator variable, which in turn influences the dependent variable (Sobel, 1990). In contrast to confounding variables, mediator variables are in the causal pathway between the explanatory variable under study and the dependent variable.

Mediator variables were used in the analyses of the association between SEP and RPTN. These analyses included a regression model that did not adjust for the potential mediator variables because the total association between SEP and RPTN was of interest: if part of the SEP association was mediated by these non-confounders, and these non-confounders were adjusted for, the adjusted association would be an underestimate of the total association.

Details of the definitions of the potential mediator variables in the analyses of RPTN are shown in Table 3.10.

#### Table 3.10: Definitions of potential mediator variables

<table>
<thead>
<tr>
<th>Data set</th>
<th>Variable</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>NHS activity data set</td>
<td>Replacement orthodontic appliance required</td>
<td>Whether or not a replacement orthodontic appliance was required during the course of active treatment was used to reflect patient compliance with treatment instructions. (However, while this variable may reflect patient compliance with instructions not to eat hard or sticky food, it is less likely to fully reflect other aspects of patient compliance such as the frequent use of intraoral elastic bands. A more comprehensive indicator of patient compliance, based on patients’ attendance and punctuality for appointments, and appliance maintenance, was used in a previous study of orthodontic treatment outcomes (Joury et al., 2011), but this information is unavailable from the NHS activity data, and it also would not completely reflect all elements of patient compliance.)</td>
</tr>
<tr>
<td>Type(s) of orthodontic appliance</td>
<td>A categorical variable was created to reflect type of orthodontic appliance used (as reported via NHS activity notification forms): fixed only, removable only, functional only, fixed and removable, fixed and functional, removable and functional, all three types, or missing data.</td>
<td></td>
</tr>
</tbody>
</table>

NHS: National Health Service

### 3.4.5 Descriptive and inferential statistics

Descriptive statistics are statistics that describe or summarise data, but a descriptive analysis does not allow conclusions to be drawn beyond those concerning the observed data. In contrast, inferential statistics do allow conclusions to be drawn beyond the data analysed. That is, statistical inference allows inferences to be made about
properties of the underlying population from which the data were drawn, as long as the data in question are subject to random variation. Inferential statistics can lead to a codification of the uncertainty due to chance variation by allowing the calculation of confidence intervals (CIs) and hypothesis testing.

The most common motivation for the use of inferential statistics occurs when dealing with random variation that arises from random sampling variation. That is, when generalising from a sample to the population from which the sample was drawn by probability sampling (i.e., where every unit in the population has a probability of greater than zero of being randomly selected, and this probability can be accurately determined). This includes simple random sampling, clustered sampling, and stratified sampling, but not nonprobability sampling techniques such as convenience sampling.

When analysing the data from the CDHS and the OHS, inferential statistics are used, as both samples are probability samples, subject to random variation due to random sampling.

Regarding the use of descriptive or inferential statistics for cases such as the analysis of the NHS activity data (which represents the entire population seen in the NHS orthodontic service in the North West), there is no generally agreed upon answer to the question of which type of statistics to use. Instead, the choice depends on the purpose of the analysis.

The first point of view is that there is no need to estimate any population parameters along with CIs. This is because the results are population parameters rather than sample statistics, i.e., they are perfectly representative of the population as there are no sampling errors due to random chance during sampling. Tests of statistical significance are also irrelevant, e.g., any differences between SEP groups would be immediately apparent. Using this approach, the data should be analysed using descriptive statistics. For example, using regression models to describe the relationships between different variables can be a useful data reduction technique even when there is no probability model of sampling cases involved (i.e., even when disregarding the CIs and tests of statistical significance on the regression coefficients that are routinely presented by statistical software). Although the coefficients generated would be population coefficients (i.e., perfectly representative of the population), judgement would still be required regarding whether the coefficients have any economic significance (as when analysing a probability sample).

On the other hand, some have argued that the use of statistical inference when analysing an entire population rather than a sample is justifiable, based on two conceptualisations.

The first way to frame the problem is to view the population as a sample from a hypothetical infinite population, i.e., a ‘super population’ (Hartley and Sielken, 1975). For example, a census of the population 10- to 17-year-olds
in the North West who utilised NHS orthodontic treatment could be viewed as a sample from a ‘super population’ of future children in the North West who might one day use the service. However, some argue that this approach is unconvincing because while a population over a given period of time may be a sample of a larger population over a longer period of time, it is a nonprobability sample (because some units of the population have no chance of being selected), i.e., the selection of units is nonrandom, so statistic inference is inapplicable.

A second way to frame the problem is to assume that the actual observations are a sample generated by an underlying stochastic data generating process (that could generate an infinite number of possible observations), which is where the required random variation arises from (Pickup, 2014). Therefore, statistical inferences can be made about the underlying process that generated the observations, and the extent to which they may have been influenced by random factors. For example, if a coin was tossed 100 times, this would not represent the entire population of coin tosses; a different set of tosses is possible and, because of the play of chance factors, a different set of tosses would likely yield different observations. A second example is that, in the NHS orthodontic service, if those from the least deprived group have more ‘assessment & review’ appointments than those from other SEP groups, it may be that chance factors caused more of those from the least deprived group to have repeated assessments compared to the other groups, even though the process by which patients are referred and assessed is fair. Using this approach, the stochastic process that generates the observations is modelled in order to understand the factors that can predict future unobserved outcomes. It is assumed that there is an underlying probability model that captures the important factors in this stochastic process. The implicit full model that explains the stochastic process includes a combination of unmeasured random additive effects (these are represented by the error term, which can be viewed as the unobserved realisation of a multivariate random variable).

Therefore, using this approach, some argue that statistical inference is meaningful even when a data set has not been arrived at via probability sampling. The inferential statistics tools for this type of population analysis include randomisation tests, which are non-parametric tests (i.e., they make no assumptions about the probability distributions of the variables being assessed (Geisser and Johnson, 2006)) that can be used to test whether the observed differences between two groups is likely to be due to random variation or a systematic process (Edgington and Onghena, 1995). In a randomisation tests comparing two groups, the basis for the estimates of standard errors involves repeated random allocations of the observations to the two groups being compared. The difference between the two groups is calculated for every possible way of dividing these pooled observations between the two groups; the set of these calculated differences represents the exact distribution of possible differences under the null hypothesis that there is no difference between the groups. The observed difference between the two groups is then compared to the probability distribution based on this randomisation procedure in order to determine if the difference is statistically significant for a given level of significance. In this way,
randomisation tests are able to consider any form of randomness, not just random sampling error. The corresponding classical parametric tests (i.e., tests that assume that the data have come from a probability distribution that can be parameterised by a finite number of unknown parameters and makes inferences about these parameters (Geisser and Johnson, 2006)) are often good approximations of randomisation tests when the number of observations is large, but randomisation tests can be used directly given that modern statistical software makes them easily available.

However, this approach of modelling the underlying stochastic data generating process assumes that the random error term represents a large number of unobserved variables that are uncorrelated with the explanatory variables and with each other, and that each have a small impact on the dependent variable (Berk et al., 1995). These unobserved variables are assumed to produce, in the aggregate, independent, identically distributed errors (Berk et al., 1995). However, when modelling the ‘social world’, the effects of the unobserved variables are not necessarily uncorrelated, so the assumption is not necessarily valid (Berk et al., 1995). In contrast, there are situations that are not part of the ‘social world’ where the assumption would be accurate, e.g., when modelling the underlying stochastic process of radioactive decay (Berk et al., 1995).

Therefore, the analyses in this thesis will use inferential statistics when analysing the probability samples from the survey data sets, and descriptive statistics when the sample involved is a nonprobability sample (which is the case for the analyses of the NHS activity data set).

3.4.6 Descriptive statistics: NHS orthodontic activity data

In order to calculate the relevant descriptive statistics using the NHS orthodontic activity data, linear probability models (LPMs) were estimated using ordinary least squares (OLS) in Stata 13, without taking into account the output concerning inferential statistics.

LPMs can be used when the value of the dependent variable for each observation is either 0 or 1. The model assumes that the conditional expectation of the binary dependent variable \( Y_i \) given a vector of explanatory variables \( X_i \) is the probability that \( Y_i \) equals one, given \( X_i \), which is equal to a linear combination of unknown parameters (where \( \beta \) is a vector of unknown parameters) and explanatory variables:

\[
E(Y_i \mid X_i) = \Pr(Y_i = 1 \mid X_i) = \beta X_i
\]

\(^7\) Using this notation, the intercept is included in the set of regressors, \( X_i \), by taking \( x_{i1} = 1 \) for all observations \( i (i = 1,\ldots, n) \); the coefficient \( \beta_1 \) corresponding to this regressor is the intercept.
Where necessary, potential confounding variables can be included as explanatory variables (i.e., in the set of regressors, \(X_i\)), in addition to the dummy SEP variables, in order to adjust for these variables.

The unknown parameters in each model were calculated using OLS, which minimises the sum of the squares of the residuals (i.e., the differences between observed values of the dependent variable and the values predicted by the model). Given that the NHS orthodontic activity data are population data, the coefficients generated in the analyses are perfectly representative of the population\(^8\).

One of the advantages of using LPMs is ease of interpretation because (unlike in nonlinear models such as logistic models) the coefficient of each binary explanatory variable can be directly interpreted as the average marginal effect of the explanatory variable on the dependent variable, i.e., the mean change in the predicted probability as the explanatory variable changes from 0 to 1 while all other variables are held constant (Lewis-Beck et al., 2003). However, a drawback of using LPMs is that the coefficients can yield predicted probabilities outside the unit interval (0, 1), i.e., it can yield predicted probabilities that are negative or greater than 100%. Nevertheless, Wooldridge highlights that ‘If the main purpose...is to approximate the [marginal] effects of the explanatory variables...then the LPM often does a very good job...The fact that some predicted values are outside the unit interval need not be a serious concern’ (Wooldridge, 2002, p. 563).

In all of the LPMs, the reference category for the categorical SEP variable was the least deprived group, i.e., IMD quintile 5, for ease of comparison of the average marginal effects for those in each of the more deprived groups.

Mediation and confounding can be quantified by measuring the change in the relationship between an explanatory and a dependent variable after adding a confounding or mediator variable to the analysis. However, they are identical statistically and can be distinguished only on conceptual grounds (MacKinnon et al., 2000). If, after adjusting for potential confounding variables, the average marginal effects of being in IMD quintiles 1-4 compared to being in IMD quintile 5 (the reference category) persist to some extent but are smaller in the adjusted analysis compared to the unadjusted analysis, this suggest that confounding was affecting the unadjusted analysis.

If, after adjusting for potential mediator variables, the average marginal effects are smaller, this suggests that these variables help to explain the variation in the dependent variable between SEP groups.

\(^8\) The fact that the random error term of a LPM is heteroscedastic (i.e., there are subpopulations that have different variabilities from others), and can therefore cause biased standard errors, is immaterial as statistical inference (which would assume conditional homoscedasticity) is not relevant in these analyses. \(Y_i\) is distributed as a Bernoulli variable and the variance of a Bernoulli variable is dependent on the probability of success, \(p_i\), for observations \(i (i = 1, \ldots, n)\), so the variance of the random error term is not constant: \(\text{var}(e_i | X_i) = p_i(1 - p_i)\) where \(p_i = Pr(Y_i = 1 | X_i)\). (The random error term also does not have a normal distribution, but this is also immaterial in these analyses.)
3.4.7 Inferential statistics: Children’s Dental Health Survey and NHS Dental Epidemiology Programme for England Oral Health Survey data

3.4.7.1 Overview

The associations between SEP and various dependent variables in the CDHS and OHS data sets were determined using inferential statistics derived from binary and multinomial logistic regression analyses, which indicate whether any differences in the dependent variables are associated with SEP rather than being a result of random sampling variation.

3.4.7.2 Generalised linear models

A generalised linear modelling approach was used in all of the analyses of the CDHS and OHS data. This approach is a flexible generalisation of linear regression (which represents the data as a linear trend that is not bounded at 0 and 1, plus independently, identically, normally distributed random errors) that allows for dependent variables such as binary and categorical variables that have non-normal random error distributions.

Generalised linear models have three parts, which allow them to be used to predict dependent variables with various types of probability distributions by fitting a linear predictor function to an arbitrary transformation of the expected value of the dependent variable:

- A response probability distribution that is a distribution in the exponential family of distributions (e.g., a binominal distribution with a fixed number of trials (see Section 3.4.7.3))
- A linear predictor function ($\eta$) that is a linear combination of unknown parameters (where $\beta$ is a vector of unknown parameters) and explanatory variables (where $X$ is a matrix of explanatory variables): $\eta = \beta X$
- A link function ($g$) such that the expected value of the dependent variable, ($E(Y)$), which is equal to the mean of the response probability distribution ($\mu$, which is unobserved), is linked to the linear predictor function ($\eta$): $E(Y) = \mu = g^{-1}(\eta) = g^{-1}(\beta X)$. As indicated, the link function transformation is applied to the parameter governing the response probability distribution (i.e., its mean, $\mu$), not the actual dependent variable. However, since this parameter is never available to transform, the actual link function ($g$) is left implicit and the model is represented by the inverse of the link function ($g^{-1}$) applied to the linear predictor function ($\eta$) instead
### 3.4.7.3 Logistic regression models

**Binary logistic regression**

In most of the analyses, the dependent variable, $Y_i$, has a Bernoulli distribution (i.e., it takes a value of 1 with success and 0 with failure). Therefore, the generalised linear models estimated for these analyses use a Bernoulli distribution as the response probability distribution. This is a special case of the binomial distribution, i.e., a discrete probability distribution of the number of successes in a sequence of independent success/failure trials (in this particular case, there is a single success/failure trial), each of which yields success with probability $p_i$ for observation $i (i = 1,..., n)$. A general property of the Bernoulli distribution is that the expected value of $Y_i$ is equal to the probability of success, $p_i$.

There are several options for link functions that can be used for binary dependent variable data, which are increasing and monotone functions (i.e., functions between ordered sets that preserve the given order) that map $(0,1)$ to $(-\infty, +\infty)$. This ensures that the expected value of the binary dependent variable, i.e., the probability of success (which is bounded by 0 and 1), can be transformed to a continuous variable that ranges between $-\infty$ and $+\infty$ (in order to match the potential range of the linear predictor function). One of the most common is the logit link function. The logit link function is the natural logarithm of the odds (i.e., the log odds, where the odds are the probability that a particular outcome is a success divided by the probability that it is a failure). The inverse of the logit function is applied to the linear predictor function; this inverse function is known as the logistic function (which is the cumulative distribution function of the standard logistic distribution).

In a logistic regression model, the logit of the probability of success (i.e., the log odds of success) is modelled as a linear combination of unknown parameters and explanatory variables (i.e., the linear predictor function) and the exponential function of the linear predictor function is the odds of success. Therefore, the coefficient of a binary explanatory variable – such as a SEP dummy variable – can be interpreted as the additive change in the log odds, given a unit increase in the explanatory variable (which is associated with being in the non-reference category for the SEP variable rather than the reference category), when all other variables are held constant. In turn, the exponentiated coefficient of the explanatory variable can be interpreted as the odds ratio (OR), which is the ratio of the odds associated with being in the non-reference category to the odds associated with being in the reference category, when all other variables are held constant.

In addition to conceptualising logistic regression as a generalised linear model, a second approach is known as the latent variable model (Strickland, 2015). Using the formulation of a latent variable model, one assumes that there
is a latent variable \((Y^*_i)\), i.e., an unobserved continuous random variable, and that the binary dependent variable \((Y_i)\) equals 1 if \(Y^*_i > 0\) and 0 otherwise. \(Y^*_i\) can be written directly in terms of the linear predictor function and an additive random error variable that is distributed according to the standard logistic distribution:

\[
Y^*_i = \beta_0 + \beta_1 X_i + \varepsilon
\]

\[Y_i = 1 \text{ if } Y^*_i > 0\]

\[Y_i = 0 \text{ otherwise}\]

where

\(Y_i\) is the observed binary dependent variable for observation \(i (i = 1,..., n)\) and \(Y^*_i\) is a latent variable reflecting the propensity for the observation to have the value of the observed binary dependent variable

\(\beta_0\) is the intercept

\(X_i\) is a vector of explanatory variables (e.g., dummy SEP variables) for observation \(i (i = 1,..., n)\) and \(\beta_1\) is a vector of corresponding coefficients

\(\varepsilon\) is the random error variable; \(\varepsilon \sim \text{standard logistic distribution}\)

In all of the logistic regression analyses, the reference category for the categorical SEP variable was the least deprived group: in the case of the analyses using IMD data, this was IMD quintile 5, and in the case of the analyses using NS-SEC data, this was category 1. The least deprived group was used for ease of comparison of the ORs for each of the more deprived groups, and for ease of comparison of the trends between analyses.

The coefficients were estimated by maximum pseudolikelihood estimation, which is an iterative numerical method that finds values that best fit the observed data (i.e., the values that give the most accurate predictions for the observed data) when analysing complex survey data. An adjusted F-test (i.e., adjusted for the number of explanatory variables) was used to assess whether each model fitted significantly better than a null model (i.e., a model with no explanatory variables). A t-test was used to assess whether the contribution of each explanatory variable to a given model was significant (if the t-statistic is statistically significant, the CI for the coefficient does not include 0).
**Multinomial logistic regression**

For the analyses exploring the association between SEP and IOTN AC scores, multinomial logistic regression was used. A multinomial logistic regression model generalises logistic regression to situations where there are more than two possible outcome categories, i.e., it can be used to estimate the probabilities of the different possible outcomes of a categorical dependent variable, given a set of explanatory variables. From the \( J \) possible outcome categories, a ‘base outcome category’ is chosen. For each of the other outcome categories, the log of the probability of the response being in a particular outcome category relative to the probability of the response being in the base outcome category is treated as a linear function of the explanatory variables and unknown parameters. Each of the \( J - 1 \) equations has a separate set of coefficients, which allow the predicted probabilities for each individual to sum to 1. This model is analogous to a binary logistic regression model, except that the response probability distribution is multinomial instead of binomial and the \( J - 1 \) multinomial logistic equations contrast each of the \( J - 1 \) outcome categories with the base outcome category, whereas a single binary logistic regression equation is a contrast between successes and failures. If \( J = 2 \) the multinomial logistic model reduces to a binary logistic model.

For all the multiple logistic regression analyses, the base outcome category for the IOTN AC score variable was IOTN AC score of 6. This category was used for ease of interpretation, as this represents the IOTN AC score eligibility threshold for NHS orthodontic treatment. The exponentiated coefficients from a multinomial logistic regression can be interpreted as relative-risk ratios, i.e., ratios of two relative-risks. With regards to a binary explanatory variable – such as a SEP dummy variable – the relative-risk ratio is the ratio of a) the relative-risk of being in a different IOTN AC score category compared to the base outcome category, *given a unit increase in the explanatory variable* (which is associated with being in the non-reference category for the SEP variable) to b) the relative-risk of being in a different IOTN AC score category compared to the base outcome category, *given the absence of a unit increase in the explanatory variable* (which is associated with being in the reference category for the SEP variable).

### 3.4.7.4 Survey design features

For the CDHS and the OHS data, several survey design features were considered in the analyses, as the samples did not represent simple random samples. These considerations involve the following survey design features.

---

9 Although the IOTN AC scores are ordinal, an ordinal logistic regression model was not used because one of the assumptions of ordinal logistic regression is that of proportional odds. This means that each explanatory variable has an identical effect at each cumulative split of the ordinal dependent variable (i.e., the effect of an explanatory variable is proportional across the cumulative odds).
Clustered sampling

Clustered sampling occurs when the population is divided into non-overlapping ‘clusters’, or subgroups, which are treated as sampling units, i.e., a sample of the clusters is selected before selecting samples of the units from each selected cluster. In the CDHS and the OHS, the purpose of clustered sampling was to reduce the fieldwork associated with the dental examinations of the children. In multistage clustered sampling, there are more than two sampling stages, so that, for example, in three-step clustered sampling, first-stage clusters are selected, then second-stage clustered as selected from the first-stage clusters, and then units are selected from the second-stage clusters. The first stage sampling unit is known as the primary sampling unit, and when using statistical software to compute standard errors from multistage clustered samples using the ‘ultimate cluster method’ it is only necessary to have a primary sampling unit identifier in the data set because the variance between primary sampling units automatically incorporates later stages of clustered sampling.

Clustered sampling leads to higher sampling error. (As the number of clusters decreases (for a given sample size) and the homogeneity of the cluster increases, the standard error of an estimate of a population parameter (i.e., the standard deviation of the theoretical sampling distribution of the sample statistic) increases.) Therefore, accounting for clustered sampling in the analyses avoids deflation of the true standard errors.

Stratified sampling

Stratified sampling, which can occur prior to each sampling stage, is a process of dividing the population into non-overlapping homogeneous ‘strata’, or subgroups, before sampling units from each of the strata separately. If the same sampling fraction is used in each stratum, this is known as proportionate stratified sampling, and if the sample fraction is not the same in each stratum, this is termed disproportionate stratified sampling. For proportionate stratified sampling, a distinction is made between explicit and implicit stratification: explicit stratification is where the population of sampling units is explicitly divided into strata and a separate sample is selected per stratum whereas implicit stratum is where the population of sampling units is sorted by the stratifying variable(s) and then the sample is selected from the sorted list using a fixed sampling interval and a random start; statistical software that calculate standard errors for stratified samples usually only allow for explicit stratification rather than implicit stratification.

Proportionate stratified sampling can help to ensure that the sample is representative of the population of interest (i.e., the sample sizes for each strata, such as different regions across a country, will be equal to their expected sizes) and to increase the precision of the estimates (i.e., it can decrease the sampling errors). Additionally,
disproportionate stratified sampling can enable some subgroups to be oversampled so that estimates of population parameters for subgroups of the population can be calculated.

Relative to a survey design with no stratification, proportionate stratified sampling can increase precision when it involves dividing a heterogeneous population into more homogenous strata, so that the variances in each strata are lower than the variance overall (or proportionate stratified sampling can have a neutral effect, but it cannot decrease precision). Therefore, failing to account for proportionate stratified sampling can inflate the true standard errors, so not taking it into account is usually conservative.

However, disproportionate stratified sampling may increase precision, decrease precision, or have a neutral effect. The effect of disproportionate stratified sampling on sampling error depends on the how the variability of the variable of interest differs between the different strata, and the relative sampling fractions between the different strata. It will increase precision, relative to a proportionate stratified sample, if the variability of the variable of interest is higher than average within the oversampled strata. However, disproportionate stratified sampling is rarely used to increase precision because an optimal sample design for one variable is unlikely to be optimal for others. As disproportionate stratified sampling can often decrease precision, not accounting for stratified sampling can deflate the true standard errors.

Weighting for unequal probabilities of selection and for non-response

Weighting can be used to allow an analysis of a survey sample to be adjusted to better represent the population. Design weights are weights that adjust for unequal probabilities of selection based on the design of the sampling scheme. In contrast, non-response weights can be used to take into account the non-response rates to a questionnaire (and also the non-consent rates for surveys that involve examinations of participants, such as the dental examinations in the CDHS and the OHS).

- In order to obtain unbiased estimates of population parameters from a disproportionate stratified sample, the estimates generally have to be weighted, where the weights are related to the inverse of the sampling fractions used in each stratum. These design weights would have to be modified for more complex surveys to take into account other design features that cause unequal selection probabilities (besides disproportionate stratified sampling). However, for surveys that use multistage clustered sampling, a technique known as probability proportional to size sampling can lead to equal selection probabilities and so design weights may not be needed, e.g., oversampling large schools (in proportion to their size) and then selecting the same number of children per schools (which amounts to undersampling at the second stage) cancels out the oversampling at the first stage.
Poststratification (i.e., stratification after the selection of a sample) is a weighting method that adjusts for instances of non-response that lead to differences between the sample and the population in terms of the distribution of a few key variables such as gender and age (as the population distribution of these variables is generally known). The main aim of poststratification is to reduce any bias in the survey due to non-response (which can occur if the non-respondents are a non-random sample of the total sample). Poststratification ensures that the weighted estimates conform to population totals within each postratum (the assumption is that although non-response biases in surveys are likely to be complex, by aligning the sample to the population along a small number of key variables, many of these complex biases will be reduced). In addition, poststratification should reduce the standard errors of most estimates, though non-response weights are not selected to improve precision.

Table 3.11 and Table 3.12 detail the considerations of survey design features for the two population-based surveys.

**Table 3.11: CDHS: Clustered sampling, stratified sampling, and weighting**

<table>
<thead>
<tr>
<th>Feature</th>
<th>Details</th>
<th>Methods</th>
<th></th>
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</table>
| Clustered sampling| Multistage clustered sampling was carried out in order to reduce the fieldwork associated with the dental examinations of the children:  
  - First stage: LADs, EAs, and UAs were sampled in England, Wales, and Scotland, respectively. (LADs, EAs, and UAs were sampled with a probability proportional to size of the pupil population.)  
  - Second stage: school groups were sampled from these LADs, EAs, and UAs (and simple random sampling of school groups was carried out in Northern Ireland).  
  - Third stage: children were sampled from the school groups.                                                                 | There were no LAD, UA, or EA identifiers in the data set, so clustered sampling was not taken into account. However, this would not affect the estimates, and would not be expected to greatly deflate the standard errors (because the clusters were not expected to be homogenous, clustered sampling should not greatly increase the standard errors). |  |
| Stratified sampling| Stratified sampling was carried out prior to each sampling stage:  
  - Prior to sampling LADs, UAs and EAs, stratification was carried out by region (explicitly for England and Wales and implicitly for Scotland, with no stratification by region in Northern Ireland).  
  - Prior to sampling school groups, stratification was carried out by country (Wales and Northern Ireland were oversampled relative to England) and whether schools were deprived or not (deprived schools, which had more than 30% of pupils who were eligible for free school meals, were oversampled).  
  - Prior to sampling children, implicit stratification was carried out by gender and date of birth.                                                                 | Region identifiers were used to take stratification by region into account, and weights (see row below) took into account the disproportionate stratification by country and by whether or not each school was deprived. Stratification by gender and date of birth could not be taken into account, but not accounting for proportionate stratification in the analysis tends to inflate the true standard errors, so not taking it into account is usually conservative. |  |
| Weighting for dental | The weights for the dental examination data allow Weighting to adjust for unequal probabilities of selection were computed as the inverse of the probabilities of selection and |  |
Table 3.12: OHS: Clustered sampling, stratified sampling, and weighting

<table>
<thead>
<tr>
<th>Feature</th>
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| **Clustered sampling**         | Multistage clustered sampling was carried out in order to reduce the fieldwork associated with the dental examinations of the children:  
- First stage: schools were sampled.  
- Second stage: children were sampled from the schools. | There were no school identifiers in the data set (primary sampling units are sometimes not included in data sets due to confidentiality issues), so clustered sampling was not taken into account. However, this would not affect the estimates, and would not be expected to greatly deflate the standard errors (because the clusters were not expected to be homogenous, clustered sampling should not greatly increase the standard errors). The PCT identifiers were used to take stratification into account (each LAD was generally conterminous with a PCT but, where this was not the case, it was ensured that the sampling would be able to produce estimates for both LADs and PCTs). |
| **Stratified sampling**        | Stratified sampling was carried out prior to each sampling stage:  
- Prior to sampling schools, stratification was carried out by LAD, with all schools sampled if the number of schools in the LAD was 6-20, 20 schools sampled if the number of schools was 20-40, and 25 or 50% (whichever was greater) of schools sampled if the number of schools was over 40.  
- Prior to sampling children, stratification was carried out by school size banding (small, medium, and large schools) when there were over 20 schools in a LAD, with stratification strategies to accommodate the local situation. A minimum sample size of 250 children was required per LAD but larger samples were sometimes taken to aid local planning (Dental Observatory and North West Public Health Observatory, 2009). However, these additional samples were not included in the data set. (The appropriate percentages of children were selected from small, medium, and large schools in order to ensure the sample was representative of the distribution in the population, e.g., all of the children in the small schools, 1 out of 2-3 of the children in medium-sized schools, and 1 out of 4 of the children in the large schools.) |                                                                 |
| **Weighting for dental examination** | Weights for the dental examination data would allow adjustment for differing probabilities of selection (e.g., due to disproportionate stratification, i.e., oversampling of some LADs, to provide reliable estimates for these LADs | The OHS did not include design weights or non-response weights. However, only the main survey sample was obtained, so |

CDHS: Children’s Dental Health Survey; EA: Education Authority; LAD: Local Authority District; NS-SEC: National Statistics Socioeconomic Classification; UA: Unitary Authority
### Assessments of goodness-of-fit

$R^2$ measures are goodness-of-fit measures that assess a model’s predictive power, i.e., they assess how well the dependent variable can be predicted based on the values of the explanatory variables:

- In OLS regressions, $R^2$ values can be interpreted as the amount of variation in the dependent variable that is explained by the model. $R^2$ is calculated by subtracting from 1 the sum of the squared residuals (representing the variability in the dependent variable that is not predicted by the model) divided by the sum of the squared differences between the observed values and their mean (representing the total variability in the dependent variable). $R^2$ ranges from 0 to 1, with a value of 0 signifying that the model explains none of the variation in the dependent and a value of 1 indicating that all of the variation is explained by the model. Direct comparisons of $R^2$ values are only possible between nested models, where the same dependent variable and data set are used, and all terms in the less complex model occur in the more complex model. For OLS regressions, Stata 13 reports the $R^2$ values adjusted for the number of explanatory variables in the model. This is useful when comparing the predictive power of the sets of models used in the analyses of assessment practices and treatment outcomes because confounding and mediator variables are included in these nested models. (That is, it is useful because unadjusted $R^2$ values do not decrease when an additional explanatory variable is added to a model, even if the additional variable does not improve the model fit, so a model with additional explanatory variables may appear to have a better fit according to the unadjusted $R^2$ values simply because it has more terms.)

- For logistic regression, there are a variety of pseudo-$R^2$ measures available that offer a comparable non-linear approach to providing evidence about how much variation in the dependent variable is explained by

<table>
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<tr>
<td>data</td>
<td>in order to facilitate local planning; however, these additional samples were not included in the data set. In addition, weights would allow adjustment for consent rate by schools (88%) and the consent rate associated with the 12-year-olds who were invited to be examined (74%).</td>
<td>weights adjusting for oversampling in some LADs were not required. In addition, the OHS ensured that appropriate proportions of children were selected from small, medium, and large schools in order to ensure the sample was representative of the distribution in the population. Lastly, it has been reported that the consent rate by schools and the consent rate associated with the 12-year-olds who were invited to be examined did not differ by IMD quintiles, which were obtained from the postcodes of both those who gave consent and those who did not give consent (Rooney et al., 2010). This meant that it was unnecessary to employ weighting to adjust for potential bias in the inclusion of children from different IMD quintiles.</td>
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</tbody>
</table>

IMD: Index of Multiple Deprivation; LAD: Local Authority District; NHS: National Health Service; OHS: Oral Health Survey; PCT: Primary Care Trust
the model. For example, Stata 13 automatically reports the widely-used McFadden’s pseudo-R² values for each logistic regression that does not use complex survey data. However, McFadden’s pseudo-R² is inapplicable to analyses of complex survey data that take into account survey design features (such as clustering and stratification) because it is based on the ratio of two log-likelihood values, and estimating likelihood values assumes that the observations are independently and identically distributed, which is not the case for complex survey data. Therefore, a pseudo-R² measure known as Efron’s R² was calculated for each of the logistic regressions. Efron’s R² is calculated in a similar way to the OLS R², by subtracting from 1 the sum of the squared residuals divided by the sum of the squared differences between the observed values and their mean. Like the OLS R², Efron’s R² ranges from 0 to 1, with higher values indicating a higher proportion of the variability explained by the model. There are no nested models in the logistic regression analyses, so there was no necessity to compare Efron’s R² values between models. If the adjusted F-tests (assessing whether each model fitted significantly better than a null model) for the logistic regressions were not statistically significant (at a level of 5%), this was noted in the results tables in Chapter 4, and no Efron’s R² values were presented.

3.4.9 Analysis-specific methods

3.4.9.1 Need and willingness to have treatment

The percentages of children with normative need, patient-defined need, and willingness to have treatment were calculated, as follows:

- Normative need among 12-year-olds (CDHS and OHS data)
  - IOTN DHC score of 4-5 and/or IOTN AC score of 6-10
  - Wearing appliance at the time of the dental examinations
- IOTN categories¹⁰ among the 10- to 17-year-olds having treatment (NHS activity data)
  - IOTN 5 – very great need
  - IOTN 4 – great need
  - IOTN 3.6-3.10 – moderate need
  - IOTN < 3.6 – need decided on a case-by-case basis

¹⁰ The NHS activity data were only used to calculate the proportions of those in treatment with each of the IOTN categories (rather than the proportion of those with normative need in the at-risk population) because the data set only contains the select group of patients who were referred to the NHS orthodontic service.
- Patient-defined need among 12-year-olds (OHS data)
  - Patient-defined need overall
  - Patient-defined need among those with no normative need
  - No patient-defined need among those with normative need
- Willingness to have treatment among 12-year-olds with patient-defined need and with normative need\(^\text{11}\) (OHS data)

Where the data sets represented probability samples of populations of interest (i.e., the CDHS and OHS data sets), 95% CIs were calculated. Several survey design features (which are detailed in Section 3.4.7.4) were considered when analysing the CDHS and OHS data, as the samples were not simple random samples.

**Associations with SEP**

In order to explore the associations between SEP and each of the dependent variables, the OHS and CDHS data were analysed using binary logistic regression models, as follows:

\[ Y_i^* = \beta_0 + \beta_1 X_i + \varepsilon \]

\[ Y_i = 1 \text{ if } Y_i^* > 0 \]

\[ Y_i = 0 \text{ otherwise} \]

where

\( Y_i^* \) is the latent variable and \( Y_i \) is the corresponding observed binary variable for observation \( i \) \((i = 1, ..., n)\) reflecting whether or not the child had:

- Normative need – IOTN DHC score of 4-5, IOTN AC score of 6-10, or wearing appliance at age 12 (CDHS data) \((3.1)\)
- Normative need – IOTN DHC score of 4-5, IOTN AC score of 6-10, or wearing appliance at age 12 (OHS data) \((3.2)\)
- Patient-defined need overall at age 12 (OHS data) \((3.3)\)

\(^{11}\) The proportion of 12-year-olds who were willing to have treatment among those who had normative need, but not necessarily patient-defined need, could not be calculated because only children with patient-defined need were asked about their willingness to have treatment.
• Patient-defined need among those with no normative need at age 12 (OHS data) (3.4)
• No patient-defined need among those with normative need at age 12 (OHS data) (3.5)
• Willingness to have treatment among those with normative need and patient-defined need at age 12 (OHS data) (3.6)

$\beta_0$ is the intercept

$X_i$ is a vector of explanatory variables (dummy SEP variables) for observation $i$ ($i = 1, \ldots, n$) and $\beta_1$ is a vector of corresponding coefficients

$\varepsilon$ is the random error variable; $\varepsilon \sim \text{standard logistic distribution}$

A statistical significance level of 5% was used, but where statistical significance of 1% was achieved, this was noted, and the survey design features (detailed in Section 3.4.7.4) were considered.

The associations between SEP and both IOTN categories (5, 4, 3.6-3.10, and < 3.6) and IOTN AC scores (1-10) were also explored, as follows:

• NHS activity data set: Inferential statistical modelling was unnecessary when analysing the associations between SEP and the IOTN categories among the 10- to 17-year-olds having treatment, as there was no sampling error to account for. Therefore, descriptive statistics consisting of the percentages of children in each IOTN category, by SEP group, were calculated. The results of these analyses were used to inform the use of IOTN categories (which reflect the severity of malocclusion) as a potential confounding variable in the subsequent analyses of SEP and assessment procedures.

• CDHS and OHS data sets: Unlike the NHS activity data set, the two population-based survey data sets did not include data on the IOTN categories, as the values of the IOTN DHC score variable were recorded as 0 (for IOTN DHC scores of 1-3) or 1 (for IOTN DHC scores of 4-5). However, the CDHS and OHS data sets both collected data on IOTN AC scores. Consequently, analyses were carried out using the OHS and CDHS data to explore whether or not there was an association between SEP and IOTN AC scores. These analyses were carried out using multinomial logistic regression, with a statistical significance level of 5%. The results of these analyses were used to inform the use of IOTN AC scores (which reflect the severity of malocclusion and treatment complexity) as a potential confounding variable in the subsequent analyses of SEP and treatment outcome.
3.4.9.2 Treatment utilisation

The percentages of children utilising orthodontic treatment were calculated, as follows:

- Utilisation among 10- to 17-year-olds in the North West (NHS activity data and 2011 census data)
  - Documented NHS orthodontic treatment claims awarded 21 UOAs (i.e., the number of UOAs awarded for orthodontic treatment of 10- to 17-year-olds) (described below*)
- Utilisation among 12-year-olds in the North West (OHS data)
  - Patient-reported NHS/private\(^{12}\) orthodontic treatment
- Utilisation among those aged 12 or under in the UK and among those aged 15 or under in the UK (CDHS data)
  - Patient-reported NHS/private\(^{13}\) orthodontic treatment
  - Parent-reported NHS/private\(^{14}\) orthodontic treatment
  - Parent-reported private orthodontic treatment

As in the analyses of need and willingness to have treatment, where the data sets represented probability samples of populations of interest (i.e., CDHS and OHS data sets), the 95% CIs were calculated, and the same survey design features (detailed in Section 3.4.7.4) were considered.

* In order to estimate the percentage of 10- to 17-year-olds who had NHS orthodontic treatment in the North West (using NHS activity data and 2011 census data), the following method was used:

- The mean annual utilisation percentage for each age group (10, 11,..., 16, and 17) was determined as follows:
  - Firstly, for each year (2008-2012), the number of treatments for each age group (shown in Table 3.13) was calculated as a percentage of each denominator population, i.e., the numbers of children in each age group (10, 11,..., 16, and 17) in the population from which the treated patients came,

\(^{12}\) The data on orthodontic treatment used in this analysis did not differentiate between NHS and private orthodontic treatment. (The data were based on children who were wearing an appliance at the time of the dental examinations, which encompasses both NHS and/or private orthodontic treatment).

\(^{13}\) The data on orthodontic treatment used in this analysis did not differentiate between NHS and private orthodontic treatment. (The data were based on answers of ‘Yes’ to the question ‘Have you got an orthodontic brace or appliance?’, which encompasses both NHS and/or private orthodontic treatment).

\(^{14}\) The data on orthodontic treatment used in this analysis did not differentiate between NHS and private orthodontic treatment. (The data were based on the answer ‘A brace fitted or adjusted’ to the survey question ‘Has your child ever had any of the following treatments?’, which encompasses both NHS and/or private orthodontic treatment. The same answer – ‘A brace fitted or adjusted’ – to a secondary survey question asking ‘What treatment did your child have that you paid for?’ does not clarify whether the answer to the first question implies NHS treatment).
according to 2011 census data (shown in Table 3.14). (It was assumed that this population was stable and therefore that it represented the population during each of the five years covered by the NHS activity data set (2008-2012)).

- Secondly, the mean of each of these age-specific annual percentages (over the years 2008 to 2012) was calculated (as shown in Table 3.15).
- Subsequently, an estimate of the cumulative utilisation percentage for those who had NHS orthodontic treatment from between the ages of 10 and 17 was calculated by summing the mean utilisation percentages at ages 10, 11, 12, 13, 14, 15, 16, and 17 (as shown in the last column of Table 3.15).

Table 3.13: Number of NHS orthodontic treatments for patients from the North West, by age and year of treatment

<table>
<thead>
<tr>
<th>Age</th>
<th>Number of treatments</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>2008</td>
</tr>
<tr>
<td>10</td>
<td>870</td>
</tr>
<tr>
<td>11</td>
<td>2,786</td>
</tr>
<tr>
<td>12</td>
<td>4,771</td>
</tr>
<tr>
<td>13</td>
<td>5,244</td>
</tr>
<tr>
<td>14</td>
<td>3,994</td>
</tr>
<tr>
<td>15</td>
<td>2,326</td>
</tr>
<tr>
<td>16</td>
<td>1,143</td>
</tr>
<tr>
<td>17</td>
<td>597</td>
</tr>
</tbody>
</table>

NHS: National Health Service
Data source: NHS activity data set

Table 3.14: Population in the North West in 2011, by age

<table>
<thead>
<tr>
<th>Age</th>
<th>Population in the North West in 2011</th>
</tr>
</thead>
<tbody>
<tr>
<td>10</td>
<td>77,255</td>
</tr>
<tr>
<td>11</td>
<td>79,207</td>
</tr>
<tr>
<td>12</td>
<td>82,454</td>
</tr>
<tr>
<td>13</td>
<td>83,281</td>
</tr>
<tr>
<td>14</td>
<td>87,472</td>
</tr>
<tr>
<td>15</td>
<td>86,769</td>
</tr>
<tr>
<td>16</td>
<td>86,866</td>
</tr>
<tr>
<td>17</td>
<td>89,868</td>
</tr>
</tbody>
</table>

Data source: 2011 census data set
Table 3.15: NHS orthodontic treatment utilisation in the North West, by age

<table>
<thead>
<tr>
<th>Age</th>
<th>Utilisation percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>10</td>
<td>1.1</td>
</tr>
<tr>
<td>11</td>
<td>3.5</td>
</tr>
<tr>
<td>12</td>
<td>5.8</td>
</tr>
<tr>
<td>13</td>
<td>6.3</td>
</tr>
<tr>
<td>14</td>
<td>4.6</td>
</tr>
<tr>
<td>15</td>
<td>2.7</td>
</tr>
<tr>
<td>16</td>
<td>1.3</td>
</tr>
<tr>
<td>17</td>
<td>0.7</td>
</tr>
</tbody>
</table>

Data sources: NHS activity data set and 2011 census data set

Associations with SEP

In order to explore the associations between SEP and utilisation, the OHS and CDHS data were analysed using binary logistic regression models, as follows:

\[ Y_i^* = \beta_0 + \beta_1 X_i + \epsilon \]

\[ Y_i = 1 \text{ if } Y_i^* > 0 \]

\[ Y_i = 0 \text{ otherwise} \]

where

\( Y_i^* \) is the latent variable and \( Y_i \) is the corresponding observed binary variable for observation \( i (i = 1, ..., n) \) reflecting whether or not the child had:

- Patient-reported NHS/private orthodontic treatment among those aged 12 in the North West (OHS data) \( (3.7) \)
- Patient-reported NHS/private orthodontic treatment among those aged 12 and under in the UK (CDHS data) \( (3.8) \)
- Parent-reported NHS/private orthodontic treatment among those aged 12 and under in the UK (CDHS data) \( (3.9) \)
• Patient-reported NHS/private orthodontic treatment among those aged 15 and under in the UK (CDHS data) (3.10)

• Parent-reported NHS/private orthodontic treatment among those aged 15 and under in the UK (CDHS data) (3.11)

$\beta_0$ is the intercept

$X_i$ is a vector of explanatory variables (dummy SEP variables) for observation $i$ ($i = 1, \ldots, n$) and $\beta_1$ is a vector of corresponding coefficients

$\varepsilon$ is the random error variable; $\varepsilon \sim$ standard logistic distribution

A statistical significance level of 5% was used, but where statistical significance of 1% was achieved, this was noted, and survey design features (detailed in Section 3.4.7.4) were considered.

Inferential statistical modelling was unnecessary when analysing the NHS activity data, as there was no sampling error to account for. Instead, the association between SEP and the percentages of 10- to 17-year-olds utilising treatment (calculated using the NHS activity data along with the 2011 census data) was explored by using a bar chart of the SEP-specific utilisation percentages.

In addition, the associations in both the NHS activity data set and the OHS data set between PCT-level utilisation and the following two PCT-level variables were explored by graphing the data (using bar charts to depict the utilisation data and line graphs to depict the PCT-level variables):

• The percentage of children attending dental check-ups, by PCT, in terms of the percentage of those aged 17 and under, by PCT, who were seen by an NHS GDP during a two-year period (1 April 2009 to 31 March 2011)

• The supply of orthodontic clinicians, by PCT, in terms of a) the total number of dentists, by PCT, on NHS contracts who provided UOAs per 1,000 10- to 17-year-old (as at 31 March 2009), and the number who were working under b) GDS contracts, and c) PDS, or mixed PDS-GDS contracts

These PCT-level analyses aimed to explore whether associations with SEP, in part, reflect SEP-associated differences in the attendance for dental check-ups (which act as a gateway for children to be referred to the NHS orthodontic service) and/or the supply of orthodontic clinicians.
3.4.9.3 Assessment procedures

The percentages of children with the following assessment procedures were calculated:

- Use of one or more ‘assessment & review’ appointments per patient among those who started treatment from 2010-2012 (NHS activity data)
- Use of two or more ‘assessment & review’ appointments per patient among those who started treatment from 2010-2012 (NHS activity data)
- Early access (i.e., early first assessment) at ages 9-10 among those aged 9 and over who were assessed from 2008-2012 (NHS activity data)
- Use of an ‘assessment & refuse’ appointment among those with IOTN scores of ≥ 3.6 and who were refused or received treatment from 2008-2012 (NHS activity data)

Associations with SEP

Inferential statistical modelling was unnecessary when analysing the associations between SEP and the assessment procedures, as there was no sampling error to account for. However, LPMs were utilised to calculate the SEP-related mean changes in the predicted probabilities of each of the assessment procedures.

Initially, unadjusted analyses were carried out, then the analyses were adjusted for potential confounding variables, i.e., a) IOTN categories alone, and b) IOTN categories, gender, and age (except for the analysis involving early access at ages 9-10, which was not adjusted for age). The models were constructed as follows:

\[ E(Y_i|X_i) = Pr(Y_i = 1 | X_i) = \beta_0 + \beta_1 X_i \]

where

\[ Y_i \] is the binary dependent variable for observation \( i \) \( (i = 1, \ldots, n) \) reflecting whether or not the patient had:

- One or more ‘assessment & review’ appointments among those who started treatment from 2010-2012 (NHS activity data) \( (3.12) \)
- Two or more ‘assessment & review’ appointments among those who started treatment from 2010-2012 (NHS activity data) \( (3.13) \)
- Early access (i.e., early first assessment) at ages 9-10 among those who were aged 9 and over who were assessed from 2008-2012 (NHS activity data) \( (3.14) \)
• An ‘assessment & refuse’ appointment among those with IOTN scores of ≥ 3.6 among those who were refused or received treatment from 2008-2012 (NHS activity data)

\[ X_i \] is a vector of explanatory variables (dummy SEP variables, and potential confounding variables, as described above) for observation \( i \) \((i = 1, \ldots, n)\) and \( \beta_1 \) is a vector of corresponding coefficients

\( \beta_0 \) is the intercept

3.4.9.4 Treatment outcomes

The percentages of patients with the following treatment outcomes were calculated:

- Treatment discontinuations (NHS activity data)
  - Total (initiated by orthodontic clinicians or patients)
  - Initiated by orthodontic clinicians
  - Initiated by patients
- IOTN outcome scores (NHS activity data)
  - RPTN
  - No RPTN
  - Missing IOTN outcome scores
    - Incomplete IOTN outcome score fields
    - Unreported treatment finishes

The percentages of patients with treatment discontinuations were calculated for those who started treatment in 2008 and had NHS activity notification forms returned (within the subsequent four years) to indicate that treatment had finished. This is because treatment durations are associated with treatment discontinuation (i.e., treatments of short duration are more likely to reflect treatment discontinuations than those of long duration), and the sample of patients that both started and finished treatment over the five years covered by the NHS activity data set would be likely to be biased, missing out more of the treatments of long duration than those of short duration.

Two analyses of the IOTN outcome scores were carried out:

- Firstly, the percentages of patients with and without RPTN were calculated on the basis of those who started treatment in 2008 whose IOTN outcome scores were reported (so that this analysis could focus on
patients who had been confirmed to have either RPTN or no RPTN rather than including those with missing IOTN outcome scores).

- Secondly, the percentages of patients with and without RPTN were calculated on the basis of all those who started treatment in 2008 (along with the percentages of patients with incomplete IOTN outcome score fields and unreported treatment finishes).

**Associations with SEP**

As for the analyses of assessment procedures, inferential statistical modelling was unnecessary when analysing the associations between SEP and treatment outcomes. However, LPMs were used to calculate the SEP-related mean changes in the predicted probabilities of each of the treatment outcomes.

Initially, unadjusted analyses were carried out. Secondly, the analyses were adjusted for potential confounding variables, i.e., a) IOTN AC scores alone, and b) IOTN AC scores, gender, and age (in order to remove any spurious association between SEP and the dependent variables due to IOTN AC scores, gender, and age). Thirdly, the analysis involving RPTN was adjusted for all the potential confounding variables and the potential mediator variables, i.e., treatment discontinuation and requirement for a replacement appliance (in order to explore how the association between SEP and RPTN is altered when variables that are potentially in the causal pathway were taken into account). The models were constructed as follows:

\[ E(Y_i | X_i) = \Pr(Y_i = 1 | X_i) = \beta_0 + \beta_1 X_i \]

where

- \( Y_i \) is the binary dependent variable for observation \( i \) (\( i = 1,.., n \)) reflecting whether or not the patient had:
  - Treatment discontinuation (initiated by orthodontic clinicians or patients) among those who started treatment in 2008 and had NHS activity notification forms returned (within the subsequent four years) to indicate that treatment had finished (NHS activity data) \( \text{(3.16)} \)
  - RPTN among those who started treatment in 2008 and had reported IOTN outcome scores (NHS activity data) \( \text{(3.17)} \)

\( X_i \) is a vector of explanatory variables (dummy SEP variables, and potential confounding and mediator variables, as described above) for observation \( i \) (\( i = 1,.., n \)) and \( \beta_1 \) is a vector of corresponding coefficients
\( \beta_0 \) is the intercept

3.4.9.5 Differences between practices/orthodontic clinicians

Using the NHS activity data, the differences between practices/orthodontic clinicians regarding various process and outcome indicators (i.e., a) the percentage of treated patients with two or more ‘assessment & review’ appointments per practice, b) the percentages of treatment discontinuations per orthodontic clinician (initiated by orthodontic clinicians or patients, by orthodontic clinicians, and by patients), and c) the percentage of patients with RPTN per orthodontic clinician) were initially explored using scatter diagrams. These graphs differentiated between the type of NHS contract (PDS, GDS, and TDS contracts) that each practice/orthodontic clinician worked under, and the sizes of the practices’/orthodontic clinicians’ NHS caseloads were plotted against the x-axes.

Secondly, the percentages of patients with the following were calculated (as described in Section 3.4.9.4), by type of NHS contract:

- Assessment procedures (NHS activity data)
  - Two or more ‘assessment & review’ appointments
- Treatment discontinuations (NHS activity data)
  - Total (initiated by orthodontic clinicians or patients)
  - Initiated by orthodontic clinicians
  - Initiated by patients
- IOTN outcome scores (NHS activity data)
  - RPTN
  - No RPTN
  - Missing IOTN outcome scores
    - Incomplete IOTN outcome score fields
    - Unreported treatment finishes

3.4.9.6 Costs

The costs of the orthodontic service to the NHS (i.e., payments to orthodontic providers for carrying out UOAs) were calculated using the NHS activity data. The costs were based on a mean value per UOA of £61 in England,
from 2008-2012 (for contracts that only included the provision of orthodontic services) (Wise, 2015), and the fact that assessments are awarded 1 UOA and courses of treatment for 10- to 17-year-olds are awarded 21 UOAs.

Firstly, the cost analyses provide an overview of the relative costs of the various aspects of NHS orthodontic care (i.e., ‘assessment & review’ appointments, ‘assessment & refuse’ appointments, and courses of treatment). Secondly, the costs analyses elucidate the costs of potential inefficiencies in the service by calculating the costs related to assessment procedures and the various treatment outcomes. Table 3.16 shows which subsets of patients each of the cost analyses was restricted to (largely in order to mitigate the risk of censored data, where the values of a variable may be only be partially known).

**Table 3.16: Subsets of patients in the NHS activity data set used in cost analyses**

<table>
<thead>
<tr>
<th>Costs analysis</th>
<th>Subset of patients used in analysis</th>
<th>Details</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Overview of costs of the various aspects of the NHS primary care orthodontic service</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>‘Assessment &amp; review’ appointments, for those aged 17 and under</td>
<td>Patients who were assessed in 2008</td>
<td>In order to give an overview of the relative costs of the different aspects of the NHS orthodontic service, data on the annual costs of assessments and treatments in 2008 were calculated (so there could be a direct comparison of the annual costs). The denominator populations were the numbers of a) 0- to 17-year-olds and b) 10- to 17-year-olds in the North West in 2011 (the year of the census), for the analyses of assessments and treatments, respectively.</td>
</tr>
<tr>
<td>‘Assessment &amp; refuse’ appointments, for those aged 17 and under</td>
<td>Patients who were assessed in 2008</td>
<td></td>
</tr>
<tr>
<td>Courses of treatment, for 10- to 17-year-olds</td>
<td>Patients who started treatment in 2008</td>
<td></td>
</tr>
<tr>
<td><strong>Costs of potential inefficiencies in the NHS primary care orthodontic service</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>‘Assessment &amp; review’ appointments, for those aged 17 and under - One or more ‘assessment &amp; review’ appointments</td>
<td>Patients who started treatment in 2012</td>
<td>In order to calculate the costs of the different assessment procedures that accrued from 2008-2012 for an annual cohort of patients, the data were restricted to patients who started treatment in 2012 (in order to ensure that all the relevant assessment data were available in the data set). The denominator populations were a) the number of 0- to 17-year-olds in the North West in 2011, for the first and third analyses, and b) the numbers of 9-, 10-, 11-, and 9- to 11-year-olds in the North West in 2011, for the second analysis.</td>
</tr>
<tr>
<td>- Two or more ‘assessment and review’ appointments</td>
<td></td>
<td></td>
</tr>
<tr>
<td>‘Assessment and review’ appointments associated with early access (i.e., early first assessment) at ages 9, 10, 11, and 9-11</td>
<td>Patients who started treatment in 2012</td>
<td></td>
</tr>
<tr>
<td>‘Assessment &amp; refuse’ appointments among those with IOTN scores of ≥ 3.6, for those aged 17 and under</td>
<td>Patients who started treatment in 2012</td>
<td></td>
</tr>
<tr>
<td>Treatment discontinuations, for 10- to 17-year-olds - Initiated by orthodontic clinicians or patients</td>
<td>Patients who started treatment in 2008</td>
<td>In order to calculate the costs of the treatments (categorised by treatment outcome) of an annual cohort of patients, the data were restricted to patients who started treatment in 2008 (in order to ensure that treatment outcome data were available in the data set). The denominator population was the number of 10- to 17-year-olds in the</td>
</tr>
<tr>
<td>Costs analysis</td>
<td>Subset of patients used in analysis</td>
<td>Details</td>
</tr>
<tr>
<td>---------------</td>
<td>-----------------------------------</td>
<td>---------</td>
</tr>
<tr>
<td>Overview of costs of the various aspects of the NHS primary care orthodontic service</td>
<td>North West in 2011.</td>
<td></td>
</tr>
<tr>
<td>- Initiated by patients</td>
<td>Patients who started treatment in 2008</td>
<td></td>
</tr>
<tr>
<td>IOTN outcome scores, for 10- to 17-year-olds</td>
<td>- RPTN</td>
<td>- No RPTN</td>
</tr>
<tr>
<td>- Incomplete IOTN outcome score fields</td>
<td>- Unreported treatment finishes</td>
<td></td>
</tr>
</tbody>
</table>

IOTN: Index of Orthodontic Treatment Need; NHS: National Health Service; RPTN: residual post-treatment need

The costs are presented as totals (for all SEP groups) and by SEP group, in order to give an indication of the differential allocation of resources between SEP groups. As the differences would partly reflect the fact that children from the most deprived groups are overrepresented in the North West (Young and Sly, 2010), the approximate costs per head of the population are also provided.

3.5 Summary

Two population-based survey data sets (the 2003 CDHS and the 2008-2009 OHS data set) and one activity data set (containing 2008-2012 NHS orthodontic activity data) were used to investigate the levels of need and willingness to have orthodontic treatment, treatment utilisation, assessment procedures, and treatment outcomes. In addition, associations between SEP and the orthodontic variables were explored using LPMs and logistic regression, and the costs of the orthodontic service to the NHS were calculated.
4 RESULTS

4.1 Overview

This chapter presents brief descriptions of the three main data sets used in the analyses followed by sections covering the findings for each of the research questions.

4.2 Data

The 2003 UK CDHS included data on random samples of 3,129 12-year-olds and 3,174 15-year-olds. Of these 12- and 15-year-olds, 2,595 and 2,142 consented to be examined in school, respectively, and 785 and 612 had SEP data (i.e., National Statistics Socioeconomic Class (NS-SEC) data), respectively. (The large difference between the number of children who were examined and the number with SEP data is due to the fact that questionnaires collecting SEP data were only sent to the parents of half the examined children and there was a 61% response rate, across all ages of children in the survey.)

The 2008-2009 North West data set of the NHS Dental Epidemiology Programme for England OHS included data on a random sample of 19,910 12-year-olds, all of whom had SEP data (i.e., IMD data).

The 2008-2012 North West data set from NHS orthodontic activity forms included data on 227,896 people aged 17 and under, 222,944 of whom were 10- to 17-year-olds. Of those aged 17 and under, 212,863 had SEP data (i.e., IMD data); 6.4% did not, due to their postcodes being recorded incorrectly.

4.3 Need and willingness to have treatment

4.3.1 Research question

What is the prevalence of a) normative need for orthodontic treatment, b) patient-defined need for orthodontic treatment, and c) willingness to have orthodontic treatment, and are they associated with SEP?
4.3.2 Results

Table 4.1 shows the percentages of children estimated to have normative need (defined in this analysis as an IOTN DHC score of 4-5 and/or an IOTN AC score of 6-10), patient-defined need, and willingness to have treatment.

The percentages of 12-year-olds who had normative need were 38.5% (95% CI: 36.1% - 41.0%) and 40.1% (95% CI: 39.5 - 40.8%), according to data from the CDHS and OHS, respectively. A further 7.9% (95% CI: 6.5% - 9.3%) of 12-year-olds in the CDHS, and a further 6.7% (95% CI: 6.5% - 7.2%) of 12-year-olds in the OHS, were wearing appliances at the time of the dental examinations (and therefore did not have their IOTN scores assessed).

However, the percentages of 12-year-olds and 15-year-olds who had normative need included some children who had already received treatment in the past and had RPTN. As many as 43.7% (95% CI: 32.2% - 55.4%) of 12-year-olds in the CDHS who had received treatment in the past had RPTN (n.b. 4.7% (95% CI: 3.7% - 5.8%) of the 12-year-olds had finished treatment). In addition, 16.1% (95% CI: 11.4% - 20.8%) of 15-year-olds in the CDHS who had received treatment in the past had RPTN (n.b. 8.2% (95% CI: 16.2% - 20.5%) of the 15-year-olds had finished treatment). In order to avoid this issue, a further analysis was carried out to calculate the percentages of children with normative need who had not received treatment in the past (and were not in treatment at the time of the dental examinations). This calculation was only applicable to the CDHS data, as the OHS did not collect data on whether the children had received treatment in the past. This further analysis showed that the percentages of 12-year-olds and 15-year-olds in the CDHS with normative need were 36.4% (95% CI: 33.9% - 38.8%) and 20.9% (95% CI: 18.7% - 23.0%), respectively, if those who had received treatment in the past (or were in treatment at the time of the dental examinations) were considered not to have normative need. These percentages are slightly lower than the percentages of those with normative need that include those who had received treatment in the past. However, some of those who had received treatment in the past may have received interceptive treatment rather than a comprehensive course of treatment.

As shown in Table 4.1, similar percentages of males and females in the CDHS had normative need at age 12 and 15, with no statistically significant differences between them.

Among the 10- to 17-year-olds receiving treatment, the NHS activity data indicated that 18.2% (19,347) had IOTN scores of 5; 74.2% (78,890) had IOTN scores of 4; 7.1% (7,552) had IOTN scores of 3.6-3.10; and 0.5% (498) had IOTN scores of < 3.6. As shown in Table 4.1, the distribution was similar for males and females.

According to data from the OHS, the percentage of 12-year-olds who had patient-defined need overall was 50.1% (95% CI: 49.3% - 50.9%). Among those who had no normative need, the percentage of 12-year-olds who had
patient-defined need was 34.8% (95% CI: 33.9% -35.7%) and, among those who had normative need, the percentage of 12-year-olds who did not have patient-defined need was 24.6% (95% CI: 23.6% - 25.7%).

According to data from the OHS, the percentage of 12-year-olds who were willing to have treatment among those who had both patient-defined need and normative need was 95.3% (95% CI: 94.7% - 95.9%).
<table>
<thead>
<tr>
<th>Data set</th>
<th>Variable</th>
<th>Total</th>
<th>Males</th>
<th>Females</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Percentage (and actual figure)</td>
<td>95% CI</td>
<td>Percentage (and actual figure)</td>
</tr>
<tr>
<td>CDHS data set – UK</td>
<td>Normative need among 12-year-olds CDHS: n = 2,585 OHS: n = 19,816</td>
<td>IOTN DHC score of 4-5 and/or IOTN AC score of 6-10</td>
<td>38.5</td>
<td>36.1 - 41.0</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Wearing appliance at the time of the dental examinations</td>
<td>7.9</td>
<td>6.5 - 9.3</td>
</tr>
<tr>
<td>OHS data set – North West</td>
<td></td>
<td>IOTN DHC score of 4-5 and/or IOTN AC score of 6-10</td>
<td>40.1</td>
<td>39.5 - 40.8</td>
</tr>
<tr>
<td>OHS data set – North West</td>
<td></td>
<td>Wearing appliance at the time of the dental examinations</td>
<td>6.7</td>
<td>6.5 - 7.2</td>
</tr>
<tr>
<td>NHS activity data set – North West</td>
<td>IOTN categories among 10- to 17-year-olds having treatment n = 106,287</td>
<td>IOTN 5 – very great need</td>
<td>18.2 (19,347)</td>
<td>-1</td>
</tr>
<tr>
<td></td>
<td></td>
<td>IOTN 4 – great need</td>
<td>74.2 (78,890)</td>
<td>-1</td>
</tr>
<tr>
<td></td>
<td></td>
<td>IOTN 3.6-3.10 – moderate need</td>
<td>7.1  (7,552)</td>
<td>-1</td>
</tr>
<tr>
<td></td>
<td></td>
<td>IOTN &lt; 3.6 – need decided on a case-by-case basis</td>
<td>0.5 (498)</td>
<td>-1</td>
</tr>
<tr>
<td>OHS data set – North West</td>
<td>Patient-defined need among 12-year-olds n = 16,406</td>
<td>Patient-defined need overall</td>
<td>50.1</td>
<td>49.3 - 50.9</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Patient-defined need among those with no normative need n = 10,233</td>
<td>34.8</td>
<td>33.9 - 35.7</td>
</tr>
<tr>
<td></td>
<td></td>
<td>No patient-defined need among those with normative need</td>
<td>24.6</td>
<td>23.6 - 25.7</td>
</tr>
<tr>
<td>Data set</td>
<td>Variable</td>
<td>Total</td>
<td>Males</td>
<td>Females</td>
</tr>
<tr>
<td>----------</td>
<td>----------</td>
<td>-------</td>
<td>-------</td>
<td>---------</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Percentage (and actual figure(^1))</td>
<td>95% CI</td>
<td>Percentage (and actual figure(^1))</td>
</tr>
<tr>
<td></td>
<td></td>
<td>95.3</td>
<td>94.7 - 95.9</td>
<td>-</td>
</tr>
</tbody>
</table>

\( n = 6,173 \)

| Willingness to have treatment among 12-year-olds with patient-defined need and with normative need | 95.3 | 94.7 - 95.9 | - | - | - | - |

\( n = 4,439 \)

\(^1\) The actual figures of children in the sample have not been added for the analyses of OHS and CDHS data because the actual numbers do not provide information on the actual numbers in the relevant populations of the North West/UK. However, the actual figures of children are included for the analyses of NHS activity data because these numbers are informative as the children represent all the children in the relevant populations (i.e., the entire population rather than a random sample was used).

\(^2\) There is no sampling error because the entire population was included rather than a random sample.

AC: Aesthetic Component; CDHS: Children’s Dental Health Survey; CI: confidence interval; DHC: Dental Health Component; IOTN: Index of Orthodontic Treatment Need; NHS: National Health Service; OHS: Oral Health Survey; UK: United Kingdom
Table 4.2 and Table 4.3 show the ORs from the binary logistic regression models analysing the associations of SEP with need and willingness to have treatment (i.e., models 3.1 to 3.6). The Efron’s $R^2$ values for most of the models are low (and for the remainder, the Efron’s $R^2$ values were not reported because the adjusted F-tests were not significant), indicating that the proportion of the variability in the dependent variables explained by the models is low.

According to data from the OHS, those in the most deprived groups were more likely to have patient-defined need overall compared to those in the least deprived group (OR for IMD quintile 1: 1.20, 95% CI: 1.09 - 1.33, and OR for IMD quintile 2: 1.13, 95% CI: 1.01 - 1.26). In addition, among those who did not have normative need in the OHS, those in the most deprived groups were more likely to have patient-defined need compared to those in the least deprived group (OR for IMD quintile 1: 1.36, 95% CI: 1.19 - 1.55, and OR for IMD quintile 2: 1.29, 95% CI: 1.11 - 1.49). Lastly, among those who had both patient-defined need and normative need in the OHS, those in the most deprived group were less likely to report willingness to have treatment compared to those in the least deprived group (OR: 0.47, 95% CI: 0.28 - 0.79).

There were no statistically significant differences between the least deprived group and the other SEP groups regarding normative need (defined as an IOTN DHC score of 4-5 and/or an IOTN AC score of 6-10, combined with those wearing appliances at the time of the dental examinations) among 12-year-olds, according to both the CDHS and OHS data. In addition, there were no statistically significant differences between the least deprived group and other SEP groups regarding patient-defined need among 12-year-olds who had normative need, according to the OHS data.

Table 4.2: Need, by SEP

<table>
<thead>
<tr>
<th>Data set</th>
<th>Variable</th>
<th>ORs (and 95% CIs) for NS-SEC categories</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Reference category: category 1 (least deprived)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2</td>
</tr>
<tr>
<td>CDHS data set – UK</td>
<td>Normative need among 12-year-olds n = 781</td>
<td>IOTN DHC score of 4-5 and/or IOTN AC score of 6-10, or wearing appliance at the time of the dental examinations (Model 3.1, adjusted F-test p-value: 0.44)</td>
</tr>
</tbody>
</table>

AC: Aesthetic Component; CDHS: Children’s Dental Health Survey; CI: confidence interval; DHC: Dental Health Component; IOTN: Index of Orthodontic Treatment Need; NS-SEC: National Statistics Socioeconomic Classification; OR: odds ratio; SEP: socioeconomic position; UK: United Kingdom

*p<0.05; **p<0.01 (there were no significant differences in the analysis)
Table 4.3: Need and willingness to have treatment, by SEP

<table>
<thead>
<tr>
<th>Data set</th>
<th>Variable</th>
<th>ORs (and 95% CIs) for IMD quintiles</th>
<th>Reference category: IMD quintile 5 (least deprived)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>1 (most deprived)</td>
<td>2</td>
</tr>
<tr>
<td>OHS data set – North West</td>
<td>Normative need among 12-year-olds</td>
<td>0.95 (0.87 - 1.04)</td>
<td>0.95 (0.86 - 1.05)</td>
</tr>
<tr>
<td></td>
<td>IOTN DHC score of 4-5 and/or IOTN AC score of 6-10, or wearing appliance at the time of the dental examinations (Model 3.2, adjusted F-test p-value: 0.28)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Patient-defined need overall n = 16,406 (Model 3.3, adjusted F-test p-value: 0.00, Efron’s R²: 0.002)</td>
<td>1.20** (1.09 - 1.33)</td>
<td>1.13* (1.01 - 1.26)</td>
</tr>
<tr>
<td></td>
<td>Patient-defined need among those with no normative need n = 10,233 (Model 3.4, adjusted F-test p-value: 0.00, Efron’s R²: 0.005)</td>
<td>1.36** (1.19 - 1.55)</td>
<td>1.29** (1.11 - 1.49)</td>
</tr>
<tr>
<td></td>
<td>No patient-defined need among those with normative need n = 6,173 (Model 3.5, adjusted F-test p-value: 0.89)</td>
<td>1.06 (0.88 - 1.28)</td>
<td>1.10 (0.89 - 1.35)</td>
</tr>
<tr>
<td></td>
<td>Willingness to have treatment among 12-year-olds with patient-defined need and with normative need n = 4,439 (Model 3.6, adjusted F-test p-value: 0.03, Efron’s R²: 0.002)</td>
<td>0.47** (0.28 - 0.79)</td>
<td>0.58 (0.33 - 1.01)</td>
</tr>
</tbody>
</table>

AC: Aesthetic Component; CI: confidence interval; DHC: Dental Health Component; IMD: Index of Multiple Deprivation; IOTN: Index of Orthodontic Treatment Need; OHS: Oral Health Survey; OR: odds ratio; SEP: socioeconomic position

*p<0.05; **p<0.01

Table 4.4 shows how the IOTN categories (5, 4, 3.6-3.10, and < 3.6) varied with SEP, according to the NHS activity data. These data indicate that there were small differences between SEP groups, e.g., 6.3% (1,939) of those from the most deprived group had IOTN DHC scores of 3.6-3.10, but 7.6% (1,939) of those from the least deprived group had IOTN DHC scores of 3.6-3.10.
Table 4.4: IOTN categories, by SEP

<table>
<thead>
<tr>
<th>Data set</th>
<th>Variable</th>
<th>Percentage (and actual figure) in each IMD quintile</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>All</td>
<td>1 (most deprived)</td>
</tr>
<tr>
<td>NHS activity data set – North West</td>
<td>IOTN categories among 10- to 17-year-olds having treatment n = 106,287</td>
<td>18.2 (19,347)</td>
</tr>
<tr>
<td></td>
<td>IOTN 5 – very great need</td>
<td>74.2 (78,890)</td>
</tr>
<tr>
<td></td>
<td>IOTN 4 – great need</td>
<td>7.1 (7,552)</td>
</tr>
<tr>
<td></td>
<td>IOTN &lt; 3.6 – need decided on a case-by-case basis</td>
<td>0.5 (498)</td>
</tr>
</tbody>
</table>

IMD: Index of Multiple Deprivation; IOTN: Index of Orthodontic Treatment Need; NHS: National Health Service; SEP: socioeconomic position

Data source: NHS activity data set

The data from the two population-based survey data sets indicated mixed results regarding differences in IOTN AC scores between SEP groups. The relative-risk ratios from multinomial logistic regression models indicate multiple statistically significant differences between SEP groups when using the OHS data set but this is not confirmed when using the CDHS data set:

- According to the OHS data set, although the pattern of relative-risk ratios is complex, there are many instances where the relative-risk ratios are statistically significant. There is evidence that having IOTN AC scores just under the threshold of 6 is more likely for those from the most deprived group compared to the least deprived group, and there is evidence that having IOTN AC scores just over the threshold of 6 is less likely for those from the most deprived group compared to the least deprived group:
  - Using an IOTN AC score of 6 as the base outcome category, for those from the most deprived group relative to those from the least deprived group, the risk of having an IOTN AC score of 4 or 5 compared 6 is larger.
  - In contrast, for those from the most deprived group relative to those from the least deprived group, the risk of having an IOTN AC score of 8 compared to 6 is smaller.
  - The other relative-risk ratios for those from the most deprived group relative to those from the least deprived group were not statistically significant.
According to the CDHS data set, none of the relative-risk ratios were statistically significant for either 12-year-olds or 15-year-olds (this may be due to the fact that the sample sizes involved were smaller than the sample size of 12-year-olds in the OHS data set).

4.3.3 Summary

According to the CDHS and OHS data, over a third of children had normative need for orthodontic treatment at age 12 (38.5%, 95% CI: 36.1% - 41.0%, and 40.1%, 95% CI: 39.5 - 40.8%, respectively) and, according to OHS data, over a fifth of children had normative need for orthodontic treatment at age 15 (24.1%, 95% CI: 21.9% - 26.4%). The NHS activity data showed that three quarters of the 10- to 17-year-olds receiving treatment had IOTN scores of 4 (74.2%, 78,890), while a fifth had IOTN scores of 5 (18.2%, 19,347), and less than a tenth had IOTN scores of 3.6-3.10 (7.1%, 7,552). The OHS data showed that half of 12-year-olds had patient-defined need (50.1%, 95% CI: 49.3% - 50.9%) and nearly all of 12-year-olds who had normative need and patient-defined need were willing to have treatment (95.3%, 95% CI: 94.7% - 95.9%).

The analyses of the CDHS and OHS data showed that SEP was not statistically significantly associated with overall levels of normative need in 12-year-olds. However, the IOTN categories (5, 4, 3.6-3.10, and < 3.6) varied slightly with SEP, according to the NHS activity data, as did the IOTN AC scores (1-10), according to the OHS data.

4.4 Treatment utilisation

4.4.1 Research question

What is the prevalence of utilisation of orthodontic treatment, and is it associated with SEP?

4.4.2 Results

Table 4.5 shows the percentages of children utilising orthodontic treatment.

In the North West, according to the NHS activity data and 2011 census data, the estimate of the percentage of those who utilised NHS orthodontic treatment between the ages of 10 and 17 is 25.9%. The utilisation percentage for females (30.7%) is considerably higher than that for males (21.3%).
According to the CDHS data, which covers the whole of the UK, 12.9% (95% CI: 11.2% - 14.6%) of 12-year-olds and 32.5% (95% CI: 29.9% - 35.1%) of 15-year-olds had patient-reported NHS/private orthodontic treatment. The percentages of 12-year-olds and 15-year-olds in the UK who had parent-reported NHS/private orthodontic treatment, according to the CDHS, were slightly larger, at 18.8% (95% CI: 15.3% - 22.2%) and 39.3% (95% CI: 34.5% - 44.1%), respectively. The percentages of 12-year-olds and 15-year-olds in the UK who had parent-reported private orthodontic treatment, according to the CDHS, were very low, at 1.0% (95% CI: 0.0% - 1.9%) and 2.4% (95% CI: 0.7% - 4.0%), respectively. (The data did not indicate what percentage of these privately treated children had normative need.)

In the North West, according to the OHS data, 6.9% (95% CI: 6.5% - 7.2%) of 12-year-olds were in treatment at the time of the dental examinations. As the OHS did not report on children who had received treatment in the past, this estimate cannot be directly compared to the CDHS estimate of patient-reported NHS/private treatment utilisation among 12-year-olds across the UK (which was 12.9%, 95% CI: 11.2% - 14.6%), as this calculation included data on those who had received treatment in the past as well as those who were in treatment at the time of the dental examinations.

As shown in Table 4.5, the CDHS data largely did not confirm the differences in utilisation between males and females indicated by the NHS activity data set – there were no statistically significant differences (according to the 95% CIs of each point estimate) between males and females in terms of the percentages with patient-reported or parent-reported treatment among 12-year-olds, or for parent-reported treatment among 15-year-olds. However, in terms of patient-reported treatment among 15-year-olds, more females had treatment (39.1, 35.3% - 42.9%) than males (25.7%, 95% CI: 22.3% - 29.0%).
Table 4.5: Treatment utilisation

<table>
<thead>
<tr>
<th>Data set</th>
<th>Variable</th>
<th>Total</th>
<th>Males</th>
<th>Females</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Percentage (and actual figure)</td>
<td>95% CI</td>
<td>Percentage (and actual figure)</td>
</tr>
<tr>
<td>NHS activity data – North West</td>
<td>Utilisation among those aged 10 to 17 in the North West</td>
<td>Documented NHS orthodontic treatment claims</td>
<td>25.9 (21,778/year)</td>
<td>-1</td>
</tr>
<tr>
<td>CDHS data set – UK</td>
<td>Utilisation among those aged 12 or under in the UK</td>
<td>Patient-reported NHS/private¹ orthodontic treatment</td>
<td>12.9</td>
<td>11.2 - 14.6</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Parent-reported NHS/private¹ orthodontic treatment</td>
<td>18.8</td>
<td>15.3 - 22.2</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Parent-reported private orthodontic treatment</td>
<td>1.0</td>
<td>0.0 - 1.9</td>
</tr>
<tr>
<td></td>
<td>Utilisation among those aged 15 or under in the UK</td>
<td>Patient-reported NHS/private¹ orthodontic treatment</td>
<td>32.5</td>
<td>29.9 - 35.1</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Parent-reported NHS/private¹ orthodontic treatment</td>
<td>39.3</td>
<td>34.5 - 44.1</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Parent-reported private orthodontic treatment</td>
<td>2.4</td>
<td>0.7 - 4.0</td>
</tr>
<tr>
<td>OHS data set – North West</td>
<td>Utilisation among those aged 12 in the North West</td>
<td>Patient-reported NHS/private¹ orthodontic treatment</td>
<td>6.9</td>
<td>6.5 - 7.2</td>
</tr>
</tbody>
</table>

CDHS: Children’s Dental Health Survey; CI: confidence interval; NHS: National Health Service; OHS: Oral Health Survey; UK: United Kingdom; UOA: Unit of Orthodontic Activity

¹There is no sampling error because the entire population was included rather than a random sample.

²These data concern all treatment (NHS or private), though the percentage of those who had private treatment is very small.
As shown in Figure 4.1, the NHS activity data indicate that there were differences between SEP groups in the percentages of 10- to 17-year-olds who had NHS orthodontic treatment in the North West. Those from the most deprived groups had lower utilisation percentages than those from the least deprived group.

**Figure 4.1: Percentage of 10- to 17-year-olds in the North West who utilised NHS orthodontic treatment, by SEP**

![Chart showing utilisation percentages for different SEP groups.](image)

**Legend:**
- **All**
- **Males**
- **Females**

**IMD: Index of Multiple Deprivation; NHS: National Health Service; SEP: socioeconomic position**

1 IMD deciles arranged from most to least deprived.

Data sources: NHS activity data set and 2011 census data set

In addition, as shown in Table 4.6, the OHS data indicate that, compared to the least deprived group, the most deprived groups had lower patient-reported utilisation at age 12 (OR for IMD quintile 1: 0.51, 95% CI: 0.43 - 0.60, OR for IMD quintile 2: 0.68, 95% CI: 0.57 - 0.81, OR for IMD quintile 3: 0.72, 95% CI: 0.60 - 0.87, and OR for IMD quintile 4: 0.84, 95% CI: 0.71 - 1.00), based on model 3.7. As shown in Table 4.6, the Efron’s $R^2$ value for the model is low, indicating that the proportion of variability in the dependent variable explained by the model is low.
Table 4.6: Treatment utilisation, by SEP

<table>
<thead>
<tr>
<th>Data set</th>
<th>Variable</th>
<th>ORs (and 95% CIs) for IMD quintiles</th>
<th>Reference category: IMD quintile 5 (least deprived)</th>
</tr>
</thead>
<tbody>
<tr>
<td>OHS data set – North West</td>
<td>Utilisation among those aged 12 in the North West</td>
<td>Patient-reported NHS/private¹ orthodontic treatment</td>
<td>n = 19,816 (Model 3.7, adjusted F-test p-value: 0.00, Efron’s R²: 0.004)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>0.51** (0.43 - 0.60)</td>
</tr>
</tbody>
</table>

CI: confidence interval; IMD: Index of Multiple Deprivation; NHS: National Health Service; OHS: Oral Health Survey; OR: odds ratio; SEP: socioeconomic position

¹ These data concern all treatment (NHS or private), though the percentage of those who had private treatment is very small.

However, as shown in Table 4.7, the CDHS data did not confirm the differences in utilisation between SEP groups indicated by the NHS activity data and the OHS data (which both covered the North West), i.e., there were no statistically significant differences in patient-reported or parent-reported utilisation of NHS/private orthodontic treatment for either 12-year-olds or 15-year-olds, based on models 3.8 to 3.11. (This may have been due to the small sample sizes in the CDHS, as opposed to the fact that the sample covered all of the UK rather than only the North West, as discussed in Section 5.4). The Efron’s R² values were not reported because the adjusted F-tests were not significant, as shown in Table 4.7.
Table 4.7: Treatment utilisation, by SEP

<table>
<thead>
<tr>
<th>Data set</th>
<th>Variable</th>
<th>ORs (and 95% CIs) for NS-SEC categories</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Reference category: category 1 (least deprived)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2</td>
</tr>
<tr>
<td>CDHS data set – UK</td>
<td>Utilisation among those aged 12 or under in the UK</td>
<td>2.45 (0.60 - 10.12)</td>
</tr>
<tr>
<td></td>
<td>Parent-reported NHS/private(^1) orthodontic treatment n = 784</td>
<td>2.45 (0.60 - 10.12)</td>
</tr>
<tr>
<td></td>
<td>Utilisation among those aged 15 or under in the UK</td>
<td>2.45 (0.60 - 10.12)</td>
</tr>
<tr>
<td></td>
<td>Parent-reported NHS/private(^1) orthodontic treatment n = 785</td>
<td>2.45 (0.60 - 10.12)</td>
</tr>
</tbody>
</table>

*CDHS: Children’s Dental Health Survey; CI: confidence interval; NHS: National Health Service; NS-SEC: National Statistics Socioeconomic Classification; OR: odds ratio; SEP: socioeconomic position; UK: United Kingdom
d
\(^{1}\) These data concern all treatment (NHS or private), though the percentage of those who had private treatment is very small.

Figure 4.2 to Figure 4.5 show further analyses of the NHS activity data and the OHS data, comparing utilisation across PCTs in the North West to a) the percentage of children attending dental check-ups, by PCT and b) the supply of orthodontic clinicians.

Figure 4.2 and Figure 4.3 show data on the attendance of dental check-ups, and they indicate that there is no association (at the PCT level) between orthodontic treatment utilisation and the percentage of children
attending check-ups. Figure 4.4 and Figure 4.5 show data on the supply of orthodontic clinicians\(^\text{15}\), and they indicate that there is no association (at the PCT level) between orthodontic treatment utilisation and the supply of orthodontic clinicians.

**Figure 4.2: Percentage of 12-year-olds in the North West who utilised orthodontic treatment compared to attendance of dental check-ups, by PCT**

![Chart showing percentage of 12-year-olds utilising orthodontic treatment and percentage of children who attended dental check-ups, by PCT.]

HSCIC: Health and Social Care Information Centre; OHS: Oral Health Survey; PCT: Primary Care Trust

Data sources: OHS data set and HSCIC data set

\(^{15}\) Both figures show that Cumbria PCT had a particularly large number of GDS clinicians. An analysis of the NHS activity data on orthodontic clinicians working in Cumbria PCT showed that, while PDS clinicians often provided courses of treatment to tens or hundreds of patients per year, the vast majority of GDS clinicians either did not provide any courses of treatment or provided a maximum of one course of treatment per year. (In addition, the GDS clinicians who provided a maximum of one course of treatment per year tended not to provide assessments for those they did not treat, but those who did not provide any courses of treatment tended to provide repeated assessments, which would dramatically increase the assessment to treatment ratio for Cumbria PCT.)
Figure 4.3: Percentage of 10- to 17-year-olds in the North West who utilised NHS orthodontic treatment compared to attendance of dental check-ups, by PCT

HSCIC: Health and Social Care Information Centre; NHS: National Health Service; PCT: Primary Care Trust

Data sources: NHS activity data set and HSCIC data set

Figure 4.4: Percentage of 12-year-olds in the North West who utilised orthodontic treatment compared to the supply of orthodontic clinicians, by PCT

GDS: General Dental Services; HSCIC: Health and Social Care Information Centre; OHS: Oral Health Survey; PCT: Primary Care Trust; PDS: Personal Dental Services

Data sources: OHS data set and HSCIC data set
Figure 4.5: Percentage of 10- to 17-year-olds in the North West who utilised NHS orthodontic treatment compared to the supply of orthodontic clinicians, by PCT

4.4.3 Summary

In the North West, according to the NHS activity data and 2011 census data, the estimate of the percentage of those who utilise NHS orthodontic treatment between the ages of 10 to 17 was 25.9%. According to the CDHS data, which covers the whole of the UK, over a tenth of 12-year-olds (12.9%, 95% CI: 11.2% - 14.6%) and nearly a third of 15-year-olds (32.5%, 95% CI: 29.9% - 35.1%) had patient-reported NHS/private orthodontic treatment. Only a small number of these children had private treatment (1.0% of 12-year-olds, 95% CI: 0.0% - 1.9%, and 2.4% of 15-year-olds, 95% CI: 0.7% - 4.0%).

The NHS activity data indicate that, compared to the least deprived group, the most deprived groups had lower percentages of 10- to 17-year-olds utilising orthodontic treatment. The OHS data also indicate that, compared to the least deprived group, the most deprived groups had lower NHS/private patient-reported utilisation at age 12 (OR for IMD quintile 1: 0.51, 95% CI: 0.43 - 0.60, OR for IMD quintile 2: 0.68, 95% CI: 0.57 - 0.81, OR for IMD quintile 3: 0.72, 95% CI: 0.60 - 0.87, and OR for IMD quintile 4: 0.84, 95% CI: 0.71 - 1.00). However, the CDHS data did not confirm these results. At PCT-level, there was no clear association between
orthodontic treatment utilisation and either attendance for dental check-ups or the supply of orthodontic clinicians, according to the OHS data and the NHS activity data.

4.5 Assessment procedures

4.5.1 Research questions

What is the prevalence in the NHS orthodontic service of a) the use of one or more ‘assessment & review’ appointments per patient, b) the use of two or more ‘assessment & review’ appointments per patient, c) early access to orthodontic assessments at ages 9-10, and d) the use of an ‘assessment & refuse’ appointment for those with IOTN scores of ≥ 3.6. Are these assessment procedures associated with SEP?

4.5.2 Results

Table 4.8 shows the percentages of children who underwent various orthodontic assessment procedures in the North West, according to the NHS activity data.

38.5% (27,458) of those who started treatment from 2010-2012 had one or more ‘assessment & review’ appointments from 2008-2012, and 12.9% (9,211) had two or more ‘assessment & review’ appointments.

2.1% (4,738) of those who were aged 9 and over and were assessed from 2008-2012 had early access (i.e., early first assessment) at age 9, and a further 4.8% (10,742) had early access at age 10.

13.0% (17,617) of those who had IOTN scores of ≥ 3.6 and were refused or received treatment from 2008-2012 had an ‘assessment & refuse’ appointment.

The percentage of males was higher than the percentage of females for all the assessment procedures, except for the percentage with early access at age 10, which was higher for females.
### Table 4.8: Assessment procedures

<table>
<thead>
<tr>
<th>Variable</th>
<th>Percentage (and actual figure)</th>
<th>All</th>
<th>Males</th>
<th>Females</th>
</tr>
</thead>
<tbody>
<tr>
<td>Use of one or more ‘assessment &amp; review’ appointments per patient from 2008-2012 among those who started treatment from 2010-2012</td>
<td></td>
<td>38.5</td>
<td>39.7</td>
<td>37.7</td>
</tr>
<tr>
<td>n = 71,292</td>
<td></td>
<td>(27,458)</td>
<td>(11,879)</td>
<td>(15,579)</td>
</tr>
<tr>
<td>Use of two or more ‘assessment &amp; review’ appointments per patient from 2008-2012 among those who started treatment from 2010-2012</td>
<td></td>
<td>12.9</td>
<td>14.0</td>
<td>12.2</td>
</tr>
<tr>
<td>n = 71,292</td>
<td></td>
<td>(9,211)</td>
<td>(4,187)</td>
<td>(5,024)</td>
</tr>
<tr>
<td>Early access (i.e., early first assessment) from 2008-2012 among those aged 9 and over who were assessed from 2008-2012</td>
<td>At age 9</td>
<td>2.1</td>
<td>2.2</td>
<td>2.1</td>
</tr>
<tr>
<td>n = 224,208</td>
<td></td>
<td>(4,738)</td>
<td>(2,140)</td>
<td>(2,598)</td>
</tr>
<tr>
<td></td>
<td>At age 10</td>
<td>4.8</td>
<td>4.6</td>
<td>4.9</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(10,742)</td>
<td>(4,578)</td>
<td>(6,164)</td>
</tr>
<tr>
<td>Use of an ‘assessment &amp; refuse’ appointment from 2008-2012 among those with IOTN scores of ≥ 3.6 and were refused or received treatment from 2008-2012</td>
<td></td>
<td>13.0</td>
<td>14.6</td>
<td>11.7</td>
</tr>
<tr>
<td>n = 135,857</td>
<td></td>
<td>(17,617)</td>
<td>(8,566)</td>
<td>(9,051)</td>
</tr>
</tbody>
</table>

IOTN: Index of Orthodontic Treatment Need

Data source: NHS activity data set

Table 4.9 shows the associations between SEP and the various assessment procedures in the North West, based on the results from models 3.12 to 3.15. The unadjusted analyses show that, compared to those in the least deprived group, those from the more deprived groups were less likely to have one or more ‘assessment & review’ appointments, two or more ‘assessment & review’ appointments, and early access (i.e., early first assessment) at ages 9-10, and these associations persisted in the adjusted analyses.

As shown in Table 4.9, the adjusted R² values for the models are low, indicating that the proportion of variability in the dependent variables explained by the models is low. For all four of the models (i.e., for use of one or more ‘assessment & review’ appointments, use of two or more ‘assessment & review’ appointments, early access at ages 9-10, and use of an ‘assessment & refuse’ appointment among those who have IOTN scores of ≥ 3.6), the adjusted R² values increase as new explanatory variables are added to the models, indicating that these more complex models explain more of the variability in the dependent variables.
### Table 4.9: Assessment procedures, by SEP

<table>
<thead>
<tr>
<th>Variable</th>
<th>Mean change in the predicted probability (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Use of one or more ‘assessment &amp; review’ appointments per patient from 2008-2012 among those who started treatment from 2010-2012 ( n = 67,100^1 ) (Model 3.12)</td>
<td>Use of two or more ‘assessment &amp; review’ appointments per patient from 2008-2012 among those who started treatment from 2010-2012 ( n = 67,100^1 ) (Model 3.13)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Variables adjusted for</th>
<th>-</th>
<th>IOTN</th>
<th>IOTN, gender, and age</th>
<th>-</th>
<th>IOTN</th>
<th>IOTN, gender, and age</th>
<th>-</th>
<th>IOTN</th>
<th>IOTN, gender, and age</th>
<th>-</th>
<th>IOTN</th>
<th>IOTN, gender, and age</th>
</tr>
</thead>
<tbody>
<tr>
<td>IMD quintile 1 (most deprived)</td>
<td>-11.6</td>
<td>-11.7</td>
<td>-10.7</td>
<td>-8.6</td>
<td>-8.6</td>
<td>-8.1</td>
<td>-2.0</td>
<td>-2.3</td>
<td>-2.3</td>
<td>-0.3</td>
<td>-0.3</td>
<td>-1.0</td>
</tr>
<tr>
<td>IMD quintile 2</td>
<td>-8.5</td>
<td>-8.7</td>
<td>-8.1</td>
<td>-6.3</td>
<td>-6.4</td>
<td>-6.1</td>
<td>-1.7</td>
<td>-1.9</td>
<td>-1.9</td>
<td>-0.5</td>
<td>-0.5</td>
<td>-1.0</td>
</tr>
<tr>
<td>IMD quintile 3</td>
<td>-6.2</td>
<td>-6.3</td>
<td>-5.8</td>
<td>-5.7</td>
<td>-5.7</td>
<td>-5.5</td>
<td>-1.4</td>
<td>-1.5</td>
<td>-1.5</td>
<td>-0.7</td>
<td>-0.7</td>
<td>-1.0</td>
</tr>
<tr>
<td>IMD quintile 4 (least deprived)</td>
<td>-5.4</td>
<td>-5.4</td>
<td>-5.1</td>
<td>-3.9</td>
<td>-3.9</td>
<td>-3.8</td>
<td>-1.0</td>
<td>-1.0</td>
<td>-1.0</td>
<td>-0.8</td>
<td>-0.8</td>
<td>-1.0</td>
</tr>
<tr>
<td>Adjusted R²</td>
<td>0.0068</td>
<td>0.0101</td>
<td>0.0178</td>
<td>0.0078</td>
<td>0.0099</td>
<td>0.0173</td>
<td>0.0009</td>
<td>0.0093</td>
<td>0.0094</td>
<td>0.0001</td>
<td>0.0080</td>
<td>0.0211</td>
</tr>
</tbody>
</table>

IMD: Index of Multiple Deprivation; IOTN: Index of Orthodontic Treatment Need; SEP: socioeconomic position

1 The analyses included only those with SEP and IOTN score data.

Data source: NHS activity data set
4.5.3 Summary

According to the NHS activity data, 38.5% (27,458) of patients had one or more ‘assessment & review’ appointments, 12.9% (9,211) had two or more ‘assessment & review’ appointments, 6.9% (15,480) had early access (i.e., early first assessment) at ages 9-10, and 13.0% (17,617) had ‘assessment & refuse’ appointments despite having IOTN scores of $\geq 3.6$. Those from the more deprived groups were less likely to have one or more ‘assessment & review’ appointments, two or more ‘assessment & review’ appointments, and early access at ages 9-10, compared to those in the least deprived group.

4.6 Treatment outcomes

4.6.1 Research questions

What is the prevalence in the NHS orthodontic service of a) treatment discontinuations and b) RPTN? Are these treatment outcomes associated with SEP?

4.6.2 Results

Table 4.10 shows details of treatment outcomes in the North West, according to the NHS activity data. The percentages of patients with and without RPTN were calculated on the basis of a) those who started treatment in 2008 whose IOTN outcome scores were reported and b) all those who started treatment in 2008 (including those that had missing IOTN outcome scores).

Among those who started treatment in 2008 and had NHS activity notification forms returned (within the subsequent four years) to indicate that treatment had finished, 9.4% (1,892) of patients had treatment discontinuations, with more discontinuations being initiated by patients (5.9%, 1,179) than by orthodontic clinicians (3.6%, 718). There was a higher percentage of males with treatment discontinuations (11.2%, 972) than females (8.1%, 920).

Among those who started treatment in 2008 whose IOTN outcome scores were reported, 8.6% (1,312) of patients had RPTN. There was a higher percentage of males with RPTN (9.1%, 592) than females (8.2%, 720).
Among all those who started treatment in 2008, 5.2% (1,312) of patients had RPTN, while a further 19.3% (4,837) had incomplete IOTN outcome score fields and 19.6% (4,905) had unreported treatment finishes. Again, there was a higher percentage of males with RPTN (5.5%, 592) than females (5.1%, 720).

**Table 4.10: Treatment outcomes**

<table>
<thead>
<tr>
<th>Variable</th>
<th>Percentage (and actual figure)</th>
<th>All</th>
<th>Males</th>
<th>Females</th>
</tr>
</thead>
<tbody>
<tr>
<td>Treatment discontinuation among those who started treatment in 2008 and had NHS activity notification forms to indicate that treatment had finished n = 20,127</td>
<td>Total (initiated by orthodontic clinicians or patients)</td>
<td>9.4 (1,892)</td>
<td>11.2 (972)</td>
<td>8.1 (920)</td>
</tr>
<tr>
<td></td>
<td>Initiated by orthodontic clinicians</td>
<td>3.6 (718)</td>
<td>4.7 (408)</td>
<td>2.7 (310)</td>
</tr>
<tr>
<td></td>
<td>Initiated by patients</td>
<td>5.9 (1,179)</td>
<td>6.5 (566)</td>
<td>5.4 (613)</td>
</tr>
<tr>
<td>IOTN outcome scores among those who started treatment in 2008 and had reported IOTN outcome scores n = 15,290</td>
<td>RPTN</td>
<td>8.6 (1,312)</td>
<td>9.1 (592)</td>
<td>8.2 (720)</td>
</tr>
<tr>
<td></td>
<td>No RPTN</td>
<td>91.4 (13,978)</td>
<td>90.9 (5,914)</td>
<td>91.8 (8,064)</td>
</tr>
<tr>
<td>IOTN outcome scores among all those who started treatment in 2008 n = 25,032</td>
<td>RPTN</td>
<td>5.2 (1,312)</td>
<td>5.5 (592)</td>
<td>5.1 (720)</td>
</tr>
<tr>
<td></td>
<td>No RPTN</td>
<td>55.8 (13,978)</td>
<td>54.7 (5,914)</td>
<td>56.8 (8,064)</td>
</tr>
<tr>
<td></td>
<td>Incomplete IOTN outcome score field</td>
<td>19.3 (4,837)</td>
<td>20.4 (2,204)</td>
<td>18.5 (2,633)</td>
</tr>
<tr>
<td></td>
<td>Unreported treatment finish</td>
<td>19.6 (4,905)</td>
<td>19.5 (2,116)</td>
<td>19.6 (2,789)</td>
</tr>
</tbody>
</table>

IOTN: Index of Orthodontic Treatment Need; NHS: National Health Service; RPTN: residual post-treatment need

Data source: NHS activity data set

Table 4.11 shows the associations between SEP and both treatment discontinuations and RPTN in the North West, based on the results from models 3.16 and 3.17.

In the unadjusted analysis of the association between SEP and treatment discontinuation, those in the more deprived groups were more likely to have treatment discontinuation than those in the least deprived group. This association persisted in the first adjusted analysis (which adjusted for IOTN AC scores) and the second adjusted analysis (which adjusted for IOTN AC scores, gender, and age).

In the unadjusted analysis of the association between SEP and RPTN, those in the more deprived groups were more likely to have RPTN than those in the least deprived group. This association persisted in the first adjusted analysis (which adjusted for IOTN AC scores) and the second adjusted analysis (which adjusted for IOTN AC scores, gender, and age). The association also persisted in the analysis that additionally adjusted for potential mediator variables (i.e., treatment discontinuation and requirement for a replacement appliance). However, the mean changes in the predicted probabilities of RPTN when in the more deprived groups compared to the least...
deprived group are considerably smaller, suggesting that these mediator variables help to explain some of the variation in RPTN between SEP groups (though they do not fully account for it).

As shown in Table 4.11, the adjusted $R^2$ values for the models are low, indicating that the proportion of variability in the dependent variables explained by the models is low. For both the model for treatment discontinuations and the model for RPTN, the adjusted $R^2$ values increase as new explanatory variables are added to the models, indicating that these more complex models explain more of the variability in the dependent variables.
Table 4.11: Treatment outcomes, by SEP

<table>
<thead>
<tr>
<th>Variable</th>
<th>Mean change in the predicted probability (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Treatment discontinuation among those who started treatment in 2008 and had NHS activity notification forms (within the subsequent four years) to indicate that treatment had finished n = 18,455¹ (Model 3.16)</td>
<td>RPTN among those who started treatment in 2008 and had reported IOTN outcome scores n = 13,975¹ (Model 3.17)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Variable adjusted for</th>
<th>-</th>
<th>IOTN AC scores</th>
<th>IOTN AC scores, gender, and age</th>
<th>-</th>
<th>IOTN AC scores</th>
<th>IOTN AC scores, gender, and age</th>
<th>IOTN AC scores, gender, age, treatment discontinuation, and requirement for a replacement appliance</th>
</tr>
</thead>
<tbody>
<tr>
<td>IMD quintile</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Reference category:</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>IMD quintile 5 (least deprived)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1 (most deprived)</td>
<td>6.3</td>
<td>6.3</td>
<td>6.1</td>
<td>3.9</td>
<td>3.8</td>
<td>3.8</td>
<td>2.9</td>
</tr>
<tr>
<td>2</td>
<td>5.3</td>
<td>5.3</td>
<td>5.2</td>
<td>4.4</td>
<td>4.4</td>
<td>4.3</td>
<td>3.4</td>
</tr>
<tr>
<td>3</td>
<td>3.0</td>
<td>3.0</td>
<td>3.0</td>
<td>2.7</td>
<td>2.7</td>
<td>2.6</td>
<td>2.0</td>
</tr>
<tr>
<td>4</td>
<td>1.2</td>
<td>1.2</td>
<td>1.1</td>
<td>1.2</td>
<td>1.2</td>
<td>1.1</td>
<td>1.0</td>
</tr>
<tr>
<td>Adjusted R²</td>
<td>0.0069</td>
<td>0.0081</td>
<td>0.0146</td>
<td>0.0031</td>
<td>0.0082</td>
<td>0.0177</td>
<td>0.0971</td>
</tr>
</tbody>
</table>

AC: Aesthetic Component; IMD: Index of Multiple Deprivation; IOTN: Index of Orthodontic Treatment Need; RPTN: residual post-treatment need; SEP: socioeconomic position

¹The analyses included only those with SEP and IOTN score data.

Data source: NHS activity data set
Table 4.12 shows a comparison of the percentages of patients with missing IOTN outcome scores, by SEP. The data indicate that, overall, there is no association between SEP and missing IOTN outcome scores. However, there is an association between SEP and both incomplete IOTN outcome score fields (which were less likely in the more deprived groups compared to the least deprived group) and unreported treatment finishes (which were more likely in the more deprived groups compared to the least deprived group).

Table 4.12: Missing IOTN outcome scores, by SEP

<table>
<thead>
<tr>
<th>IMD quintile</th>
<th>Percentage (and actual figure) among those who started treatment in 2008</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Either incomplete IOTN outcome score field or unreported treatment finish</td>
<td>Incomplete IOTN outcome score field</td>
<td>Unreported treatment finish</td>
</tr>
<tr>
<td>1 (most deprived)</td>
<td>38.8 (2,388)</td>
<td>18.0 (1,108)</td>
<td>20.8 (1,280)</td>
</tr>
<tr>
<td>2</td>
<td>39.1 (1,565)</td>
<td>19.1 (762)</td>
<td>20.1 (803)</td>
</tr>
<tr>
<td>3</td>
<td>39.4 (1,575)</td>
<td>19.7 (788)</td>
<td>19.7 (787)</td>
</tr>
<tr>
<td>4</td>
<td>40.1 (1,756)</td>
<td>20.3 (891)</td>
<td>19.8 (865)</td>
</tr>
<tr>
<td>5 (least deprived)</td>
<td>38.8 (1,723)</td>
<td>21.0 (932)</td>
<td>17.8 (791)</td>
</tr>
<tr>
<td>All</td>
<td>38.9 (9,742)</td>
<td>19.3 (4,837)</td>
<td>19.6 (4,905)</td>
</tr>
</tbody>
</table>

IMD: Index of Multiple Deprivation; IOTN: Index of Orthodontic Treatment Need; NHS: National Health Service; SEP: socioeconomic position

Data source: NHS activity data set

4.6.3 Summary

Among those who started treatment in 2008 and had NHS activity notification forms returned (within the subsequent four years) to indicate that treatment had finished, 9.4% (1,892) of patients had treatment discontinuations. Among all those who started treatment in 2008, 5.2% (1,312) of patients had RPTN, while a further 19.3% (4,837) had incomplete IOTN outcome score fields and 19.6% (4,905) had unreported treatment finishes. Among those who started treatment in 2008 who also had IOTN outcome scores, 8.6% (1,312) of patients had RPTN.

Those in the more deprived groups were more likely to have treatment discontinuations and RPTN than those in the least deprived group, e.g., the mean change in the predicted probability of treatment discontinuation when in the most deprived group compared to the least deprived group was 6.1% (after adjusting for IOTN AC.
scores, gender, and age) and the mean change in the predicted probability of RPTN was 3.8% (after adjusting for IOTN AC scores, gender, and age).

### 4.7 Differences between practices/orthodontic clinicians

#### 4.7.1 Research questions

Do assessment procedures (i.e., the use of two or more ‘assessment & review’ appointments per patient) and treatment outcomes (i.e., treatment discontinuations and RPTN) vary between practices/orthodontic clinicians? Are the differences associated with the types of NHS contracts that the orthodontic clinicians work under (i.e., PDS, GDS, or TDS contracts)?

#### 4.7.2 Results

Figure 4.6 to Figure 4.10 show scatter diagrams indicating the percentages of patients in the North West with two or more ‘assessment & review’ appointments, treatment discontinuations, and RPTN, arranged by the size of the practices'/orthodontic clinicians’ NHS caseloads. While many practices/orthodontic clinicians had very low percentages of patients with these process and outcome indicators, some had very high percentages (up to 100%) of patients with these indicators. The scatter diagrams indicate that there were no clear distinctions between patients treated under PDS, GDS, and TDS contracts.
Figure 4.6: Percentage of treated patients in the North West with two or more ‘assessment & review’ appointments, by size of practice NHS caseload

GDS: General Dental Services; NHS: National Health Service; PDS: Personal Dental Services; TDS: Trust-led Dental Services

Data source: NHS activity data set

Figure 4.7: Percentage of patients in the North West with treatment discontinuation initiated by orthodontic clinicians or patients, by size of NHS caseload

GDS: General Dental Services; NHS: National Health Service; PDS: Personal Dental Services; TDS: Trust-led Dental Services

Data source: NHS activity data set
Figure 4.8: Percentage of patients in the North West with treatment discontinuation initiated by orthodontic clinicians, by size of NHS caseload

GDS: General Dental Services; NHS: National Health Service; PDS: Personal Dental Services; TDS: Trust-led Dental Services

Data source: NHS activity data set

Figure 4.9: Percentage of patients in the North West with treatment discontinuation initiated, by patients by size of NHS caseload

GDS: General Dental Services; NHS: National Health Service; PDS: Personal Dental Services; TDS: Trust-led Dental Services

Data source: NHS activity data set
Figure 4.10: Percentage of patients in the North West with RPTN, by size of NHS caseload

GDS: General Dental Services; NHS: National Health Service; PDS: Personal Dental Services; RPTN: residual post-treatment need; TDS: Trust-led Dental Services

Table 4.13 shows the percentages of patients with two or more ‘assessment & review’ appointments, treatment discontinuations, and IOTN outcome scores (including RPTN) in the North West, by type of NHS contract. The percentages of patients with and without RPTN were calculated on the basis of a) those who started treatment in 2008 whose IOTN outcome scores were reported and b) all those who started treatment in 2008 (including those that had missing IOTN outcome scores).

PDS patients were more likely to have two or more ‘assessment & review’ appointments (13.6%, 8,071) compared to either GDS patients (10.0%, 1,070) or TDS patients (7.0%, 70).

Among those who started treatment in 2008 and had NHS activity notification forms (within the subsequent four years) to indicate that treatment had finished, GDS patients were more likely to have treatment discontinuations (10.3%, 347) compared to PDS patients (9.0%, 1498). However, TDS patients were much more likely to have treatment discontinuations (25.7%, 47) compared to either PDS or GDS patients.

Among those who started treatment in 2008 whose IOTN outcome scores were reported, GDS patients were more likely to have RPTN (12.6%, 361) compared to PDS patients (7.6%, 935). However, TDS patients were more likely to have RPTN (17.4%, 294) compared to either PDS or GDS patients.

Among all those who started treatment in 2008, GDS patients were more likely to have RPTN (8.2%, 361) compared to both PDS patients (4.6%, 935) and TDS patients (7.5%, 29). Among these patients, TDS patients were much more likely to have unreported treatment finishes (53.0%, 206) compared to either GDS patients (23.2%, 1,018) or PDS patients (18.2%, 3,681). In addition, PDS patients were more likely to have incomplete
IOTN outcome score fields (21.2%, 4,300) compared to either GDS patients (11.6%, 508) or TDS patients (7.5%, 29).

Table 4.13: Assessment procedures and treatment outcomes, by type of NHS contract

<table>
<thead>
<tr>
<th>Variable</th>
<th>Percentage (and actual figure) of patients</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Treated under PDS contracts</td>
</tr>
<tr>
<td>Assessment procedures</td>
<td>Use of two or more ‘assessment &amp; review’ appointments per patient from 2008-2012 among those who started treatment from 2010-2012</td>
</tr>
<tr>
<td>PDS: n = 59,565</td>
<td>Total (initiated by orthodontic clinicians or patients)</td>
</tr>
<tr>
<td>GDS: n = 10,733</td>
<td>Initiated by orthodontic clinicians</td>
</tr>
<tr>
<td>TDS: n = 944</td>
<td>Initiated by patients</td>
</tr>
<tr>
<td>Treatment discontinuation among those who started treatment in 2008 and had NHS activity notification forms (within the subsequent four years) to indicate that treatment had finished</td>
<td>RPTN</td>
</tr>
<tr>
<td>PDS: n = 16,572</td>
<td>No RPTN</td>
</tr>
<tr>
<td>GDS: n = 3,372</td>
<td></td>
</tr>
<tr>
<td>TDS: n = 183</td>
<td></td>
</tr>
<tr>
<td>IOTN outcome scores among those who started treatment in 2008 and had reported IOTN outcome scores</td>
<td>RPTN</td>
</tr>
<tr>
<td>PDS: n = 12,272</td>
<td>No RPTN</td>
</tr>
<tr>
<td>GDS: n = 2,864</td>
<td></td>
</tr>
<tr>
<td>TDS: n = 154</td>
<td></td>
</tr>
<tr>
<td>IOTN outcome scores among those who started treatment in 2008</td>
<td>RPTN</td>
</tr>
<tr>
<td>PDS: n = 20,253</td>
<td>No RPTN</td>
</tr>
<tr>
<td>GDS: n = 4,390</td>
<td></td>
</tr>
<tr>
<td>TDS: n = 389</td>
<td></td>
</tr>
<tr>
<td>Incomplete IOTN outcome score field</td>
<td>Unreported treatment finish</td>
</tr>
</tbody>
</table>

GDS: General Dental Services; IOTN: Index of Orthodontic Treatment Need; NHS: National Health Service; PDS: Personal Dental Services; RPTN: residual post-treatment need; TDS: Trust-led Dental Services

Data source: NHS activity data set

Table 4.14 shows a comparison of the percentages of patients with missing IOTN outcome scores, by type of NHS contract.

The data indicate that TDS clinicians had considerably more patients with missing IOTN outcome scores (60.4%, 235) than PDS clinicians (39.4%, 7,981) and GDS clinicians (34.8%, 1,526), mainly because they had more patients with unreported treatment finishes (53.0%, 206) than PDS clinicians (18.2%, 3,681) and GDS clinicians (23.2%, 1,018).
PDS clinicians had slightly more patients with missing IOTN outcome scores (39.4%, 7,981) than GDS clinicians (34.8%, 1,526), mainly because PDS clinicians had more patients with incomplete IOTN outcome score fields (21.2%, 4,300) than GDS clinicians (11.6%, 508).

Table 4.14: Missing IOTN outcome scores, by type of NHS contract

<table>
<thead>
<tr>
<th>Type of NHS contract</th>
<th>Percentage (and actual figure) among those who started treatment in 2008</th>
<th>Unreported treatment finish</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Either incomplete IOTN outcome score field or unreported treatment finish</td>
<td>Incomplete IOTN outcome score field</td>
</tr>
<tr>
<td>PDS</td>
<td>39.4 (7,981)</td>
<td>21.2 (4,300)</td>
</tr>
<tr>
<td>GDS</td>
<td>34.8 (1,526)</td>
<td>11.6 (508)</td>
</tr>
<tr>
<td>TDS</td>
<td>60.4 (235)</td>
<td>7.5 (29)</td>
</tr>
<tr>
<td>All</td>
<td>38.9 (9,742)</td>
<td>19.3 (4,837)</td>
</tr>
</tbody>
</table>

GDS: General Dental Services; IOTN: Index of Orthodontic Treatment Need; NHS: National Health Service; PDS: Personal Dental Services; TDS: Trust-led Dental Services

Data source: NHS activity data set

4.7.3 **Summary**

According to the NHS activity data, the percentages of patients with two or more ‘assessment & review’ appointments per treated patient, treatment discontinuations, and RPTN (both among all those who started treatment in 2008 and among those who started treatment in 2008 whose IOTN outcome scores were reported) vary between practices/orthodontic clinicians. For all the process and outcome indicators, the ranges were from 0% for some practices/orthodontic clinicians to 100% for others. The percentages of patients with these indicators were associated with the type of NHS contract.

4.8 **Costs**

4.8.1 **Research question**

What are the costs of the NHS orthodontic service, including the costs associated with the various assessment procedures and treatment outcomes?
4.8.2 Results

This section covers the costs associated with the NHS orthodontic service in the North West. The costs are based on payments to orthodontic clinicians for carrying out UOAs. A single UOA has an approximate value of £61 (Wise, 2015), and 1 UOA is awarded for an assessment, while 21 UOAs are awarded for treatment of a 10- to 17-year-old (which is inclusive of a single assessment). The costs are presented as totals (for all SEP groups) and by SEP group, in order to give an indication of the differential allocation of resources between SEP groups. As this partly reflects the fact that children from the most deprived groups are overrepresented in the North West (Young and Sly, 2010), the approximate costs per head of the population are also provided.

Table 4.15 shows, according to the NHS activity data, the annual cost to the NHS of orthodontic assessments and treatments in the North West. ‘Assessment & review’ appointments amounted to £1.9 million and ‘assessment & refuse’ appointments amounted to £0.5 million, for those aged 17 and under. The cost of treatments was £31.2 million, for 10- to 17-year-olds.

Table 4.15: Overview of costs to the NHS of the orthodontic service in the North West

<table>
<thead>
<tr>
<th>Annual costs (GBP) per IMD quintile (and approximate costs per head of the population1)</th>
<th>All</th>
<th>1 (most deprived)</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5 (least deprived)</th>
<th>IMD quintile data missing</th>
</tr>
</thead>
<tbody>
<tr>
<td>‘Assessment &amp; review’ appointments in 2008, for those aged 17 and under</td>
<td>1,892,891 (1.30)</td>
<td>420,656 (0.70)</td>
<td>294,569 (1.10)</td>
<td>306,464 (1.40)</td>
<td>335,317 (1.50)</td>
<td>403,027 (1.90)</td>
<td>132,858 (-)</td>
</tr>
<tr>
<td>‘Assessment &amp; refuse’ appointments in 2008, for those aged 17 and under</td>
<td>495,137 (0.30)</td>
<td>107,604 (0.20)</td>
<td>73,322 (0.30)</td>
<td>76,006 (0.30)</td>
<td>87,474 (0.40)</td>
<td>116,449 (0.50)</td>
<td>34,282 (-)</td>
</tr>
<tr>
<td>Courses of treatment that started in 2008, for 10- to 17-year-olds</td>
<td>31,157,763 (46.30)</td>
<td>7,669,347 (32.70)</td>
<td>4,976,685 (41.60)</td>
<td>4,957,470 (47.50)</td>
<td>5,432,721 (49.80)</td>
<td>5,546,730 (52.60)</td>
<td>2,574,810 (-)</td>
</tr>
</tbody>
</table>

GBP: Great Britain Pound; IMD: Index of Multiple Deprivation; NHS: National Health Service

1 The denominator populations were the numbers of a) 0- to 17-year-olds and b) 10- to 17-year-olds in the North West in 2011 (the year of the census), for the analyses of assessments and treatments, respectively.

Data sources: NHS activity data set and 2011 census data set

The costs to the NHS in the North West of potential inefficiencies associated with assessment procedures are highlighted in Table 4.16. These potential inefficiencies are as follows:

- The cost, for all those who started treatment in 2012, of having one or more ‘assessment & review’ appointments from 2008-2012, which amounted to approximately £0.8 million, and included the cost of
‘assessment and review’ appointments associated with early access (i.e., early first assessment) at ages 9-11, which amounted to £0.2 million

- The cost, in 2012, of ‘assessment & refuse’ appointments for those with IOTN scores of ≥ 3.6, which amounted to £0.2 million
Table 4.16: Costs to the NHS associated with assessment procedures in the North West

<table>
<thead>
<tr>
<th>Assessment procedures</th>
<th>Costs (GBP) per IMD quintile (and approximate costs per head of the population&lt;sup&gt;1&lt;/sup&gt;)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>All</td>
</tr>
<tr>
<td>‘Assessment &amp; review’ appointments from 2008-2012, for those aged 17 and under who started treatment in 2012</td>
<td>One or more ‘assessment &amp; review’ appointments</td>
</tr>
<tr>
<td></td>
<td>Two or more ‘assessment and review’ appointments</td>
</tr>
<tr>
<td>‘Assessment and review’ appointments associated with early access (i.e., early first assessment), for those who started treatment in 2012</td>
<td>At age 9</td>
</tr>
<tr>
<td></td>
<td>At age 10</td>
</tr>
<tr>
<td></td>
<td>At age 11</td>
</tr>
<tr>
<td></td>
<td>At ages 9-11</td>
</tr>
<tr>
<td>‘Assessment &amp; refuse’ appointments for those aged 17 and under with IOTN scores of ≥ 3.6 in 2012</td>
<td>184,586&lt;sup&gt;2&lt;/sup&gt; (0.10)</td>
</tr>
</tbody>
</table>

GBP: Great Britain Pound; IMD: Index of Multiple Deprivation; IOTN: Index of Orthodontic Treatment Need; NHS: National Health Service

<sup>1</sup>The denominator populations were a) the number of 0- to 17-year-olds in the North West in 2011 (the year of the census), for the first and third analyses, and b) the numbers of 9-, 10-, 11-, and 9- to 11-year-olds in the North West in 2011, for the second analysis.

<sup>2</sup>The costs of potential inefficiencies are highlighted, i.e., a) the cost of one or more ‘assessment & review’ appointments from 2008-2012, for those who started treatment in 2012 (including the cost of ‘assessment and review’ appointments associated with early access (i.e., early first assessment) at ages 9-11), and the cost of ‘assessment & refuse’ appointments for patients with IOTN scores of ≥ 3.6, in 2012.

Data sources: NHS activity data and 2011 census data set
As shown in Table 4.17, the cost to the NHS in the North West of treatments for 10- to 17-year-olds that started in 2008 and ended in discontinuations amounted to £2.4 million. The cost of treatments for 10- to 17-year-olds that started in 2008 and ended with RPTN was £1.8 million. However, the cost of treatments in 2008 that had incomplete IOTN outcome score fields was much higher, at £6.5 million, and the cost of treatments in 2008 that had unreported treatment finishes was also £6.5 million.
**Table 4.17: Costs to the NHS associated with treatment outcomes in the North West**

<table>
<thead>
<tr>
<th>Treatment outcomes</th>
<th>Costs (GBP) per IMD quintile (and approximate costs per head of the population$^1$)</th>
<th>IMD quintile data missing</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>All</td>
<td>1 (most deprived)</td>
</tr>
<tr>
<td>Treatment discontinuations among those who started treatment in 2008, for 10- to 17-year-olds</td>
<td>Total (initiated by orthodontic clinicians or patients)</td>
<td>2,364,726$^2$ (3.50)</td>
</tr>
<tr>
<td></td>
<td>Initiated by orthodontic clinicians</td>
<td>900,543 (1.30)</td>
</tr>
<tr>
<td></td>
<td>Initiated by patient</td>
<td>1,470,588 (2.20)</td>
</tr>
<tr>
<td>IOTN outcome scores among those who started treatment in 2008, for 10- to 17-year-olds</td>
<td>RPTN</td>
<td>1,752,347$^2$ (2.60)</td>
</tr>
<tr>
<td></td>
<td>No RPTN</td>
<td>19,369,818 (28.80)</td>
</tr>
<tr>
<td></td>
<td>Incomplete IOTN outcome score field</td>
<td>6,462,218$^2$ (9.60)</td>
</tr>
<tr>
<td></td>
<td>Unreported treatment finish</td>
<td>6,540,786$^2$ (9.70)</td>
</tr>
</tbody>
</table>

GBP: Great Britain Pound; IMD: Index of Multiple Deprivation; IOTN: Index of Orthodontic Treatment Need; NHS: National Health Service; RPTN: residual post-treatment need

$^1$ The denominator population was the number of 10- to 17-year-olds in the North West in 2011 (the year of the census).

$^2$ The costs of potential inefficiencies are highlighted, i.e., the costs of treatments for 10- to 17-year-olds who started treatment in 2008 and finished with discontinuations, RPTN, incomplete IOTN outcome score fields, and unreported treatment finishes.

Data sources: NHS activity data set and 2011 census data set
4.8.3 Summary

The costs to the NHS in the North West from 2008-2012 of ‘assessment & review’ appointments for those who started treatment in 2012 was £0.8 million. Of this £0.8 million, the cost associated with having two or more ‘assessment & review’ appointments was £0.5 million, and the cost associated with children who had their first assessment at ages 9-11 was £0.2 million. The cost of ‘assessment & refuse’ appointments in 2012 for patients with IOTN scores of ≥ 3.6 was £0.2 million.

The costs to the NHS in the North West of treatments for 10- to 17-year-olds that started in 2008 and ended in discontinuations, RPTN, incomplete IOTN outcome score fields, and unreported treatment finishes were £2.4 million, £1.8 million, £6.5 million, and £6.5 million, respectively.
5 DISCUSSION

5.1 Overview

This chapter discusses the findings of the research in light of the aim of the research to explore the relationships between SEP and various aspects of the NHS orthodontic service, including need, demand, supply and outcomes:

- Section 5.2 provides a summary of the main findings of the research and an interpretation of the findings in light of the current literature
- Section 5.3 discusses the broad strengths of each of the data sets
- Section 5.4 discusses the broad limitations of each of the data sets, followed by discussions of the limitations of the SEP data and of the analysis-specific methods
- Section 5.5 concerns the implications of the findings for NHS commissioning (each of the analyses are discussed in turn, and a critique of the IOTN is provided along with a discussion of the future of the assessment of malocclusion in the NHS)
- Lastly, Section 5.6 concerns the key unanswered questions for future research

5.2 Summary and interpretation

5.2.1 Need and willingness to have treatment

According to the CDHS and OHS data, over a third of children were found to have normative need for orthodontic treatment at age 12 (38.5%, 95% CI: 36.1% - 41.0%, and 40.1%, 95% CI: 39.5 - 40.8%, respectively). The NHS activity data showed that three quarters of the 10- to 17-year-olds receiving treatment had IOTN scores of 4 (74.2%, 78,890), while a fifth had IOTN scores of 5 (18.2%, 19,347), and less than a tenth had IOTN scores of 3.6-3.10 (7.1%, 7,552).

The OHS data indicated that half of 12-year-olds had patient-defined need (50.1%, 95% CI: 49.3% - 50.9%). The data also showed that a third of those with no normative need had patient-defined need (34.8%, 95% CI: 33.9% -35.7%), while a quarter of those with normative need did not have patient-defined need (24.6%, 95% CI: 23.6% - 25.7%). The mismatch between normative need and patient-defined need highlights questions
about whether need should be assessed solely normatively or whether the patients’ perspectives should also be taken into account.

As a previous report comparing children from deprived and non-deprived schools in the UK has shown (Chestnutt et al., 2004), the analyses using the CDHS data and the OHS data confirmed that SEP is not statistically significantly associated with overall levels of normative need (above the NHS IOTN eligibility threshold of 3.6) among 12-year-olds. This finding implies that SEP should not legitimately have an influence on utilisation of the NHS orthodontic service, so normative need cannot confound the association between SEP and utilisation. The OHS data also showed that SEP is not associated with patient-defined need among those who have normative need, as reported in a previous study of SEP and patients’ self-assessment of orthodontic treatment need (Christopherson et al., 2009).

The OHS data also indicated that, among children who did not have normative need, compared to those in the least deprived group, those in the most deprived groups were more likely to have patient-defined need (OR for IMD quintile 1: 1.36, 95% CI: 1.19 - 1.55, and OR for IMD quintile 2: 1.29, 95% CI: 1.11 - 1.49). It is unclear why this is the case but variations in individuals’ self-esteem and health beliefs (which affect individuals’ attitudes towards orthodontic treatment) may play a role. For example, the differences in the importance placed on dental aesthetics could explain the differences in patient-defined need (a Swedish study on the importance of dental aesthetics to adults reported that low education was associated with high importance of dental aesthetics (Söderfeldt et al., 1993)).

Among those with patient-defined need and normative need, compared to those in the least deprived group, those in the most deprived group were less likely to be willing to have treatment (OR: 0.47, 95% CI: 0.28 - 0.79). Differences in health beliefs such as considering the short-term disadvantages of wearing orthodontic appliances to be greater than the long-term benefits of treatment may reduce willingness to have treatment for those in the most deprive group. Studies on health behaviours have frequently reported that deprivation is associated with lower health consciousness, stronger beliefs in the influence of chance on health, and less thinking about the future, which, in turn, are associated with unhealthy behavioural choices (Wardle and Steptoe, 2003). However, the differences in willingness to have treatment between the SEP groups are not economically significant: the vast majority of those in all of the SEP groups were willing to have treatment if they were reported to have patient-defined need and normative need, i.e., 95.3% (95% CI: 94.7% - 95.9%) were willing to have treatment. This may be due to the widespread familiarity with orthodontic appliances, which is known to increase willingness to have treatment (Burden, 1995).
The IOTN categories (5, 4, 3.6-3.10, and < 3.6) varied by SEP, according to the NHS activity data. The NHS activity data indicated that there were small differences between SEP groups, e.g., 6.3% (1,939) of those from the most deprived group who had NHS orthodontic treatment had IOTN DHC scores of 3.6-3.10, but 7.6% (1,939) of those from the least deprived group had IOTN DHC scores of 3.6-3.10. There could be a number of reasons for these findings, rather than an underlying association in the at-risk population between SEP and the IOTN categories. This is because the data set is not a population-based data set. For example, some children in the least deprived group could have received early private treatment if they had the IOTN scores of 5, and therefore there would be fewer of these children from the least deprived group in the data set. Nevertheless, these results informed the use of IOTN categories (which can be used to reflect the severity of malocclusion) as a potential confounding variable to be adjusted for in the subsequent analyses of SEP and assessment procedures.

The IOTN AC scores (which range from 1 (representing very straight teeth) to 10 (representing severe malocclusion)) showed statistically significant variation between SEP groups, according to the OHS data set, which is a population-based data set. There were no statistically significant differences found in the CDHS data set, though this may be due to the small sample size. The trends in the differences between SEP groups in the OHS data set were complex, which was expected given that the prevalences of risk factors for the different types and severities of malocclusions (Ingervall and Bitsanis, 1987; Lieberman et al., 2004; Mossey, 1999) do not necessarily follow simple trends across the SEP groups. These results informed the use of IOTN AC scores (which can be used to reflect the severity of malocclusion and treatment complexity) as a potential confounding variable to be adjusted for in the subsequent analyses of SEP and treatment outcomes.

5.2.2 Treatment utilisation

The CDHS data indicated that, across the UK, by age 12, over a tenth of children had received patient-reported NHS/private16 orthodontic treatment (12.9%, 95% CI: 11.2% - 14.6%) and, by age 15, this figure had increased to nearly a third (32.5%, 95% CI: 29.9% - 35.1%). Of these children, very few have private treatment (1.0% of 12-year-olds, 95% CI: 0.0% - 1.9%, and 2.4% of 15-year-olds, 95% CI: 0.7% - 4.0%). Accordingly, by age 15, the percentage of children who had received orthodontic treatment remained well below point estimate of the percentage of 12-year-olds with normative need who were surveyed in the CDHS (i.e., 38.5%, and a further 7.9% who were wearing orthodontic appliances at the time of the dental examinations, which equates to

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16 The data on orthodontic treatment used in this analysis did not differentiate between NHS and private orthodontic treatment. (The data were based on answers of ‘Yes’ to the question ‘Have you got an orthodontic brace or appliance?’), which encompasses both NHS and/or private orthodontic treatment.)
46.4%). This can be interpreted as meaning that approximately a fifth of children still require orthodontic treatment at age 15 (i.e., 46.4% minus the 32.5% who have already been treated), as determined using the NHS IOTN eligibility threshold of 3.6. This may, in part, be due to the long waiting list in parts of the country (Health, Wellbeing and Local Government Committee, 2011).

In the North West, according to the NHS activity data and 2011 census data, the estimate of the percentage of those who utilised NHS primary care orthodontic treatment between the ages of 10 and 17 (i.e., while they remained eligible for free NHS orthodontic treatment) was 25.9%. This is lower than the percentage of 15-year-olds (who were surveyed in the CDHS) from across the UK who had patient-reported NHS/private orthodontic treatment, which was nearly a third (i.e., 32.5%, 95% CI: 29.9% - 35.1%, as stated above). However, of this third, a small percentage – 2.4% – had parent-reported private treatment, and a small percentage–approximately 3.0% – had hospital treatment17 rather than primary care treatment).

The analysis of 10- to 17-year-olds in the NHS activity data set showed that utilisation of the NHS primary care orthodontic service in the North West increased across SEP groups, with those in the least deprived group being the most likely to receive treatment, as shown in the bar chart in Figure 4.1 in Section 4.4.2. This is despite the fact that overall normative need did not vary by SEP. These results mirror several other studies in England that reported that higher SEP is associated with the utilisation of orthodontic treatment (Drugan et al., 2007; Mandall et al., 2000; Morris and Landes, 2006).

The inverse care law states that ‘the availability of good medical care tends to vary inversely with the need of the population served’ (Tudor Hart, 1971, p. 405), which implies that where health conditions increase in frequency or severity (e.g., between SEP groups), the availability of care decreases. This law applies to the distribution of services for many health conditions across SEP groups, such as antenatal midwifery care (Kirkham et al., 2002) and the treatment of depression (Chew-Graham et al., 2002). However, as the findings in this thesis show, unlike these health conditions, there is no marked SEP gradient for malocclusion, as the risk factors (including genetic risk factors (Mossey, 1999)) for the different types and severities of malocclusion are largely not factors that are associated with SEP.

17 Hospital Episode Statistics data on the number of finished consultant episodes are recorded according to the most resource intensive procedure of the episode. The number of ‘orthodontic operations’ carried out in hospital (involving the following procedures: insertion of fixed, moveable or ‘not elsewhere classified’ orthodontic appliances, insertion of orthodontic anchorage, surgical exposure of tooth, and other specified or unspecified orthodontic operations) is 5,777 per year, according to 2011-2012 data. Extrapolating the number of orthodontic treatments carried out by primary care orthodontic clinicians in the North West to the whole of England gives 183,930 treatments, according to the 2011 NHS activity data. (In 2011, the usual resident populations of the North West and of England were 7,052,200 and 53,012,500, respectively (according to 2011 census data), so those in the North West represented 13% of the population of England.) This means that ‘orthodontic operations’ carried out in hospitals equated to approximately 3.0% of the total number of treatments in England (though some of the hospital episodes may involve the same patient, so this is likely to be an overestimate).
Although the findings indicate that the treatment of malocclusion in the NHS does not reflect the inverse care law (Tudor Hart, 1971), the findings do indicate that the healthcare system is not delivering care equitably between SEP groups, which, in the case of orthodontics, amounts to delivering care equally between SEP groups (given that normative need does not vary by SEP). The SEP-related differences in utilisation in the North West may be due access issues (McIntyre et al., 2009) for those in the more deprived groups. These access issues may include barriers due to availability (e.g., the quantity of NHS orthodontic services is inadequate in some areas of the country (Health, Wellbeing and Local Government Committee, 2011)), affordability (e.g., lack of affordable transport and lost pay for parents accompanying their children to orthodontic appointments over two years (Gosney, 1985)), and acceptability (e.g., differences in health beliefs and difficulties with meeting the high standards of oral hygiene required to receive treatment (Holmes et al., 2015; Locker, 2000)). However, the factors involved cannot be elucidated fully from these analyses due to the lack of patient-level data on these factors. The graphs comparing the prevalence of utilisation at PCT-level to a) the proportions of children attending dental check-ups and b) the supply of orthodontic clinicians indicated that, at PCT-level, there was no association with either variable.

In common with the NHS activity data findings, the OHS analysis of children in the North West showed that, compared to those than the least deprived group, those in the most deprived groups had lower patient-reported utilisation at age 12 (OR for IMD quintile 1: 0.51, 95% CI: 0.43 - 0.60, OR for IMD quintile 2: 0.68, 95% CI: 0.57 - 0.81, OR for IMD quintile 3: 0.72, 95% CI: 0.60 - 0.87, and OR for IMD quintile 4: 0.84, 95% CI: 0.71 - 1.00). However, the CDHS analyses of 12- and 15-year-olds across the whole of the UK did not support these findings, as the CDHS data indicated that there were no statistically significant differences in utilisation between SEP groups. However, this most likely reflects the small sample sizes used in the CDHS analysis. Alternatively, there may be more access issues (McIntyre et al., 2009) differentially affecting the more deprived groups in the North West (where the NHS activity data and OHS data analyses indicated a SEP-related association) compared to in other areas of the UK (where the CDHS analysis did not support a SEP-related association).

### 5.2.3 Assessment procedures

According to the NHS activity data, 38.5% (27,458) of treated patients had one or more ‘assessment & review’ appointments, 12.9% (9,211) of treated patients two or more ‘assessment & review’ appointments, 6.9% (15,480) of those who were aged 9 and over had early access (i.e., early first assessment) at ages 9-10, and 13.0% (17,617) of those who were refused or received treatment had ‘assessment & refuse’ appointments despite having IOTN scores of ≥ 3.6.
The cost to the NHS in the North West over the years 2008 to 2012 of ‘assessment & review’ appointments for those who started treatment in 2012 was £0.8 million. Of this £0.8 million, the cost associated with having two or more ‘assessment & review’ appointments was £0.5 million, and the cost associated with children who early access (i.e., early first assessment) at ages 9-11 was £0.2 million. This may indicate some UOAs were being utilised for repeatedly reviewing children on waiting lists, without sufficient priority setting regarding the severity of their malocclusions and the optimum times to begin treatment (which can be assessed using information provided by the referring GDP and/or during the first assessment appointment) (McGrady and Bridgman, 2013).

In addition, the NHS activity data showed that the cost of ‘assessment & refuse’ appointments in 2012 for patients with IOTN scores of ≥ 3.6 was £0.2 million. This indicates that some UOAs were being utilised for assessing children who had been referred to the NHS orthodontic service too early, or were referred despite having poor oral hygiene and/or lacking willingness to have treatment. The cost of ‘assessment and review’ appointments associated with early access at ages 9-11 and the cost of ‘assessment & refuse’ appointments for patients with IOTN scores of ≥ 3.6 reflect the findings of a recent report on Manchester’s centralised referral validation and triage system, which stated that 17.4% of referrals were rejected in 2012-2013, and one of the most common reasons for this was due to patients being referred to the service too early (McGrady and Bridgman, 2013).

2013 guidance from NHS England states that, in order to manage demand so that orthodontic practices can achieve closer to a 1:1 ratio of assessments to treatments, some health localities have implemented centralised referral validation and triage systems (NHS England Primary Care Commissioning, 2013). At these centralised clinics, referral validations can involve ensuring that the patients have IOTN scores of ≥ 3.6 and good oral hygiene, and they are likely to comply with treatment instructions, but they are not intended to be full assessments and are reimbursed at a sessional rate, without using UOAs (McGrady and Bridgman, 2013). Validated referrals are then forwarded to orthodontic clinicians for full assessments (which can involve taking photographs, radiographs, and models of the patient’s occlusion, and treatment planning) before treatment (McGrady and Bridgman, 2013).

The 2013 guidance from NHS England also notes that some orthodontic practices have implemented rapid referral validation and triage clinics in order to assess the appropriateness of referrals (NHS England Primary Care Commissioning, 2013). The clinicians only claim a UOA if a full assessment is completed as part of treatment (NHS England Primary Care Commissioning, 2013), which is beneficial to the NHS, as no extra costs are incurred by the NHS. Therefore, these clinics are likely to be more cost-effective for the NHS than centralised referral validation and triage systems. The widespread use of rapid referral validation and triage
clinics could lead to the production of validated waiting lists of patients, categorised into optimum time to begin treatment (in order to reduce the likelihood of patients having repeated ‘assessment & review’ appointments) (McGrady and Bridgman, 2013), which would help to reduce the numbers of children on waiting lists for treatment. The clinics also help to triage patients so they are prioritised based on need, as well as optimum time to treatment (NHS England Primary Care Commissioning, 2013). Occasional rejections can still occur after a full assessment is completed, but this approach would help to reduce the assessment to treatment ratio closer to 1:1.

In addition, in the future, orthodontic Dental Care Professionals (i.e., support staff for orthodontic clinicians) such as orthodontic therapists could be involved in screening patients’ IOTN scores at centralised clinics or the orthodontic providers’ clinics, as, in 2013, the General Dental Council published new rules on direct access for the public to orthodontic Dental Care Professionals (General Dental Council, 2013). These rules clarified that orthodontic therapists can carry out IOTN screening without the patient having to see an orthodontic clinician first (i.e., orthodontic therapists can carry out IOTN screening ‘direct to patients or as part of a structured public health programme led by a specialist in orthodontics, a consultant in dental public health, a specialist in dental public health or a General Dental Practitioner’ (General Dental Council, 2013, p. 5).

Those from the more deprived groups were less likely to have one or more ‘assessment & review’ appointments, two or more ‘assessment & review’ appointments, and early access (i.e., early first assessment) at ages 9-10, compared to those in the least deprived group. These SEP-related differences provide evidence that some of reasons behind the inefficiencies in the assessment system are linked with SEP.

For example, these findings suggest that patients and their parents, particularly those from the least deprived groups, may influence the referral process by making requests to GDPs for referrals to orthodontists in order to be placed on waiting lists earlier, as reported anecdotally in Wales (Health, Wellbeing and Local Government Committee, 2011). Although earlier orthodontic treatment does not necessarily lead to better treatment outcomes (DiBiase, 2002; Kiyak et al., 2004), there is an incentive to have earlier treatment because it ensures less time spent in adolescence with malocclusion. Studies on various other health conditions have shown that deprivation is associated with later diagnoses (Barnabe et al., 2014; Fountain et al., 2011; Lyratzopoulos et al., 2013). The findings could also be due to higher levels of attendance for dental check-ups at earlier ages by those in the least deprived groups. For example, evidence from the literature shows that, among 12-year-olds, a larger percentage of children from families with managerial and professional backgrounds attended GDPs regularly (70%) compared with children from families with routine and manual backgrounds (64%) (Morris et al., 2004). These factors can lead to premature access to the NHS orthodontic service, and unnecessary repeated assessments.
5.2.4 Treatment outcomes

According to the NHS activity data set, 9.4% (1,892) of orthodontic treatments in the North West for those who started treatment in 2008 (and finished within the subsequent four years) resulted in discontinuation (i.e., the patients did not complete their courses of treatment). Among all those who started treatment in 2008, and among all those who started treatment in 2008 who had reported IOTN outcome scores, 5.2% (1,312) and 8.6% (1,312) of patients had RPTN, respectively.

Those in the more deprived groups were more likely to discontinue treatment and have RPTN than those in the least deprived group (both before and after adjusting for potential confounding factors). Previous UK studies have also indicated that there are associations between low SEP and poor treatment outcomes such as treatment discontinuation (Turbill et al., 2003) and ‘limited improvement in malocclusion’ (defined as an ICON improvement score lower than the median of the sample) (Joury et al., 2011). Treatment discontinuation can be caused by selecting patients for treatment who have a lack of motivation to complete a full course of treatment and/or to comply with oral hygiene advice, and by having a strict policy on discontinuing treatment for patients who miss appointments (Welsh Assembly Government Dental Division, 2013). This can result in more treatment discontinuations (which can increase the likelihood of RPTN) for those in the more deprived groups because they are less likely to be willing to have treatment, more likely to have poor oral hygiene (Holmes et al., 2015; Locker, 2000), and more likely to miss orthodontic appointments (Can et al., 2003).

The cost to the NHS of orthodontic treatments for 10- to 17-year-olds in the North West that started in 2008 and resulted in discontinuations and RPTN amounted to £2.4 million and £1.8 million, respectively, with a further £6.5 million spent on treatments that resulted in incomplete IOTN outcome score fields, and another £6.5 million spent on treatments that resulted in unreported treatment finishes. Efforts to devise efficiency savings in the NHS are paramount in light of the fact that the NHS currently has the largest budget deficit in its history (in large part due to rising demand as a result of the ageing population with more lifestyle-related illnesses) (Campbell, 2015). In addition, it is predicted that the deficit will increase to £30 billion by 2020 unless more funding is provided or staff numbers are reduced and patient care standards are allowed to deteriorate (Campbell, 2015). Given this financial pressure and the opportunity cost of funding the NHS orthodontic service rather than other areas of the NHS, the levels of discontinuations, RPTN, incomplete IOTN outcome score fields, and unreported treatment finishes raise questions about the cost-effective of the orthodontic service.
5.2.5 Differences between practices/orthodontic clinicians

According to the NHS activity data, the percentages of patients with two or more ‘assessment & review’ appointments per treated patient, treatment discontinuations, and RPTN vary considerably between NHS primary care practices/orthodontic clinicians, from 0% for some practices/orthodontic clinicians to up to 100% for others.

However, as shown in the scatter diagrams in Figure 4.6 to Figure 4.10 in Section 4.7.2, those with large NHS caseloads tended not to be among the practices/orthodontic clinicians that had have very large percentages of patients with two or more ‘assessment & review’ appointments per treated patient, treatment discontinuations, and RPTN. This may be because a) before NHS commissioners decide whether to grant a provider with a larger contract, they would ensure that the quality of care delivered by the provider met high standards, and b) higher throughputs of patients provide more experience for the providers, which can lead to improvements in quality. This means that the impact of the practices/orthodontic clinicians with 100%, or close to 100%, of patients with any of the three process and outcome indicators is not as problematic as it would be if those with poor outcomes had large NHS caseloads.

The percentages of patients with each of the three process and outcome indicators were associated with the type of NHS contract that the patients were treated under: GDS contracts (which focus on providing comprehensive primary care dentistry rather than solely specialist orthodontists), PDS contracts (which are not required to provide the full range of mandatory dental services, so they can involve solely specialist orthodontic treatment), and TDS contracts (which are much less common than the other two types of contract, and involve paying dentists directly, in the form of a salary, for undertaking orthodontic treatment for vulnerable patients with special needs) (Elliott, 2012; Hodge and Parkin, 2015).

PDS patients were more likely to have two or more ‘assessment & review’ appointments (13.6%, 8,071) compared to GDS patients (10.0%, 1,070) and TDS patients (7.0%, 70). However, there was a great deal of variation among practices working under the same type of contract; while many practices had no patients with two or more ‘assessment & review’ appointments, many, working under PDS, GDS, and TDS contracts, carried out two or more ‘assessment & review’ appointments for over half of their patients.

This may, in some cases, be evidence of supplier-induced demand, which is demand that exists beyond what would have occurred in a market in which patients are fully informed (Donaldson et al., 2004). This can lead to a large ratio of assessments to treatments, as many patients have two ‘assessment & review’ appointments (which amounts to three assessments in total, when treatment is eventually started) or more than two (i.e., up to ten, according to the NHS activity data set). A 2008-2009 study in Wales on the inefficiencies in the NHS
orthodontic service found that 27 out of 135 contracts involved solely assessments and no treatments and another 62 out of 135 contracts involved fewer than 50 treatments per year (Richmond and Karki, 2012). This may have occurred because it may be more difficult to recruit specialist orthodontists to areas of Wales and so more non-specialists are contracted, and they tend to provide fewer treatments compared to the numbers of assessments of patients attending their practices for dental check-ups (Richmond and Karki, 2012).

The fact that TDS patients were less likely to have two or more ‘assessment & review’ appointments (7.0%, 70) than PDS patients (13.6%, 8,071) and GDS patients (10.0%, 1,070) may be due to the fact that orthodontic clinicians working under TDS contracts are salaried, rather than paid on the basis of whether or not they meet activity targets. This means that they do not have financial incentives (which have been shown to produce changes in clinical activity undertaken by primary care dentists (Brocklehurst et al., 2013)) to repeatedly assess the same patient. However, it is also plausible that their patients may be less likely to ask to be referred prematurely (referrals to TDS clinicians can be made by dentists, general practitioners, other healthcare professionals, and social care representatives).

GDS patients were slightly more likely to have treatment discontinuations (10.3%, 347) compared to PDS patients (9.0%, 1498), but not compared to TDS patients (25.7%, 47). In addition, among those who started treatment in 2008 who had reported IOTN outcome scores, GDS patients were considerably more likely to have RPTN (12.6%, 361) compared to PDS patients (7.6%, 935), though not compared to TDS patients (17.4%, 294). Likewise, among all those who started treatment in 2008, GDS patients were considerably more likely to have RPTN (8.2%, 361) compared to PDS patients (4.6%, 935), and they were also slightly more likely to have RPTN compared to TDS patients (7.5%, 29).

The fact that PDS clinicians had lower levels of patients with treatment discontinuations and RPTN than GDS clinicians may be related to the distribution of the types of clinicians working under these contracts, i.e., specialist orthodontists and non-specialists. These clinicians are likely to differ in terms of many factors that could influence treatment outcomes, including training, experience, appliance types favoured, mean treatment duration, and case mix. Several previous studies in England and Wales, the US, and Brazil that found that patients treated by specialist orthodontists had better treatment outcomes compared to non-specialists (Abei et al., 2004; Marques et al., 2011; Richmond et al., 1993). The fact that TDS patients were much more likely to have treatment discontinuations than PDS and GDS patients is likely to be reflective of the fact that these patients are more likely to have poor compliance with treatment instructions (e.g., to maintain their oral hygiene) as they tend to be vulnerable patients with special needs. Given that one of the eligibility criteria to receive orthodontic treatment is that patients must have the motivation to undergo the full course of treatment, this indicates that many of the TDS patients may not have been ready to start treatment.
Despite the differences in treatment outcomes between clinicians working under different types of NHS contract, there was a great deal of variation among clinicians working under the same type of contract. Orthodontic treatment requires considerable patient compliance for successful outcomes, and some of the orthodontic clinicians working under each of the types of NHS contract are shown never to have patients with discontinuations or RPTN, or to very rarely have patients with these treatment outcomes. This suggests that some orthodontic clinicians may be effective at selecting highly compliant patients and/or may be able to modify the effect of potential poor patient compliance with good communication of treatment instructions and feedback.

5.3 Strengths of the research

5.3.1 Overview

The three main orthodontic data sets used in this research are the most suitable to answer the research questions as they were, at the time the research was undertaken, the most up-to-date data sets that included data from children in the UK on both orthodontics and SEP. In particular, the post-2006 data from the 2008-2009 NHS Dental Epidemiology Programme for England OHS and the 2008-2012 NHS orthodontic activity forms ensured that the research took the 2006 dental reforms into account.

The CDHS data set covered the whole of the UK, but both the OHS data set and the NHS activity data set only included data from the North West, so the findings from some of the analyses may not be generalisable to rest of the country. However, approximately 13% of the population of England reside in the North West (Office for National Statistics, 2012), so the analyses were conducted on a significant percentage of the population of England, which has a diversity of individuals from different socioeconomic backgrounds, and of orthodontic coverage.

5.3.2 Children’s Dental Health Survey and NHS Dental Epidemiology Programme for England Oral Health Survey data

The CDHS and the OHS data sets each used a different method of assigning a SEP group to the survey participants: a household-level measure (the NS-SEC) and an area-level measure (the IMD). In general, this is useful because different measures of SEP have different limitations, so assessing differences associated with SEP using two SEP measures can make the findings, when they concur, more robust.
In addition, the CDHS and OHS data sets included data on 12-year-olds, which is useful because, at this age, many children will not yet have started wearing orthodontic appliances – and therefore normative need is easier to assess – because it is common to wait until the early permanent dentition develops in order to start treatment (Clinical Standards Committee of the British Orthodontic Society, 2010).

Furthermore, the CDHS data set includes data on 15-year-olds, which is useful because most individuals are no longer entitled to free NHS orthodontic treatment after the age of 17 (i.e., NHS orthodontic services are only free at the point of delivery to those who are 17 and under (NHS Choices, 2015b), except under certain circumstances such as if the patient is a nursing mother or aged 18 and in full-time education (Drakeford, 2015)). Therefore, many of the children with normative need would have been in treatment or would have finished treatment by the time they reached 15 years old.

Both surveys were carried out by trained and calibrated examiners according to a standard protocol. Both surveys involved random samples, to ensure the data were representative. Both also allowed analyses to be carried out at the individual, rather than ecological, level. Lastly, where possible, survey design features were taken into account, as described in Section 3.4.7.4.

5.3.3 NHS orthodontic activity data

The 2008-2012 NHS activity data set provided comprehensive data on all NHS primary care orthodontic assessments and treatments provided in the North West, as the data were collected in order to produce the providers’ financial statements. The data have not previously been analysed, and the data set enabled the exploration of the associations of SEP with both assessment procedures and treatment outcomes. The data also enabled the exploration of the associations of types of NHS contracts with both assessment procedures and treatment outcomes, as the data set differentiates between services provided by orthodontic clinicians working under PDS, GDS, and TDS contracts.

In addition, most of the analyses using the NHS activity data were carried out at the individual level rather than at an ecological level (with the exception of the analyses involving the percentages of children who attended dental check-ups and the supply of orthodontic clinicians).
5.4 Limitations of the research

5.4.1 Children’s Dental Health Survey and NHS Dental Epidemiology Programme for England Oral Health Survey data

One of the major limitations of the CDHS data set is that the samples of 12-year-olds (n = 785) and 15-year-olds (n = 612) who were both clinically examined and had SEP data were relatively small, which leads to less power to detect effects, such as the differences between SEP groups. Although the CDHS was a small survey, the OHS data set is much larger (n = 19,910), providing more power to detect effects.

In addition, there may have been response/consent bias in the surveys, which would affect the validity of the findings. Differences in response/consent could have occurred between SEP groups, between those who had received orthodontic treatment and those who had not, and between levels of severity of malocclusion.

In the CDHS, 65% of schools consented to take part and, within these, the consent rates for the 12-year-olds and 15-year-olds invited to be examined were 83% and 68%, respectively, and the response rate to the questionnaire was 61%. However, there is no information on whether or not the response/consent rate varied between SEP groups, between those who had received orthodontic treatment and those who had not, or between levels of severity of malocclusion.

- Response bias to the CDHS questionnaire may have occurred between those who had received orthodontic treatment and those who had not: the higher utilisation percentage indicated by the parent-reported data compared to that indicated by the patient-reported data could be explained by response bias, i.e., parents of children who had received orthodontic treatment may have been more likely to respond to the survey.

- In addition, the (potentially) different response/consent rates by NS-SEC categories were not explicitly taken into account (though weighting by whether or not each school was classed as deprived was carried out). Although the information on the CDHS did not include information on how the response/consent rate varied by SEP, findings in this thesis regarding the CDHS data indicate that SEP was not associated with either normative need or utilisation across the UK at the 1% level of statistical significance (as shown in Table 4.2 in Section 4.3.2 and Table 4.7 in Section 4.4.2). Therefore, any response/consent bias between SEP groups would not have a great effect on the estimated percentages of those with normative need and those who utilised orthodontic treatment. Nevertheless, it remains unclear whether there were different response/consent rates by SEP groups. With regard to mailed health surveys, those with higher levels of education and professional jobs (Barton et al., 1980; Boström
et al., 1993; Sonne-Holm et al., 1989) and those in less deprived groups (Forthofer, 1983; Sonne-Holm et al., 1989) tend to be more likely to respond. However, weighting by SEP – in terms of whether or not each school was classed as deprived – was carried out, which would theoretically ameliorate any potential response/consent bias by SEP.

In the OHS, 88% of schools consented to take part and, within these, the consent rate for the 12-year-olds invited to be examined was 74%. In contrast to the CDHS researchers, the OHS researchers reported that the levels of consent by schools, and by parents and their 12-year-olds, did not differ by IMD quintiles, which were obtained from the postcodes of both those who gave consent and those who did not give consent (Rooney et al., 2010). However, like for the CDHS data, biases in the levels of consent between those who had received orthodontic treatment and those who had not, and between levels of severity of malocclusion, could not be determined.

5.4.2 **NHS orthodontic activity data**

The NHS activity data set included data on the NHS primary care orthodontic service, but it did not include information on activity in the NHS hospital orthodontic service. However, the vast majority of orthodontic provision is carried out in the primary care orthodontic service. In addition, the NHS activity data set does not include data on orthodontic activity in the private sector (though the percentage of 12-year-olds and 15-year-olds with parent-reported private orthodontic treatment was shown to be very small, according to findings in this thesis). There are also limitations with data set concerning censoring. These concerns are particularly applicable to the data on assessments and treatment outcomes, but they are mitigated by the restrictions put on the patients used in the analyses (in terms of the timeframes covered).

The NHS activity data were collected before PCTs (which commissioned the orthodontic services) were disbanded as part of the 2013 NHS reforms (UK Parliament, 2012). The responsibility for commissioning in England was then passed to NHS England area teams (NHS England Primary Care Commissioning, 2013). These newly formed area teams contract new orthodontic providers and review contracts as they come to an end in order to consider whether or not to renew them (for 6 months to 3 years) (NHS England Primary Care Commissioning, 2013). This involves carrying out local HNAs and auditing the providers using a Quality and Value Audit Framework, which includes assessing the value of a UOA according to each contract, the ratio of assessments to treatments, and treatment outcomes in terms of the percentages of completed treatments and PAR scores (NHS England Primary Care Commissioning, 2013). These 2013 changes to the commissioning of NHS orthodontic services may lead to changes in the future levels of treatment utilisation, discontinuations,
and RPTN, and the differences between SEP groups, as the numbers of orthodontic clinicians and their performance management changes.

5.4.3 Socioeconomic position data

Data on NS-SEC categories (Office for National Statistics, 2010) and IMD quintiles (Department for Communities and Local Government, 2011, 2007) were used to represent SEP. Although they have both been widely-used, they both have limitations, with neither of them being a perfect measure of SEP (the construction of any measure of SEP is challenging as there are often limited data available, and there is no ‘gold standard’ against which one measure can be compared with another (Psaki et al., 2014)):

- The NS-SEC (which takes into account details such as whether the household reference person is an employer, self-employed, or an employee, whether he/she is a supervisor, and the number of employees at his/her workplace (Office for National Statistics, 2010)) can be used as a household-level measure of SEP. The NS-SEC improved upon previously used SEP classification systems by having rules for classifying all of the population, and it has been rigorously validated. However, household-level measures of SEP have several limitations, the main one being that they tend to use a small number of indicators (or just one). These indicators tend not to fully reflect all the aspects of SEP that can have an influence on an individual’s healthcare utilisation and outcomes. The main advantage of area-level measures of SEP over household-level measures of SEP is that they include numerous domains, which take into account a broad range of indicators.
- In addition, using indicators that fully, or largely, reflect income can lead to individuals with the same income but who are living in different parts of the country with vast discrepancies in costs of living being labelled as being from the same SEP group, even though they have very different levels of disposable income.
- The IMD (which takes into income, employment, health, education, crime, housing and services, and living environment) is an area-level measure rather than individual-or household-level measure.
  - Area-level measures were used in two of the data sets, as there were no household-level data on income, occupation, or other indicators of SEP. One of the limitations of the IMD is that not everyone living in a deprived area is deprived and not all deprived people live in deprived areas, so any SEP-related associations may be attenuated.
  - This caveat is more important when investigating the associations of SEP with treatment outcomes, as the strength of any association may be underestimated, given that any potential
effect of SEP may act via the self-efficacy and resultant compliance of the individual patient with treatment instructions. (This hypothesis is proposed in light of the fact that SEP has been shown to have an effect on a child’s development of self-efficacy (Boardman and Robert, 2000) which has, in turn, been shown to influence health behaviours (Luszczynska and Schwarzer, 2005). Moreover, deprivation is associated with poor oral health practices (Maes et al., 2006) and missed orthodontic appointments (Can et al., 2003)).

- However, when investigating the associations of SEP with treatment utilisation, area-level deprivation is important, as it could be associated with area-level access issues that differentially affect SEP groups. For example, access issues can arise in more deprived areas due to transport costs and lack of time off work for parents accompanying their children to appointments. Deprivation, at both the area-level and the household-level, can act independently as a risk factor for health outcomes (Smith et al., 1998), so area-level SEP analyses are important in order to fully understand the interplay between socioeconomic factors and health.

- Also, the IMD quantifies urban and rural deprivation collectively although they could be conceived as entirely different entities (Environment Partnership, 2007) (with vastly different access issues when considering specialist services like the NHS orthodontic service), so there have been calls for the development of separate indices to take this into account.

### 5.4.4 Analysis-specific limitations

#### 5.4.4.1 Need and willingness to have treatment

One of the main limitations of the analyses of patient-defined need and willingness to have treatment is that the data were cross-sectional, and it is important to acknowledge that the 12-year-olds surveyed may change their minds as they grow older, e.g., due to adapting to having malocclusion or due to seeing their peers undergoing orthodontic treatment. A US study reported that as children get older they are more likely to be critical of their teeth and to want to have orthodontic treatment (Christopherson et al., 2009).

In addition, regarding associations between SEP and patient-defined need, a recent Canadian study conceptualised patient-reported health measures as consisting of a) latent health and b) reporting behaviour, and this study found that reporting behaviour varies by SEP, with those from more deprived groups exhibiting more optimism about their health than on average (Layes et al., 2012). The authors concluded that it may be misleading to take patient-reported health status at face value (Layes et al., 2012).
Lastly, IOTN DHC scores of 3 were not recorded in the CDHS and OHS data sets (because, in both surveys, a modified version of the IOTN was used to classify individuals as having either IOTN DHC scores of 1-3 or IOTN DHC scores of 4-5 (and the IOTN AC scores were assessed as normal)). Therefore, in this thesis, IOTN AC scores of 6-10 (representing the most severe malocclusions according to the 10-point aesthetic scale) were treated as representing normative need, irrespective of whether or not the IOTN DHC scores were 3. Therefore, the estimates of the percentages of those with normative need may be slightly overestimated. However, the percentage of those with an IOTN DHC score of 1-2 and an IOTN AC score of 6-10 is likely to have been extremely small: firstly, a 2014 study in Malaysia reported that 1 out of a sample of 700 13- to 14-year-old children had an IOTN DHC score of 1-2 and an IOTN AC score of 6-10, which amounts to 0.1% of the sample (Zamzuri et al., 2014) and secondly, a 2014 study in India reported that 22 out of the sample of 5,232 11- to 14-year-old children had an IOTN DHC score of 1-2 and an IOTN AC score of 6-10, which amounts to 0.4% of the sample (Sharma and Sharma, 2014).

5.4.4.2 Treatment utilisation

Unlike the CDHS data set, the OHS data set only included data on orthodontic treatment utilisation at the time of the dental examinations at age 12, not on past utilisation (before the age of 12). Many of the survey participants who were not receiving orthodontic treatment at the time of the dental examinations may have received treatment earlier or later in life rather than at 12 years old. The age at which these survey participants received treatment may have been associated with SEP. For example, children from more deprived groups may take longer to be referred to the NHS orthodontic service if they rarely visit GDPs. For example, the report from the 2003 CDHS stated that, among 12-year-olds, a larger percentage of children from families with managerial and professional backgrounds attended GDPs regularly (70%) compared with children from families with routine and manual backgrounds (64%) (Morris et al., 2004).

The use of the two PCT-level variables (i.e., the percentage of those aged 17 and under, by PCT, who were seen by an NHS GDP during a two-year period (1 April 2009 to 31 March 2011) and the number of dentists, by PCT, on NHS contracts who provided UOAs per 1,000 10- to 17-year-old (as at 31 March 2009)) was intended to help to determine whether any associations with SEP in the utilisation analyses were, in part, reflecting SEP-associated differences in the attendance of dental check-ups (which act as a gateway for children to be referred to the NHS orthodontic service) and the supply of orthodontic clinicians.

Both of the variables have the limitation that they were measured at the level of PCTs, which corresponded to relatively large populations (ranging from 13,200 10- to 17-year-olds in Blackpool PCT to 45,400 in Cumbria Teaching PCT, with an average of 28,200 across the North West). There was not a great deal of variation in
these variables at the PCT-level, e.g., 71% of the PCTs had levels of attendance of dental check-ups of 70%-80%. The variation in the variables may have been larger if they were measured at the level of smaller geographical units. However, if, for example, the first variable was measured at a lower area level, the measure would only be a crude estimate of the percentages of children who attended dental check-ups. This is because the data are recorded according to the location of the dental practices rather than the patients, and the patients may have travelled from outside of the area. The variable representing the supply of orthodontic clinicians was measured at PCT-level because it was based on the records of the number of orthodontic clinicians commissioned by PCTs to provide services to those who resided within each PCT’s statutory geographical area (though the practices were not necessarily situated within the PCTs’ boundaries).

The data on the percentages of children attending dental check-ups covered the two years between 1 April 2009 and 31 March 2011 and the data on the supply of orthodontic clinicians reflected the number of orthodontic providers as at 31 March 2009. Data from these time points were the optimal options available (given the intention was to match them with the timeframes of the 2008-2009 OHS data set and the 2008-2012 NHS activity data set) and both variables had little variation at the PCT-level over the timeframes considered. However, the variation in these factors may have changed since the PCTs were disbanded, as the commissioning of NHS orthodontic services (based on local HNAs) has undergone change (NHS England Primary Care Commissioning, 2013).

Regarding the first variable, used to reflect attendance at dental check-ups, the HSCIC does not provide a breakdown of the data by age (i.e., all data on those aged 17 and under are grouped together), so the percentages of 10- to 17-year-olds could not be calculated. Therefore, the variable on those aged 17 and under does not directly correspond to the orthodontic utilisation data on 10- to 17-year-olds.

The second variable, used to reflect the supply of orthodontic clinicians, has several further limitations:

- The number of dentists providing UOAs under NHS contracts is not a completely accurate measure of the full-time equivalent supply of NHS orthodontic clinicians because some of the clinicians will also have commitments in the general NHS dental service and in the private sector, and some will work part-time (e.g., those who are semi-retired). However, given that the clinicians who provide UOAs participate in the NHS orthodontic service to some extent, this variable can be used to represent the theoretical NHS orthodontic capacity.

- An alternative variable could have been the annual number of UOAs contracted per 10- to 17-year-old in the population, by PCT. However, this variable is almost identical to the number of UOAs utilised (i.e., it is a measure of utilisation rather than of supply), and it does not represent the capacity for supply
because the clinicians may be able to increase the number of UOAs supplied if their contracts were
altered. In comparison to this alternative variable, the variable used is, conceptually, a better indicator of
supply, with greater face validity.

In addition, in the analysis of NHS activity data on the utilisation of orthodontic treatment by PCT, data on
patients from the two PCTs in Cheshire (Central and Eastern Cheshire PCT and Western Cheshire PCT) were
combined because Western Cheshire PCT undertook the commissioning of NHS orthodontic services for those
living under the remit of Central and Eastern Cheshire PCT during 2009. (In 2009, Cheshire County Council
underwent a major reorganisation to create two UAs and, as a result, the two Cheshire PCTs reorganised their
service delivery to reflect the lack of a co-terminus approach with the new UAs).

5.4.4.3 Assessment procedures

Early access (i.e., early first assessment) at ages 9-10 may represent a legitimate early referral for advice from
an orthodontic clinician, or for early treatment. That is, early referrals for advice or treatment cannot be
differentiated from premature referrals (e.g., for early access to the waiting lists). Furthermore, not all decisions
not to start treatment for children after an assessment at ages 9-10 are due to premature early access, as lack of
oral hygiene or motivation can also play a role (British Orthodontic Society, 2008). However, if a patient has
an ‘assessment & review’ appointment at ages 9-10 (rather than starting treatment) it is likely that premature
referral was the reason for the decision to review the patient at a later date. Nonetheless, the reasons for the
decisions are unclear and are likely to be multidimensional (though they are not related to financial incentives,
as referring GDPs are not paid for referring children to the NHS orthodontic service).

5.4.4.4 Treatment outcomes

One of the major limitations of the analyses of treatment outcomes is that there is a great deal of missing
information on whether or not treatment was discontinued and on IOTN outcome scores. Although it is
mandatory for IOTN scores to be reported at the end of treatment, 19.3% (4,837) of those who started treatment
in 2008 had incomplete IOTN outcome score fields. In addition to this 19.3%, a further 19.6% (4,905) of those
who started treatment in 2008 did not have NHS activity notification forms returned (within the subsequent
four years) to indicate whether treatment had been discontinued or completed, despite the fact that NHS
orthodontic contracts require NHS activity notification forms to be submitted at the end of treatment.

In some cases, incomplete IOTN outcome score fields may have been due to the fact that the patient
discontinued treatment and did not attend an appointment to allow the clinician to measure the IOTN outcome
score (i.e., if the patient was being treated with removable rather than fixed appliances, and so did not have to return to have them removed). However, many cases where there is no IOTN outcome score occur because the orthodontic clinician declined to provide this information, which is a problem that has been raised by the recent Welsh inquiry into the NHS orthodontic service (Health, Wellbeing and Local Government Committee, 2011).

It is unknown whether or not incomplete IOTN outcome score fields and unreported treatment finishes are associated with treatment outcomes. However, it is likely that there were biases in the completion of IOTN outcome score fields and reporting of treatment finishes (i.e., data would be more likely to be missing when treatment was discontinued or the treatment finished with RPTN) so the estimates of the percentages of those who had treatment discontinuations and RPTN are likely to be underestimated, as are the estimates from the cost analyses. In addition, the associations with SEP and NHS contract types may be affected if there were SEP-related and/or NHS contract type-related biases in the missing treatment outcome data.

The comparison of the missing IOTN outcome scores by SEP indicates that there was no association between SEP and missing IOTN outcome scores overall. However, there was an association between SEP and incomplete IOTN outcome score fields (which were more likely in the less deprived groups), and SEP and unreported treatment finishes (which were more likely in the more deprived groups).

The reasons for the association between those in less deprived groups and incomplete IOTN outcome score fields are unclear. However, the association between those in more deprived groups and unreported treatment finishes may be related to the fact that being in the more deprived groups was associated with treatment discontinuation, which may have led to a lack of reporting if the orthodontic clinicians were initially unsure whether or not the patient would return (despite the fact that the NHS activity notification forms are still required to be submitted once it has been established that the patient does not wish to return).

The comparison of the percentages of patients with missing IOTN outcome scores by type of NHS contract indicates that TDS clinicians were much more likely to have patients with unreported treatment finishes (53.0%, 206) than GDS clinicians (23.2%, 1,018) and PDS clinicians (18.2%, 3,681), and PDS clinicians were considerably more likely to have patient with incomplete IOTN outcome score fields (21.2%, 4,300) than GDS clinicians (11.6%, 508) and TDS clinicians (7.5%, 29).

The fact that TDS clinicians had more patients with unreported treatment finishes than PDS and GDS clinicians was largely driven by the high levels of unreported finishes of treatments carried out under 3 out of the 7 TDS contracts in the data set (i.e., the other 4 TDS contracts had much lower rates). The reason behind the fact that PDS clinicians had more patients with incomplete IOTN outcome score fields than GDS and TDS clinicians is unclear. It is not related to PDS clinicians being less likely to report IOTN outcome scores when their patients
discontinue treatment, as the data show that, for the subset of patients who have incomplete IOTN outcome score fields, PDS clinicians actually have a lower percentage of treatment discontinuations than GDS and TDS clinicians.

Assessing the associations between NHS contract types and treatment outcomes is more problematic than assessing the associations between SEP and treatment outcomes, as there does appear to be significant bias with regards to how the various NHS contract types are associated with incomplete IOTN outcome score fields (i.e., PDS clinicians are the most likely to fail to complete IOTN outcome score fields) and the return of NHS activity notification forms (i.e., TDS clinicians are the most likely to fail to return these forms). For example, more of the cases of RPTN for patients treated by PDS clinicians may have been unreported compared to cases of RPTN for patients treated by GDS and TDS clinicians, which may explain the lower percentage of PDS patients with RPTN.

In addition, the validity of the reporting of IOTN outcome scores and whether or not the patients discontinued treatment is unknown. In particular, the IOTN outcome scores are self-reported by the orthodontic clinicians rather than being independently validated. This may have led to bias in terms of the number of poor outcomes reported, and the bias would not necessarily affect all SEP groups and types of NHS contract to the same degree.

Moreover, although the information on treatment discontinuations indicates whether they were initiated by orthodontic clinicians or by patients, it does not give an indication of what drove the clinicians or patients to discontinue treatment, which makes it difficult to target policies to decrease the levels of treatment discontinuation.

There has also been some criticism regarding the ability of the IOTN to measure outcomes (Daniels and Richmond, 2000), and the use of IOTN scores at the end of treatment were to calculate RPTN:

- Firstly, the developers of the ICON argue against the use of the IOTN to investigate outcomes on the basis that it was ‘developed and validated to assess treatment entry and exits as separate phenomena, when they are clearly part of the same clinical process. This requires additional training and duplicates the effort of measuring what are often similar occlusal traits’ (Daniels and Richmond, 2000, p. 150). Nonetheless, treatment need indices such as the IOTN have often been used to assess outcomes (Elderton and Clark, 1984, 1983; Lobb et al., 1994; Richmond et al., 1994; Richmond and O’Brien, 1996) and the IOTN is used in these analyses on the basis that it indicates the degree of residual normative need after active treatment has finished. Moreover, the IOTN remains the principal index used to assess orthodontic treatment need in the NHS, and using the same index to establish both a
baseline assessment for an individual patient and his/her treatment outcome is practical for determining whether or not there has been an improvement.

- Secondly, the IOTN scores are measured at the end of active treatment, but there can be relapse after active treatment has finished, particularly if there is poor compliance with retention instructions (e.g., wearing retainers at night). A UK study on relapse rates post-retention was carried out on patients treated in the NHS hospital dental service, and it found that, at a mean post-retention time of 6.5 years, 24% of patients had IOTN DHC scores of 4-5 and a further 33% had IOTN DHC scores of 3 (Linklater and Fox, 2002). From this point of view, the levels of RPTN are underestimated (as are the corresponding costs of treatments that lead to RPTN), which may differentially affect patients from different SEP groups (e.g., patients from less deprived groups may be more likely to undergo retention for longer periods of time).

- In comparison to a recent UK study on SEP and orthodontic treatment outcomes (Joury et al., 2011), the RPTN measure used in this thesis more clearly reflects poor treatment outcomes. The previous study used ‘limited improvement in occlusion’ as an outcome, and defined this as an ICON improvement score lower than the median of the sample, which does not necessarily reflect a poor treatment outcome, as it is dependent on the standards achieved by the orthodontic clinicians in the sample, who were all working in the NHS hospital orthodontic service (Joury et al., 2011). In addition, the treatment outcomes were measured at 1 year rather than at the end of active treatment, and the measurement did not take into account the IOTN AC score of the ICON (i.e., the most heavily weighted component of the five components of the ICON (Daniels and Richmond, 2000)) due to the presence of fixed orthodontic appliances in situ.

5.5 Implications of the research for NHS policy on commissioning orthodontic services

5.5.1 Need and willingness to have treatment

The fact that normative need and patient-defined need did not always correspond, and the fact that the percentage of 12-year-olds with patient-defined need was higher than the percentage of 12-year-olds with normative need has implications for GDPs managing the demand for referrals to the orthodontic service. In order to manage the demand effectively, GDPs need to be fully trained in how to use the IOTN and how to assess a patient’s eligibility for referral in terms of appropriate oral hygiene, willingness to have treatment, and optimum time to begin treatment (NHS England Primary Care Commissioning, 2013).
In-depth training in the application of the IOTN is particularly important (McGrady and Bridgman, 2013). The BOS has stated that GDPs often have a poor understanding of the IOTN and it is important that they are provided with improved education on the IOTN at university and through the Continuing Professional Development process (IOTN training is not currently a mandatory part of this process but, in general, dentists are expected to keep up to date about all clinical issues) (Health, Wellbeing and Local Government Committee, 2011). In addition, a report on a survey of NHS GDPs concluded that there is a need for the development of clearer orthodontic referral guidelines, in addition to improved referral training (Jackson et al., 2009). 2013 guidance from the NHS recommended that rejected referrals should be returned to the referring GDPs with detailed explanations in order to reduce the number of future rejections (NHS England Primary Care Commissioning, 2013). This is more likely to be successful if combined with contract penalties for large numbers of inappropriate referrals (as financial incentives have been shown to produce changes to levels of dental activity (Brocklehurst et al., 2013)) – the inquiry into the NHS orthodontic service in Wales specifically discussed issuing a contract penalty to GDPs who make a large volume of early referrals in order to discourage this practice (Health, Wellbeing and Local Government Committee, 2011).

The finding showed that 7.1% (7,552) of treated 10- to 17-year-olds had IOTN scores of 3.6-3.10, which cost £9.7 million in the North West over the five years covered by the data set (i.e., £1.9 million per year). These patients would no longer be eligible for NHS orthodontic treatment if the eligibility threshold was increased from an IOTN score of 3.6 (Department of Health, 2006) to an IOTN score of 4, as is similar to that used in the Republic of Ireland (Republic of Ireland Healthcare service Executive, 2006).

5.5.2 Treatment utilisation

The differences in utilisation between SEP groups in the North West has implications for the NHS commissioners, who aim to ensure equal access to services, irrespective of factors unrelated to the need for healthcare, such as SEP (Department of Health, 2010; NHS England, 2009), because the NHS may be able to influence some of the factors involved, though it is likely that there are wider determinants (rather than solely NHS-related factors) that may necessitate broader governmental policies.

5.5.3 Assessment procedures

In order to reduce the costs to the NHS of assessments, the referral system involving GDPs could be improved by more training, clearer referral guidelines, feedback on inappropriate referrals, and financial incentives, as discussed in Section 5.5.1. In addition, the inquiry into the NHS orthodontic service in Wales recommended the
development of an electronic referral system, which would allow referrals to be monitored centrally (Health, Wellbeing and Local Government Committee, 2011). Orthodontic contracts could also take into account the number of treatments (and completions) an orthodontic clinician is required to carry out rather than just the delivery of UOAs (Health, Wellbeing and Local Government Committee, 2011). There is also a need to influence the behaviour of patients and their parents by making them fully aware about the appropriate ages and stage of dental development for referral to the orthodontic service. In addition, the assessment system could be improved by considering validation of referrals at centralised clinics or at the orthodontic providers’ clinics, potentially involving orthodontic therapists, who are cheaper to employ compared to clinicians.

5.5.4 Treatment outcomes

There are several implications of the findings of the analyses of treatment outcomes. In particular, the quality of the NHS activity data could be increased by ensuring IOTN scores are reported for completions, and for discontinuations, where possible. In order to ensure that IOTN scores are reported, the related fields could be required to be filled in to pass processing validation by the Dental Practice Division of the NHSBSA. This is in line with recent guidelines on the management of NHS orthodontic contracts in Wales, which have highlighted that the quality of the activity data in Wales is poor, and consequently the Welsh government has discussed arrangements for the rejection of incomplete NHS activity forms (Welsh Assembly Government Dental Division, 2013). A specific problem raised in Wales is the lack of submission of NHS activity notification forms after treatment has finished, which may be due to poor treatment outcomes (Welsh Assembly Government Dental Division, 2013). Therefore, it is important to investigate and rectify this across the NHS, by mandating the submission of fully completed NHS activity notification forms.

While the IOTN continues to be used to assess treatment need, it would be useful to mandate the reporting of IOTN AC scores at the start and end of treatment, as the IOTN AC score takes very little time to assess and it provides a useful 10-point indicator of need and treatment outcome. Mandating that photographic records of the malocclusions are returned along with each NHS activity form would also help to ensure that the reporting of IOTN AC scores is unbiased. In order to keep the costs of monitoring the service to a minimum, random samples of these photographic records could be routinely and independently examined. In addition to helping to monitor treatment outcomes, this would provide information about the appropriateness of referrals.

As recommended by the recent inquiry into the NHS orthodontic service in Wales, cost-effective systems of PAR score monitoring could be developed further to monitor the quality of care provided (Health, Wellbeing and Local Government Committee, 2011). Currently, orthodontic clinicians in the NHS are required to provide PAR scores for 20 patients plus 10% of the additional patients (Richmond et al., 1992). Before the 2013 NHS
reforms, some NHS commissioners recommended that providers monitor consecutive cases in order to minimise selection bias (British Orthodontic Society, 2013). In addition, self-assessment of treatment outcomes can be subject to bias, so the commissioners encouraged providers to utilise the services of an independent third party calibrated in the use of the IOTN and the PAR index (British Orthodontic Society, 2013). Due to the potential for bias, the BOS noted that commissioners may eventually make participation in a peer review process a contractual requirement (British Orthodontic Society, 2013). However, after the 2013 reforms, the NHS issued new guidance on commissioning of primary care orthodontic services, but only stipulated that the individual scoring the models of the patients’ occlusions should have undergone calibration training, and stated that it would be good practice to monitor the PAR scores of consecutive cases (NHS England Primary Care Commissioning, 2013). Nevertheless, the guidance also stated that ‘PAR scoring will in future be undertaken within a managed orthodontic clinical network under a peer review mechanism’ (NHS England Primary Care Commissioning, 2013, p. 20).

Payment by Results (PbR) remuneration is used in many areas of the NHS (Conrad and Uslu, 2011), and could potentially help to improve outcomes of orthodontic treatment (Richmond et al., 1992). However, a difficulty with implementing this policy is that there is variation in case mix (e.g., different percentages of patients from more deprived groups) between orthodontic clinicians, which would influence the percentages of patients who discontinue treatment and have RPTN. In addition, although contract penalties for treatment discontinuations may help to reduce the SEP-related inequities in treatment outcomes, care would need to be taken to ensure that treatment was not continued in cases where there could be risk of harm to the patient (i.e., if compliance with oral hygiene advice was poor).

Lastly, there is evidence that a large percentage of orthodontic patients experience relapses after orthodontic treatment has finished (Linklater and Fox, 2002), which raises questions about whether orthodontic clinicians could play a larger role in reducing the rates of relapse (e.g., by educating their patients about the long-term use of retainers and providing reminders for their patients), as maintaining good treatment outcomes is a crucial part of treatment. However, it is difficult to incentivise this practice using financial incentives as it would be costly to follow-up patients after treatment and it would effectively increase the cost of treatment if further payments were awarded long after active treatment was finished.

5.5.5 Differences between practices/orthodontic clinicians

Given that there is a great deal of variation in the process and outcome indicators between orthodontic clinicians, these indicators could be published in order to increase the transparency of the service (particularly as large numbers of newly qualified orthodontic therapists will be joining the orthodontic workforce over the
next few years), and NHS commissioners could consider taking levels of RPTN into account when renewing contracts. However, there is currently no orthodontic treatment outcome measure used in the NHS for assessing the quality of the service in terms of a professionally assessed outcome measure combined with a patient-reported outcome measure, which limits the benefits of transparency and assessing outcomes during the contract renewal process.

5.5.6 Critique of the IOTN and the future of the assessment of malocclusion in the NHS

The following sections discuss the use of the IOTN in the NHS in more detail:

- Section 5.5.6.1 discusses the use of the IOTN by orthodontic clinicians, in light of the purpose orthodontic treatment
- Section 5.5.6.2 discusses the use of the IOTN by referring GDPs
- Section 5.5.6.3 provides information on the development of future indices to measure pre-treatment and post-treatment malocclusions

5.5.6.1 Critique of the use of the IOTN by orthodontic clinicians as an index to measure need

The NHS has stated that cosmetic surgery (i.e., a type of surgery used to change a person’s appearance to achieve what they perceive to be a more desirable look) is rarely provided, and there must be a major psychological need for the surgery if it is to be provided (NHS Choices, 2015c). The types of cosmetic surgery that are occasionally provided by the NHS include ear reshaping (e.g., to improve psychological health due to bullying), liposuction (e.g., when used as part of reconstructive surgery), tummy tucks (e.g., to remove excess fat or skin after essential abdominal surgery), and the removal of benign lesions (NHS Choices, 2015c). Other non-surgical treatments for cosmetic conditions are also available from the NHS, though availability differs in different parts of the country. Many of these conditions are dermatological conditions that have cosmetic implications, such as port wine stains, vitiligo, acne, scars, and hair loss (including hair loss caused by fungal infection or an overactive immune system).

The evidence for orthodontic treatment leading to significant improvements in physical health at the population-level is tenuous (Benson et al., 2015), so the main justification for the NHS to provide orthodontic treatment is improvement in dental aesthetics, which can lead to increased social wellbeing and OHQoL (as treatment allows individuals to cope more effectively in social situations, without concern for the appearance of their teeth) (Benson et al., 2015; Borzabadi-Farahani, 2012). Therefore, treating certain types of malocclusion is comparable to treating other cosmetic conditions, such as dermatological conditions, that can cause low
quality of life. This is in line with the World Health Organization’s definition of health as ‘mental and social wellbeing’, in addition to ‘physical health’ (World Health Organization, 2009), and with the argument that, ‘From a sociological point of view, the need and desire of members of a society to achieve a culturally acceptable body image constitutes neither frivolity nor luxury. If children’s teeth do not naturally meet the societal norms for dental aesthetics, the response of families to sociocultural expectations and pressures produces a culturally valid need for orthodontic intervention.’ (Jenny, 1975, p. 248).

On the other hand, some have raised questions about the justification for orthodontic treatment given that many studies have shown orthodontic treatment has no long-term effect on factors related to psychological wellbeing, such as self-esteem (Arrow et al., 2011; Kenealy et al., 2007; Shaw et al., 2007) and the evidence suggests that treatment only has a modest effect, on average, on OHQoL (Liu et al., 2009). In addition, the Secretary of State for Health, Jeremy Hunt, recently voiced his strong opposition to the NHS’s provision of ‘cosmetic treatment’ in light of the financial pressure the NHS is under (Tran, 2014) and, even if having a ‘culturally acceptable body image constitutes neither frivolity nor luxury’ (Jenny, 1975, p. 248), this does not inevitably mean that having malocclusion constitutes a need for publically-funded treatment.

England spends more public money on orthodontic services than any other country in the world (British Orthodontic Society, 2013) but given the current context of financial strain (Johnstone, 2015) and the increasing expectations of potential patients (Health, Wellbeing and Local Government Committee, 2011), some question the appropriateness of continuing to fund the current levels of NHS orthodontic treatment. Therefore, it is important that wider society has a role in determining how public funds are spent on managing a condition such as malocclusion. In particular, there should be a consensus on how need should be measured, what the eligibility threshold of malocclusion severity should be, and what other restrictions should be placed on access:

- The development of the IOTN represented an important advancement in the evolution of orthodontic treatment need indices (de Oliveira, 2003). However, the IOTN is over two and a half decades old. The original article on its development stated that, at the time, there was ‘uncertainty [regarding] the relative contribution that each occlusal trait makes to the longevity and satisfactory functioning of the dentition [and] doubt surrounding the importance of aesthetics in the provision of orthodontic care’ (Brook and Shaw, 1989, p. 310). In addition, society’s values regarding dental aesthetics have changed dramatically, which in turn has changed the level of demand for orthodontic treatment (de Oliveira, 2003). Given society’s changing values, and the fact that the IOTN was designed to reflect the values of dentists rather than the public or patients’ perceptions of need (unlike the DAI, which takes into account societal perceptions of aesthetic norms (Cons et al., 1987)), some feel that the use of the IOTN should
be reassessed (O’Brien, 2014). As shown by this research, the IOTN is a poor predictor of patient-defined need: a third of 12-year-olds with no normative need, according to the IOTN, had patient-defined need, while a quarter of 12-year-olds with normative need, according to the IOTN, did not have patient-defined need. In addition, other studies have also found that children and parents tend to give different ratings of severity to various features of malocclusion compared to specialist orthodontists (Abdullah and Rock, 2002).

- Some consider the current threshold of IOTN 3.6 to be arbitrary (McIntyre, 2012), reflecting the fact that the IOTN is used as a device for cost containment. Some have suggested that the threshold used in publically-funded healthcare services should be increased to an IOTN DHC score of 4 (Northern Ireland British Dental Association, 2012). The finding that 5.6% of patients in the North West had IOTN scores of 3.6-3.10 indicates that approximately one twentieth of patients currently receiving treatment would not be eligible for treatment if the NHS IOTN eligibility threshold were raised to 4. Other occlusal indices have eligibility thresholds that are adjustable depending on available resources and the perception of need in a given region (Borzabadi-Farahani, 2011), reflecting that fact that the condition of malocclusion is socially defined by deviation of occlusions from social norms (Jenny and Cons, 1996). For example, in the US, Medicaid (a social healthcare programme that is provided for those with low income and limited resources) covers the treatment of malocclusion across the US, but some states use much higher eligibility thresholds (based on the HLD index) than others (Theis et al., 2005).

- In addition, even if an individual meets the IOTN criteria for normative need, there are currently discrepancies in who gets access to the NHS orthodontic service based on age, i.e., access is largely restricted to children, and it is much more difficult for adults who have the same condition to receive treatment. If the traits that are used to determine eligibility for publically-funded treatment that truly reflects need (on the grounds of physical health, social wellbeing, or OHQoL), it is currently difficult to justify why adults are not assessed to be equally in need of treatment (i.e., if they had not been treated during their adolescence) and why people who meet the criteria for normative need after they finish treatment, and experience relapse, are denied re-treatment.

5.5.6.2 Critique of the use of the IOTN by referring GDPs

The results of this research show that the use of the IOTN by referring GDPs may not be ideal because of the high rates of ‘assessment & refuse’ and ‘assessment & review’ appointments. However, it is likely that before the use of the IOTN was implemented, more patients who had mild malocclusion were referred and rejected, and more patients received unnecessary treatment. For example, a study before the widespread introduction of the IOTN across the NHS concluded that the delivery of orthodontic services was based neither on need nor on
equitable distribution of resources (Kisely et al., 1997). Nonetheless, according to the BOS, GDPs often have a poor understanding of the IOTN and therefore the BOS recommends improving how the IOTN system is taught to GDPs (Health, Wellbeing and Local Government Committee, 2011). Furthermore, a recent study in Scotland of 356 NHS GDPs reported that only 56% of respondents had received IOTN training during their undergraduate dental degree and 61% of respondents did not use the IOTN (the main reason being that the index was only considered suitable for use in orthodontic practices) (Puri et al., 2015). Like the BOS, the authors concluded that training in the use of the IOTN should be improved (Puri et al., 2015).

Another problem with the IOTN’s use as a referral tool is that it does not assess complexity, which means that referrals are not necessarily made to the most suitable provider: a UK study on the strengths and weaknesses of the IOTN (which involved sending a questionnaire to all 47 consultants in dental public health in the UK) found that the main weakness reported (by 70.5%) was that the IOTN categories do not reflect complexity (de Oliveira, 2003). Some patients with an IOTN DHC score of 5 can be treated relatively easily, while others with an IOTN DHC score of 3 are more difficult and time consuming to treat. Ideally, clinicians in the hospital dental service would treat only patients with malocclusions requiring the most complex treatment while other orthodontic clinicians would treat the remainder within primary care.

Besides more training for GDPs in the use of the IOTN, simpler indices of need and complexity could be developed for use by referring GDPs, as the large numbers of inappropriate referrals highlight questions concerning the IOTN’s complexity and appropriateness as a tool to contain demand.

5.5.6.3 Future orthodontic indices

The main motivation for patient’s seeking orthodontic treatment is usually improved dental aesthetics, leading to improved social wellbeing and OHQoL (Benson et al., 2015; Borzabadi-Farahani, 2012). Therefore, an index that takes into account patient perspectives would be useful to measure both eligibility for NHS orthodontic treatment and treatment outcomes (in order to understand who might benefit the most from treatment, and how much benefit treatment provides), using the same measurement tool. As patient-reported outcome measures are increasingly used across the healthcare system, it is very likely that, in the future, there will be an increasing use of patient reported outcome measures (such as OHQoL questionnaires) to assess the need for and the benefits of orthodontic treatment, particularly in clinical trials (Benson et al., 2015). However, one study has suggested that the Child Perceptions Questionnaire (CPQ), which is a widely used measure of OHQoL fails to fully capture the impact of malocclusion on an individual’s daily life (Marshman et al., 2010), so a condition-specific measure would need to be developed.
Any index occlusal developed in the future for assessing malocclusion in the NHS will need to have its purpose clearly defined, and should be valid (i.e., measures what it claims to measure), reliable (i.e., able to produce similar results under consistent condition), and easy to apply with commonly available resources (Borzabadi-Farahani, 2011).

5.6 Implications for future research

5.6.1 Need and willingness to have treatment

There are several further questions resulting from the analyses of need and willingness to have treatment, including how the percentages of children with patient-defined need are changing over time, and the impact this may have on the management of demand for the NHS orthodontic service.

5.6.2 Treatment utilisation

Key unanswered questions on orthodontic treatment utilisation include how utilisation varies between different parts of the country due to the uneven distribution of the orthodontic workforce. In addition, as a result of the financial difficulties that the NHS is currently in, the impact of alternative eligibility criteria and funding models could be considered. For example, the IOTN eligibility threshold could be raised so that only those with the most severe malocclusions would be treated, which would target the service to those who could most benefit from treatment, and would continue to help to improve the likelihood of equal access to treatment for those from every SEP group. In addition, patient co-payments, which are currently not required for child dental treatment in the NHS, could be introduced for children. However, although this would reduce the cost to the NHS of a course of treatment, and would be likely to reduce the number of courses that are provided, it would also have a detrimental impact on the SEP-related equity of access by creating a ‘two-tier’ dental service, where some families could afford the co-payments for orthodontic treatment and others could not.

5.6.3 Assessment procedures

There are also further questions resulting from the analyses of assessment procedures, including which interventions for reducing the assessment to treatment ratio in the NHS orthodontic service are the most cost-effective (e.g., the various implementations of centralised referral validation and triage systems in different health localities, rapid referral validation and triage clinics implemented by orthodontic providers, and/or
schemes that involve direct patient access to orthodontic therapists for IOTN screening), given that they may reduce a considerable number of ‘assessment & review’ and ‘assessment & refuse’ appointments.

5.6.4 Treatment outcomes

Key areas to be explored regarding treatment outcomes include the factors that mediate the associations between SEP and RPTN, as the association between SEP on RPTN is not reduced to zero after taking into account the ‘indirect’ effect due to treatment discontinuation and the requirement for a replacement appliance. In addition, as patients tend to experience some degree of relapse after active treatment has finished if there is poor compliance with retention instructions (Clinical Standards Committee of the British Orthodontic Society, 2010), further research into the association between SEP and RPTN in the years after active treatment is warranted.

5.6.5 Differences between practices/orthodontic clinicians

Some orthodontic clinicians have very high levels of two or more ‘assessment & review’ appointments and poor treatment outcomes, irrespective of whether they work under PDS, GDS, or TDS contracts. Therefore, further research is warranted into which factors predict successful assessment procedures and treatment outcomes, and are amenable to change by clinicians, as this would help to improve the quality of the service.
6 CONCLUSIONS

This chapter sets out each of the research questions in turn and outlines the key findings of the research.

What is the prevalence of a) normative need for orthodontic treatment, b) patient-defined need for orthodontic treatment, and c) willingness to have orthodontic treatment, and are they associated with socioeconomic status (SEP)?

As shown in Section 4.3.2, over a third of 12-year-olds had normative need for orthodontic treatment (where normative need was defined as an IOTN DHC score of 4-5 and/or an IOTN AC score of 6-10): 38.5% (95% CI: 36.1% - 41.0%) and 40.1% (95% CI: 39.5 - 40.8%), according to data from the CDHS and OHS, respectively. A further 7.9% (95% CI: 6.5% - 9.3%) of 12-year-olds in the CDHS, and a further 6.7% (95% CI: 6.5% - 7.2%) of 12-year-olds in the OHS, were wearing appliances at the time of the dental examinations and therefore were likely to have had normative need in the past.

50.1% (95% CI: 49.3% - 50.9%) of 12-year-olds in the OHS had patient-defined need. However, not all of those who had normative need had patient-defined need: 24.6% (95% CI: 23.6% - 25.7%) had no patient-defined need out of all those who had normative need. In addition, some of those who did not have normative need had patient-defined need: 34.8% (95% CI: 33.9% -35.7%) had patient-defined need out of all those who did not have normative need.

The fact that the percentage of 12-year-olds with patient-defined need was higher than the percentage of 12-year-olds with normative need has implications for GDPs, who are the gatekeepers to NHS orthodontic care. In order to improve the management of demand for referrals to the NHS orthodontic service, GDPs could receive improved training in a) how to use the IOTN and b) how to explain the reasons behind their decisions not to refer children to those who are ineligible for NHS orthodontic treatment. This training may be more effective used in combination with contract penalties for those who make large volumes of inappropriate referrals (Health, Wellbeing and Local Government Committee, 2011).

In addition, given that the purpose of most orthodontic treatment is to improve OHQoL (Benson et al., 2015), the mismatch between normative need and patient-defined need highlights concerns about whether the assessment of need should take into account the patients’ perspectives.

In this thesis, overall levels of normative need among 12-year-olds were not associated with SEP, nor were levels of patient-defined need among 12-year-olds who had normative need. However, those in the most deprived groups tended to be more likely than those in the least deprived group to have patient-defined need.
without normative need. One potential explanation for this is that those from deprived groups could be placing more importance on their dental appearance, even when there is no normative need for treatment (this would concur with the findings of a Swedish study on the importance of dental appearance to adults, which reported that low education was associated with a high importance placed on dental appearance (Söderfeldt et al., 1993)).

In addition, those in the most deprived group tended to be less likely to be willing to have treatment compared to those in the least deprived group, among those who had normative need and patient-defined need. However, the vast majority of those in all SEP groups were willing to have treatment if they had normative need and patient-defined need (i.e., 95.3%, 95% CI: 94.7% - 95.9%).

*What is the prevalence of utilisation of orthodontic treatment, and is it associated with SEP?*

As shown in Section 4.4.2, according to the CDHS data, 32.5% (95% CI: 29.9% - 35.1%) of 15-year-olds in the UK received orthodontic treatment (this figure includes a small percentage who received private treatment and a small percentage who received NHS hospital treatment, i.e., approximately 2.4% and 3%, respectively). In the North West, NHS activity data indicates that 25.9% of 10- to 17-year-olds utilised NHS primary care orthodontic treatment. Given the fact that over a third of 12-year-olds had normative need18, as shown in Section 4.3.2, this indicates that many in the North West failed to receive treatment for their malocclusion while they remained eligible for free NHS orthodontic treatment (i.e., between the ages of 10 and 17). This highlights the fact that the IOTN is largely used to ration orthodontic treatment, as adults who have normative need but who were not provided with treatment when they were aged 17 or under are not automatically eligible for treatment: only a small number of adults with the most severe malocclusion receive NHS orthodontic treatment (Health, Wellbeing and Local Government Committee, 2011).

Despite the fact that overall levels of normative need do not vary by SEP and patient-defined need among those who have normative need also does not vary by SEP, the NHS activity data and the OHS data indicate that, in the North West, those in the most deprived groups tended to have lower levels of orthodontic treatment than those in the least deprived group, as shown in Figure 4.1 and Table 4.6 in Section 4.4.2. Both Figure 4.1 and Table 4.6 suggest that the NHS is not providing orthodontic care equitably between SEP groups, which has implications for NHS commissioners who aim to ensure equal access to services, irrespective of non-need factors such as SEP (Department of Health, 2010; NHS England, 2009).

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18 Over a third of 12-year-olds had normative need for orthodontic treatment: 38.5% (95% CI: 36.1% - 41.0%) and 40.1% (95% CI: 39.5 - 40.8%), according to data from the CDHS and OHS, respectively. A further 7.9% (95% CI: 6.5% - 9.3%) of 12-year-olds in the CDHS, and a further 6.7% (95% CI: 6.5% - 7.2%) of 12-year-olds in the OHS, were wearing appliances at the time of the dental examinations, and therefore were likely to have had normative need in the past.
What is the prevalence in the NHS orthodontic service of a) the use of one or more ‘assessment & review’ appointments\(^{19}\) per patient, b) the use of two or more ‘assessment & review’ appointments per patient, c) early access to orthodontic assessments at ages 9-10, and d) the use of an ‘assessment & refuse’ appointment\(^{20}\) for those with IOTN scores of \(\geq 3.6\)?\(^{21}\) Are these assessment procedures associated with SEP?

According to the NHS activity data, 38.5% of treated patients had one or more ‘assessment & review’ appointments, 12.9% of treated patients had two or more ‘assessment & review’ appointments, 6.9% of assessed patients had early access (i.e., early first assessment) at ages 9-10, and 13.0% of those who had IOTN scores of \(\geq 3.6\) and were refused or received treatment had ‘assessment & refuse’ appointments, as shown in Section 4.5.2.

These findings indicate there are multiple explanations as to why orthodontic practices fail to achieve a 1:1 ratio of assessments to treatments. These inefficiencies include the fact that patients are referred to the NHS orthodontic service too early for treatment and are consequently reviewed rather than receiving immediate treatment. Moreover, some patients are \textit{repeatedly} reviewed, without sufficient priority setting regarding the severity of their malocclusion and the optimum time to start treatment (McGrady and Bridgman, 2013). In addition, patients with IOTN scores of \(\geq 3.6\) may be referred to the orthodontic service when they still have poor oral hygiene or when they lack the willingness to have treatment, and they are therefore ineligible for NHS orthodontic treatment.

Compared to those in the least deprived group, those from the more deprived groups were less likely to have one or more ‘assessment & review’ appointments, two or more ‘assessment & review’ appointments, and early access at ages 9-10. These differences suggest that some of the reasons behind inefficient assessment procedures are linked with SEP, including, for example, requests from patients’ parents for early referral, particularly by those from the least deprived groups (Health, Wellbeing and Local Government Committee, 2011).

\(^{19}\) ‘Assessment & review’ appointments are clinical examinations that result in the orthodontic clinician deciding that NHS orthodontic treatment is indicated, but the patient is not ready to start treatment.

\(^{20}\) ‘Assessment & refuse’ appointments are clinical examinations that result in the orthodontic clinician deciding that NHS orthodontic treatment is unnecessary or inappropriate.

\(^{21}\) An IOTN score of 3.6 is the threshold that indicates eligibility for NHS orthodontic treatment.
What is the prevalence in the NHS orthodontic service of a) treatment discontinuations and b) RPTN? Are these treatment outcomes associated with SEP?

As shown in Section 4.6.2, among all those who started orthodontic treatment in 2008 in the North West and had NHS activity notification forms submitted within the subsequent four years, 9.4% of treatments resulted in discontinuation. Among all those who started treatment in 2008, 5.2% of patients had RPTN. However, 19.3% did not have their IOTN outcome scores reported at the end of treatment and a further 19.6% did not have notification forms submitted within the subsequent four years.

Those in the more deprived groups were more likely to discontinue treatment and have RPTN than those in the least deprived group (even after adjusting for potential confounding factors). Treatment discontinuation can be due to poor case selection for treatment, (i.e., treating patients with a lack of motivation to complete a full course of treatment and/or to comply with oral hygiene advice) or a strict policy on discontinuing treatment for patients who miss appointments, which can result in more treatment discontinuations and RPTN for those in the more deprived groups because they are less likely to be willing to have treatment, more likely to have poor oral hygiene (Holmes et al., 2015; Locker, 2000), and more likely to miss orthodontic appointments (Can et al., 2003).

Do assessment procedures (i.e., the use of two or more ‘assessment & review’ appointments per patient) and treatment outcomes (i.e., treatment discontinuations and RPTN) vary between practices/orthodontic clinicians? Are the differences associated with the types of NHS contracts that the orthodontic clinicians work under (i.e., PDS, GDS, or TDS contracts)?

As shown in Section 4.7.2, according to the NHS activity data, the percentages of patients with two or more ‘assessment & review’ appointments per treated patient, treatment discontinuations, and RPTN varied considerably between practices/orthodontic clinicians, from 0% for some practices/orthodontic clinicians to up to 100% for others. The wide range of process and outcome indicators is concerning, as it raises issues about quality of the overall service.

The percentages of patients with these process and outcome indicators were associated with the type of NHS contract that the patients were treated under. (However, the analyses of treatment outcomes are affected by the fact that TDS clinicians were much more likely to have patients with missing IOTN outcome scores compared to PDS and GDS clinicians, and PDS clinicians were slightly more likely to have patients with missing IOTN outcome scores compared to GDS clinicians.) In addition, there was a great deal of variation among practices/orthodontic clinicians working under the same type of contract. For example, some orthodontic clinicians had treatment discontinuations for 100% of their patients while others never have patients with the
treatment discontinuations; this suggests that some orthodontic clinicians may be effective at selecting highly compliant patients and/or may be able to modify the effect of potential poor patient compliance with good communication of treatment instructions and feedback. Further research into which factors, other than the type of NHS contract that the patients were treated under, predict certain assessment procedures and treatment outcomes would be useful to design interventions to reduce costs and improve outcomes.

What are the costs of the NHS orthodontic service, including the costs associated with the various assessment procedures and treatment outcomes?

The NHS currently has the largest budget deficit in its history and it will continue to grow unless NHS funding is increased and/or services are reduced and patient care standards are allowed to deteriorate (Campbell, 2015). This raises the question about the extent to which the state can afford to pay for ‘cosmetic treatment’ for malocclusions that do not cause physical disabilities, and whether any efficiency savings can be made to avoid any reductions in the levels of service provided.

As shown in Section 4.8.2, the costs to the NHS in the North West of potential inefficiencies in the referral and assessment systems include the cost of ‘assessment & review’ appointments, which was £0.8 million for those who started treatment in 2012 (of this, £0.5 million was spent on those who had two or more ‘assessment & review’ appointments and £0.2 million was associated with children who had their first assessment at ages 9-11) and the costs of ‘assessment & refuse’ appointments for patients with IOTN scores of ≥ 3.6, which was £0.2 million in 2012.

However, the costs due to potential inefficiencies in the referral and assessment systems are relatively minor compared to the costs of treatments that result in treatment discontinuations and RPTN, which were £2.4 million and £1.8 million, respectively, for 10- to 17-year-olds who started treatment in 2008. The costs due to treatments that result in unreported IOTN outcome scores and unreported treatment finishes were larger still (i.e., £13.0 million for 10- to 17-year-olds who started treatment in 2008) due to the lack of enforcement of the reporting of treatment outcomes.

Finally, if the NHS eligibility threshold were increased from an IOTN score of 3.6 to an IOTN score of 4, 7.1% (7,552 per year) of 10- to 17-year-old patients in the North West would no longer be treated in the NHS orthodontic service, saving £1.9 million per year. However, many of these patients with IOTN scores of 3.6-3.10 would, based on the impact of their malocclusion on their OHQoL, have higher need than those with low IOTN AC scores but DHC scores of 4-5.
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